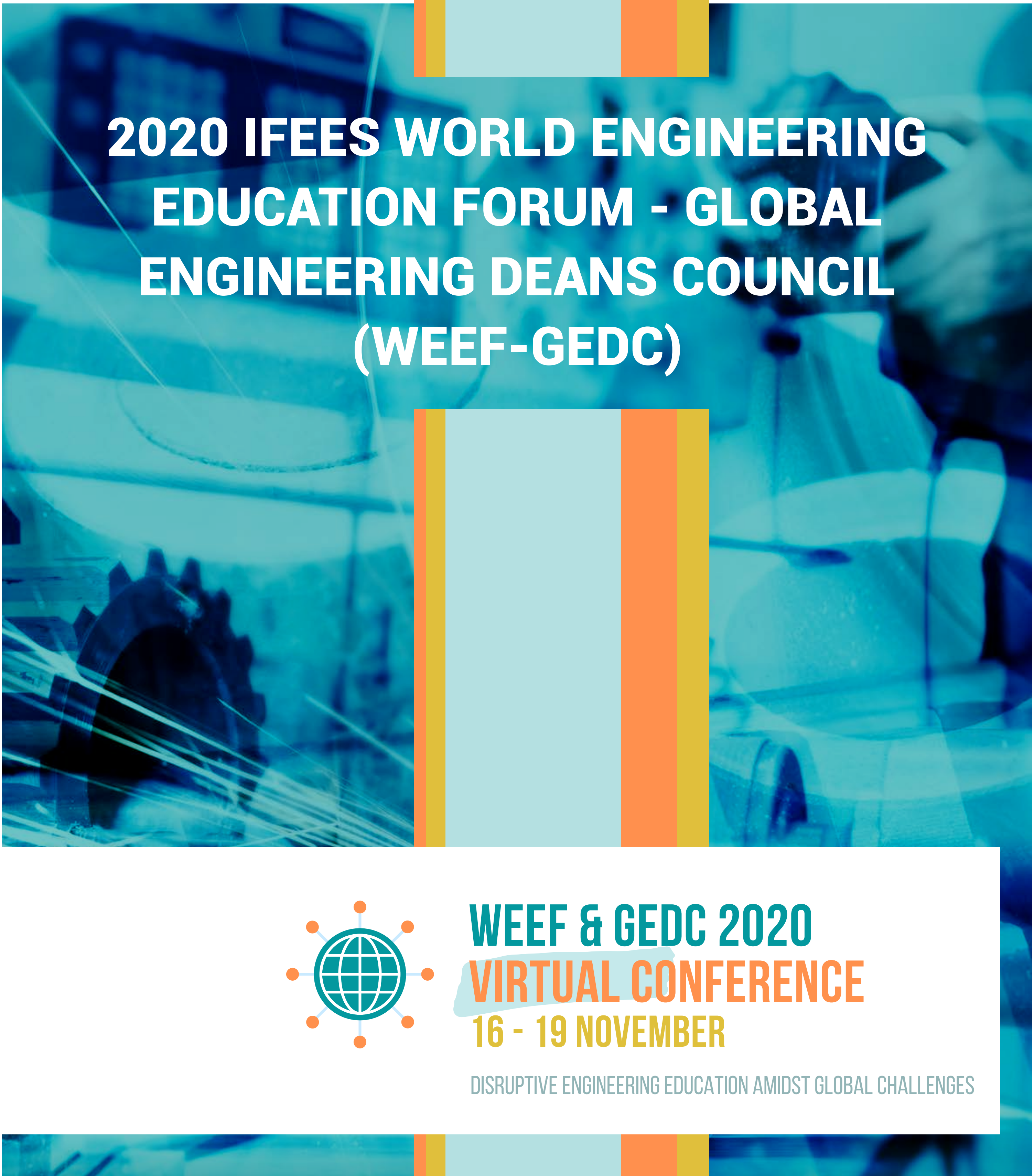
2020 IFEES WORLD ENGINEERING EDUCATION FORUM - GLOBAL ENGINEERING DEANS COUNCIL (WEEF-GEDC)



WEEF & GEDC 2020
VIRTUAL CONFERENCE
16 - 19 NOVEMBER

DISRUPTIVE ENGINEERING EDUCATION AMIDST GLOBAL CHALLENGES

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VIRTUAL CONFERENCE PROCEEDINGS

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Message from the General Conference Chair

Prof Sunil Maharaj
General Conference Chair

We are extremely pleased to welcome you to the 2020 World Engineering Education Forum and The Global Engineering Deans Council (WEEF&GEDC) being held virtually, from 16 to 19 November 2020.

Each year, IFEES holds the World Engineering Education Forum in different locations around the world. On even years, the conference is jointly convened with the Global Engineering Deans Council Conference. This is the largest global gathering in engineering education and includes participation from a large number of stakeholders – Engineering educators, leaders, students, industry, governmental organisations, non-governmental organisations, among others – who share and build fruitful and long-term collaborations during the event.

The South African Society for Engineering Education (SASEE), as a member of IFEES, is co-hosting this event with the University of Pretoria, in conjunction with the South African Engineering Deans' Forum. The WEEF/GEDC provide a strong platform for interaction and consultation with international delegates for the sharing of interests and expertise, and we look forward to welcoming back our returning supporters and providing opportunities for new partners.

The virtual conference will include both live and pre-recoded events, which will give our sponsors maximum visibility. The live events will be recorded and available to delegates beyond the conference dates hence giving the sponsors maximum and extended visibility. There will be a separate Studio for all corporate sponsors to showcase themselves during and after the conference both live and also asynchronously.

We look forward to working with you and thank you in advance for your important support of the congress.
We plan to have an exciting line-up at the Conference.

Message from the Executive Secretary (GEDC) and Secretary General (IFEES)

Prof Hans J. Hoyer
Executive Secretary (GEDC) and Secretary General (IFEES)

It is my great pleasure to welcome you to the World Engineering Education Forum and the Global Engineering Deans Council (WEEF-GEDC) Virtual Conference to be held November 16-19, 2020.

WEEF has been an important event in furthering the International Federation of Engineering Education Societies' (IFEES) and GEDC's mission to bring together the global community to build excellence in engineering education. It is uniquely designed, inviting participation from Profs, academics, engineering educators, researchers, and students to governmental organizations, industry leaders, and other stakeholders. WEEF/GEDC offers this dynamic group a strong platform for interaction and consultation with international delegates sharing interests and expertise. Participants convene to discuss how to move institutions forward, motivated by purpose to contribute to more equitable, inclusive, and sustainable development.

As many things in 2020 halted in response to the COVID-19 global pandemic, our team decided to persist. They worked tirelessly to adapt the format of our annual conference into a dynamic virtual experience out of necessity and purpose.

My sincerest gratitude to our Conference Chair, Sunil Maharaj, Conference Co-Chairs Sirin Tekinay and Ramiro Jordan, Co-Chair for Student Activities Mr. Yashin Brijmohan, and the organizing committee for their detailed, passionate, and effective dedication to making WEEF/GEDC 2020 a successful event. I would also like to express my appreciation for the student leaders who coordinated many wonderful and informative sessions to amplify the student voice.

We are certain that you will both gain insight and feel inspired by our diverse sessions and complex and engaging dialogue. Join us in creating disruptive innovations for engineering education, for a world that is beset with challenges, to change the trajectory of humanity and to create a sustainable and ethical future for all.

Sincerely, Prof Hans J. Hoyer

Message from the GEDC Chair

Prof Sirin Tekinay
Conference Vice-Chair & GEDC Chair

Dear Global Engineering Education Community, it is truly an honor and apleasure to extend a warm personal welcome to you as GEDC Chair and Conference Vice-Chair of **World Engineering Education Forum (WEEF) & GEDC Conference 2020**.

How the world has changed since we started to plan **WEEF-GEDC 2020**! In August of 2019, a few of us from IFEES/GEDC leadership flew from our homes in various parts of the world to beautiful Cape Town to visit and inspect the conference site, accommodations, and nearby attractions. We started to work hard on the program as usual, but then, a lot more, to transform all of our preparations, and time-honored annual traditions into the virtual event our conference has become for the first time. While we look forward to getting together face to face in Cape Town in 2022, we are delighted and proud to have overcome distances this time around, thanks to our South African colleagues, our global team, and our technology partners. Once again, but for the first time virtually, our annual conference will serve our mission of sharing best practices, promoting global quality standards, bringing university and industry together, and generally empowering engineering education community to achieve heightened impact.

I am especially proud to see student engagement increase at our conferences. This time, we have even more student-led events than before. It is so very gratifying to see our students owning up to their education in general, and in particular, making use of this space for networking, and making impact along themes of their choice. The university-industry events at the conference, with the experience of an extremely successful recent virtual GEDC Industry Forum under our belt, are geared towards blurring the boundaries between the academic dimensions of education and research, integrating it all into innovation, co-creation, design, and impact. The skillset of the new engineering student and graduate is best shaped hand in hand with industry. Our GEDC-initiated global virtual internship program has added to the palette of modalities of university-industry interaction.

I am thrilled to invite you to participate in, and contribute to, upholding our time-honored traditions such as the IFEES Award, and celebrations of diversity. We will hold our GEDC Diversity Award Ceremony, and host a panel of authors of the second edition of our publication, "Rising to the Top: Global Women Engineering Leaders Share Their Journeys of Professional Success," as we gear up for its third and fourth installments. Our GEDC and General Assembly included, all of the sessions of the conference will connect the globe in real time.

We are physically distanced, but socially, globally tighter connected than ever.

Please stay safe, healthy, and in touch.

Message from the Conference Vice-Chair & IFEES President

Prof Ramiro Jordan
Conference Vice-Chair & IFEES President

On behalf of the International Federation of Engineering Education Societies (IFEES), it an honor and a pleasure to welcome you to the World Engineering Education Forum and the Global Engineering Deans Council (WEEF-GEDC) Virtual Conference, to be held from 16 – 19 November 2020.

This year, COVID-19 has pressed the RESET button for the planet. 2020 is a challenging year where all existing models will have to be re-engineered, re-imagined. Models like healthcare, transportation, supply chains, energy, water, other. For IFEES is the engineering education model, how we teach, learn, do research, collaborate and organize entrepreneurial activities.

The WEEF-GEDC virtual event has been designed to foster the exchange of new ideas, experiences, products, services, facilitate new collaboration opportunities, and networkingamong Profs, academics, engineering educators, industry leaders, researchers, students, governmental organizations, and concerned global citizens. We encourage you to engage and helps us design the future of engineering education. It is about you. We want to thank all the dedicated volunteers, event planners, sponsors, student organizations, IFEES and GEDC members for making this conference anoutstanding success!

My sincere thanks to the General Conference Chair Prof Sunil Maharaj, Conference Co-Chair Prof Sirin Tekinay, Co-Chair for Student Activities Mr. Yashin Brijmohan as well as the rest of the conference organizing committees for their time, effort, dedication, and commitment for making WEEF-GEDC-2020 a successful event!

I would like to wish all of you a very productive experience and a successful event.

Respectfully, Prof Ramiro Jordan

Message from the IFEES President Elect

Alaa K. Ashmawy
IFEES President Elect

Welcome to the 2020 WEEF-GEDC Conference. This year's conference takes place against the backdrop of extraordinary circumstances that disrupted our conventional operations. The ongoing COVID-19 pandemic presented formidable challenges, but it also gave us a chance to reflect on our priorities; it provided our global engineering education community with purpose and context as we move forward.

With travel restrictions and economic adversities in place, the organizing committee wasted no time in putting together a world-class virtual conference that engaged not only educators, but also industry professionals, researchers, and students in a quest to define new norms in teaching and learning. This is evident in the diversity of topics covered in this year's papers and presentations, as well as the emergence of new solutions to facilitate distance education, virtual classrooms, and remote collaborative learning. Our community has also recognized the importance of addressing large-scale threats to our planet and refocusing our curricula toward the attainment the planet's sustainable development goals. Another important dimension covered in the conference is the recognition of the societal, psychological, and ethical challenges surrounding remote and virtual learning.

One of the most important takeaways from this year's conference is the resilience of the global engineering education community, as we continue to build bridges between industry, academia, and society at large. The live streaming of the interactive workshops and technical sessions will serve as a model for hybrid editions of the conference in the future. This will enable a larger audience of students and professionals who have limited travel resources to engage with the face-to-face participants.

I wish to thank our colleagues from South Africa who put together an exceptional conference through a virtual platform, and look forward to congratulating them in person, at the Cape Town edition in 2022.

Message from the Technical Program Committee

Dr Helen Inglis
WEEF & GEDC 2020 Technical Program Committee Chair

On behalf of the Technical Program Committee, I am extremely pleased to share with you the proceedings of the WEEF & GEDC 2020 Virtual Conference. These proceedings present original research and innovative pedagogical practices implemented by authors from across the globe, as well as potential directions for engineering education researchers and practitioners through various position papers.

All the papers included in the proceeding went through a two- or three-step review process. To improve the quality of the reviews and provide the authors with constructive directions for developing the paper, the Technical Program Committee organised an online review workshop for reviewers. Authors were initially invited to submit 500 word abstracts. These abstracts went through a double blind review process in which each abstract was reviewed by at least two reviewers. Out of the 111 abstracts received at this stage, we invited 94 to be submitted as full papers.

The full papers submitted by the authors underwent another round of double blind peer review. Papers that required minor revisions were accepted to be included in the proceedings with the authors being encouraged to incorporate in the final version the suggestions made by the reviewers. The authors of the papers that required substantial changes were asked to submit a revised version of the paper with details on how the reviewer feedback was incorporated in the revised version. These revised papers underwent an editorial review before being accepted into the proceedings. Out of the 54 full papers initially submitted, we accepted 42 to be included in the proceedings. The authors who contributed these studies represent more than 25 different universities in more than 16 countries around the world.

I would like to extend my heartfelt gratitude to the members of the Technical Program Committee, who reviewed abstracts and full papers. The timely and constructive feedback from reviewers contributed to improving the quality of the papers. I am also extremely grateful for the commitment of the Technical Program Committee Vice-Chairs: Dr Ashish Agrawal (University of Cape Town), Prof Deborah Blaine (Stellenbosch University), Prof Johnson Carroll (University of Johannesburg), Dr Lelanie Smith (University of Pretoria), and Prof Alta van der Merwe (University of Pretoria). Their dedicated effort and thoughtful engagement ensured the integrity and quality of the process of publishing these proceedings.

I hope you enjoy reading through the proceedings, and that these papers open new ways for you to think about engineering education research and teaching.

Sincerely, Dr Helen Inglis

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Keynotes & Speakers

Prof Tawana Kupe

Bio: Prof Tawana Kupe is currently the Vice-Chancellor & Principal at the University of Pretoria and is the 13th vice-chancellor to take up the reins of this 111-year old university and commenced his duties on 14 January 2019. Prior to his appointment, he served as the Vice-Principal of the University of the Witwatersrand (Wits), responsible for the daily running of that institution and the coordination of operations across all executive portfolios. Before that, he held the rotating Vice-Principal post and also served as the Deputy Vice-Chancellor for Advancement, Human Resources and Transformation. Prof Kupe holds a Bachelor of Art Honours degree and Master's in English from the University of Zimbabwe, as well as a DPhil in Media Studies from the University of Oslo, Norway. A highly published academic, he has authored several journal articles, books and book chapters in his main discipline, Media Studies and Journalism.

Prof Barbara Oakley

Bio: Prof Barbara Oakley is a Prof of Engineering at Oakland University in Rochester, Michigan. Prof Oakley holds Bachelor of Science in Electrical Engineering, from the University of Washington, in 1986, a Master of Science in Electrical and Computer Engineering degree from Oakland University in 1995, and a Ph.D. in Systems Engineering from the same University. Her work focuses on the complex relationship between neuroscience and social behavior. She teaches Coursera – UC San Diego's "Learning How to Learn," one of the world's most popular massive open online course with over three million registered students. Barb is a New York Times best-selling author—her book A Mind for Numbers has sold nearly a million copies in twenty languages worldwide.

Prof Bevlee A. Watford

Bio: Prof Bevlee A. Watford is a Prof in Engineering Education, Associate Dean for Equity and Engagement and Exectuve Director of the Center for Enhancement of Engineering Diversity at the College of Engineering at Virginia Tech. Prof Watford earned all of her degrees from Virginia Tech's College of Engineering (BS Mining Engineering, MS and PhD in Industrial Engineering and Operations Research). Prof Watford has worked at Virginia Tech since 1992, becoming associate dean in 1997. Her professional interests are focused on ensuring that all students who desire an engineering degree are successful. She is particularly interested in helping under-represented students achieve their educational and professional goals, whether these goals are in engineering or any other field.

Prof Ramiro Jordan

Bio: Prof Ramiro Jordan is a scientist, innovator, educator and entrepreneur. He is a faculty member of the Electrical and Computer Engineering (ECE) department at the University of New Mexico, and is currently the Associate Dean of Engineering for International Programs. His research activities include sustainability, Smart Grid, cognitive radio, multi-dimensional signal processing, and software development. He is a dedicated educator, actively creating educational infrastructure in academic institutions worldwide with emphasis on the "culture of quality" in educational programs for accreditation and certification. Prof Jordan is a recognized leader in his field and serves on the Board of Directors of several industrial and professional organizations. An active member of scientific and professional societies including ASEE and IEEE, Prof Jordan has published extensively in books, journals, magazines and on the Web.

Keynotes & Speakers

Mr Xavier Fouger

Bio: Mr Xavier Fouger An Industrial Engineer, former Science Attaché in Vienna, Xavier Fouger joined Dassault Systemes in 1990. He developed innovation processes for various automotive manufacturers in Germany and Korea. He created the corporate organization in charge of global academia. He created Dassault Systemes' Learning Lab that conducts collaborative educational research with various universities, funded by US and European agencies on the use of digital technologies in education and the development of lifelong learning of emerging engineering practices. His current focus is on developing industry-inspired learning centres, establishing educational government programs and nurturing collaboration with engineering education societies.

Dr Michael K. J. Milligan

Bio: Dr Michael K. J. Milligan is the Executive Director and Chief Executive Officer of ABET, the global accreditor of over 4,000 college and university programs in applied and natural science, computing, engineering and engineering technology. Dr Milligan earned his Ph.D. from the University of Texas at Austin, his M.S.E. from the University of Massachusetts at Lowell, and his B.S. from Michigan State University — all in electrical engineering. He also earned an M.B.A. in Business Administration from Western New England College, is a registered Professional Engineer (PE) in Colorado and Maryland, and a Certified Association Executive (CAE). Dr Milligan is also a member of the Tau Beta Pi Engineering Honor Society, IEEE Eta Kappa Nu Electrical and Computer Engineering Honor Society, and a senior member of the Institute of Electrical and Electronics Engineers (IEEE).

Prof Cindy Cooper

Bio: Prof Cindy Cooper is Program Officer for The Lemelson Foundation and supports higher education initiatives that promote invention education and invention-based entrepreneurship to improve lives. She also leads the Foundation's Engineering for One Planet initiative accelerate environmentally and social conscious engineering by mobilizing changes in engineering education. Prof Cooper holds a Global M.B.A. with distinction from Thunderbird School of Global Management and earned a B.A. summa cum laude in Psychology/Spanish from Claremont McKenna College. She has experience in global marketing and has consulted to corporations, foundations and NGOs on social innovation and environmental impact projects.

Mr Michael Carone

Bio: Mr Michael Carone joined MathWorks in 2003. During his career, he has held positions as an application support engineer, industry marketing analyst, and product marketing manager for Stateflow. He is currently a principal product marketing manager for Simulink, focused on guiding the strategic direction of Simulink and Model-Based Design, especially in the areas of modeling, simulation analysis, and online collaboration. Michael received his Bachelor of Science degree in mechanical engineering and a minor in economics at Lehigh University. He received his Master of Science degree in mechanical engineering at the Georgia Institute of Technology.

Keynotes & Speakers

Prof Gong Ke

Bio: Prof Gong Ke obtained his Bachelor's degree from Beijing Institute of Technology in 1982. He gained his doctor degree of Technological Science at the Technical University Graz, Austria in 1987. He is member of the Communication Technology Committee of the Ministry of Industry and Information Technology of China, member of the China Standardization Experts Committee, member of the Artificial Intelligence Technology Innovation Expert Group of the Ministry of Education of China. He is foreign fellow of the Russian Academy of Aerospace Sciences. He has an honorary doctoral degree from the University of Glasgow. In January 2014, he was appointed by then General Secretary Ban Ki-moon to the Scientific Advisory Board of the Secretary-General of the United Nations. He has been working in WFEO as Chair of Committee on Information and Communication, then Chair of Engineering for Innovative Technologies since 2009. He took the office of President at WFEO in 2019.

Prof WU Qidi

Bio: Prof WU Qidi is a Prof of Tongji University and Tsinghua University, Director of Center for Engineering Education, Chairperson of National Accreditation Committee of Engineering Education and member of National Education Advisory Committee and Education Committee of Chinese Academy of Engineering. She served as President of Tongji University, Director of Department of Management Sciences of National Science Fund of China (NSFC), Vice Minister of Education and Member of the People's Congress. Madame WU received her PhD from Federal Institute of Technology (ETH) Switzerland, MA and BA in E.E. from Tsinghua University. Her major research interests are control theory, electrical engineering and engineering management, published several books and more than 100 papers. She received many awards including Grand Cross of the Order of Merit of the Federal Republic of Germany.

Mr Prasad Mavuduri

Bio: Mr Prasad Mavuduri is the CEO, at University of Emerging Technologies and a Senior business leader, entrepreneur working for the past thirty two years in the fields of Higher Education, Emerging Technologies (such as Big Data, AI / ML, Blockchain, Cloud Computing etc.), Business Process Re-engineering, Business Transformations, Enterprise Resource Planning systems, Business Intelligence, Governance & Compliance. Prasad holds an MBA from Kellogg School of Management (Northwestern University) and an MS (Technology) from Andhra University.

Ms Sabine Dall'Omo

Bio: Ms Sabine Dall'Omo attained her Higher Commercial Certificate from Heinrich-Thoene College in 1985 and did vocational training at Siemens Germany between 1986 and 1989. She took on the responsibility of Commercial Officer: Accounting Services and shortly thereafter Commercial Officer: Sales until 1995. In 1998, she became Commercial Manager for a Siemens' Automation and Drives business in Germany, a position she held for over three years. Later, she progressed to Commercial Manager for the Siemens Automation and Drives Office in Shanghai, China, until 2004. Sabine joined Siemens South Africa in 2004 as Head of Risk and Controlling, Mergers and Acquisitions where she was instrumental in executing major transactions. In 2012, she was appointed Chief Financial Officer of the Siemens Cluster Africa and two years later became Chief Executive Officer of Siemens Southern and Eastern Africa.

Keynotes & Speakers

Mr Sun Gang

Bio: Mr Sun Gang is the Director of Global Talent Ecosystem Development at Huawei Technologies Co., Ltd. He manages Huawei's ICT Talent Eco-system and related operations globally, including Huawei ICT Academy. Mr Gang has extensive experience in Huawei and has been in various executive positions in regions including China, Europe, and Head Office.

Mr Tommie Chambers

Bio: Mr Tommie Chambers attained his B.Eng Electronic Engineering degree in 1988 at the "Potchefstroom University for Christian Higher Education" (now part of the North-West University) and in 1995 earned a B.Sc Computer Science degree (cum laude) from the same university. He is a business developer for the Siemens Digital Enterprise portfolio in South Africa. He started his career at Eskom, a power utility, in 1989 as an engineer in training and later worked as a turbine maintenance engineer. He moved to Siemens in 1996 working on power station projects. He moved to the automation marketing team as a technical consultant for visualization systems and IT/OT integration at the end of 1998. In 2018, Tommie assumed the responsibility of business development for Factory Automation digitalization solutions and now for Siemens Digital Enterprise.

Mrs Dora Smith

Bio: Mrs Dora Smith directs the global academic program for Siemens. Under her leadership, the global academic program is a strategic initiative for the company. The program empowers the next generation of digital talent through industrial strength software and curriculum, project-based learning, and STEM competitions to support more than 1 million students and more than 3,000 institutions worldwide. Dora serves in academic-industry advisory roles as chair-elect on the American Society for Engineering Education's Corporate Member Council and director on the International Federation of Engineering Education Societies executive committee. Dora earned her bachelor's degree in journalism from University of Missouri-Columbia and a master's in business administration from Washington University. She is an accredited business communicator with more than 25 years of experience in the engineering and manufacturing industry with leadership roles across disciplines.

Mr Hakan Bulgurlu

Bio: Hakan Bulgurlu is the CEO of Arçelik, a leading manufacturer of home appliances. Arçelik has annual revenues of five billion euros and its brands hold prominent leadership positions across global markets. Under his leadership, the company has generated solid topline growth, and expanded its global manufacturing network to 23 plants in nine countries. Hakan is passionate about creating positive social impact and driving change that fosters inclusive, sustainable, and responsible business. This vision drove Arçelik to become an Industry Leader in the Dow Jones Sustainability Index and to be included in the FTSE4Good Index for four consecutive years. After graduating from the University of Texas, Austin he earned his MBA from the joint program of Northwestern University and the Hong Kong University of Science and Technology.

Dr Will Greenwood

Bio: Dr Will Greenwood is Higher Education Content Manager at MathWorks. Dr Greenwood completed his Bachelor of Science (BS) in Civil Engineering at University of Vermont in 2013 and completed his PhD at University of Michigan in 2018.

Keynotes & Speakers

Mr Paul Karam

Bio: Mr Paul Karam is the Director of Research & Development at Quanser. Paul's vision and guidance is essential to ensuring that the R&D team is able to deliver solutions that are effective, sustainable, and academically appropriate. Before assuming his current position, Paul Karam managed Quanser's industrial projects and robotics technologies for six years. He was involved in the design and implementation of Quanser's original integration with National Instruments (NI) LabVIEW™ control design software and played a pivotal role in the development of the QNET line of engineering trainers for the NI ELVIS platform. He holds an honours bachelor degree in Electrical Engineering from the University of Waterloo.

Professior Ishwar K Puri

Bio: Prof Ishwar K. Puri is the Dean of Engineering at McMaster University. Prof Puri obtained his B.Sc. in Mechanical Engineering at University of Delhi in 1982 and Applied Mechanics at University of California San Diego in 1984 and his Ph.D. in Applied Mechanics from the same University. His expertise are Transport Phenomena; Heat Transfer, Energy Storage; Fluid Mechanics; Self Assembly & Nanostructure Synthesis; Combustion & Pollutant Airborne Emissions; Mathematical Biology; Bioinspired Computational Biology.

Dr Armin Veitl

Bio: Dr Armin Veitl is Senior Director for Global Academic Programs at Altair. In this role, he combines all activities in the regions to promote teaching and learning with the latest simulation technologies. Prior to his current position, he supported Altair's global indirect business as Technical Director. From 2016 to 2018, he led the technical team in Greater China from our regional office in Shanghai. He gained his technical expertise through numerous service projects in the field of lightweight design in the automotive and aerospace industries for German and European customers. He joined Altair in 2000 after completing his studies in multi-body dynamics at the Technical University of Munich with a PhD.

Mr Mark Burns

Bio: Mr Mark Burns is Director of Data Analytics for SLED Team across North America and based out of US in New Hampshire. He assists organizations achieve their goals through Data Analytics and oversees a data analytics sales and solutions team based in North America. Mr Burns areas of expertise include Data Prep, Data Quality, ERP Systems Reporting and Data Science.

Ms Thandi Majola

Bio: Ms Thandi Majola is an experienced Business Development Manager with a strong background in the Education & Skills Development field with a demonstrated history of working in the cloud computing and software industry. She currently fulfils this role within Amazon Web Services (AWS), where she has served in this role since 2018. A key component of Thandi Majola's business development activities entails capacitating educational institutions with the knowledge and platforms required to enable the effective delivery of virtual learning environments for hybrid learning. Additionally, Thandi also has a strong focus on driving digital skills development initiatives within the South African region.

Keynotes & Speakers

Mr Anthony Tattersall

Bio: Mr Anthony Tattersall is the Vice President of Coursera in Europe, Middle East and Africa. He has more than 20 years of experience in the technology and corporate learning space. Before joining Coursera at the beginning of 2019, he held several leadership positions including Area Vice President UK at Cornerstone OnDemand, Chief Sales Officer for Launchpad Recruits, Sales Director EMEA for Cogeco Peer 1, and UK Country Manager for Kronos. He holds an MBA from Durham University Business School.

Mr Jesús Sancho

Bio: Mr Jesús Sancho holds a Master Degree of Aeronautical Engineering from Universidad Politécnica de Madrid (Spain) and an Executive MBA Diploma from IESE Business School (Madrid). He presently holds the position of Middle East Managing Director of Spain´s ACCIONA (www.acciona-me.com). He has been based in Dubai (UAE) since 2008. Mr. Sancho has recently been included in the Forbes List "Global Meets Local: Top 100 executives in the Middle East 2018" as well as in the Construction Week's "ME Power 100 List.

Dr Bernard Amadei

Bio: Dr Bernard Amadei is a Distinguished Prof and Prof of Civil Engineering at the University of Colorado at Boulder. He received his Ph.D. in 1982 from the University of California at Berkeley. Dr Amadei is the Founding Director of the Mortenson Center in Engineering for Developing Communities. He is also the Founding President of Engineers Without Borders – USA and the co-founder of the Engineers Without Borders-International network. Among other distinctions, Dr Amadei is an elected member of the US National Academy of Engineering and the National Academy of Construction. He is also an elected Senior Ashoka Fellow. Dr Amadei holds seven honorary doctoral degrees (UMass Lowell; Carroll College; Clarkson; Drexel; Worcester Polytechnic Institute; the Technion in Israel; and SUNY-ESF). In 2013 and 2014, Dr Amadei served as a Science Envoy to Pakistan and Nepal for the US Department of State. Dr Amadei holds a commercial pilot license (multi-engine land, instrument).

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Dr Alpaslan Özerdem

Bio: Dr Alpaslan Özerdem is Dean of the Jimmy and Rosalynn Carter School for Peace and Conflict Resolution (formerly known as the School for Conflict Analysis & Resolution) and Prof of peace and conflict studies. Prior to his appointment as Dean in August 2019, Dr Özerdem was Associate Pro-Vice-Chancellor for Research at Coventry University in the UK. Dr Özerdem specializes in conflict resolution, peacebuilding and post-conflict reconstruction. With over 20 years of field research experience in Afghanistan, Bosnia-Herzegovina, El Salvador, Indonesia, Kosovo, Lebanon, Liberia, Nepal, Nigeria, Philippines, Sierra Leone, Solomon Islands, Somalia, Sri Lanka, Tajikistan and Turkey

Panel Sessions

Dr Michael Milligan
Winston Erevelles, PhD; ABET Adjunct Accreditation Director, Dean of Science, Engineering and Technology, St. Mary's University

Dr Joe Sussman
ABET Chief Accreditation Office

Uriel Cukierman
Former IFEES President

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José Luis Roces
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Prof Susan Conry
ABET Adjunct Accreditation Director, Prof Emerita, Distinguished Prof of Electrical and Computer Engineering Clarkson University

Mario Gómez Mejía
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Prof David Tomasko
Associate Dean and Prof of Chemical and Biomolecular Engineering, Ohio State University

Julio Fernández
National Academy of Engineering, President

Prof Jeffrey Fergus
ABET Engineering Accreditation Commission Past- Chair, Associate Dean and Prof of Materials Engineering, Auburn University

Jaime Dominguez Abascal
Royal Academy of Engineering, Member

Workshop Sessions

1) Session: Crisis Online Learning Workshop

Topic:
Actionable Insights from Engineering Educators During Emergency Remote Teaching

Overview:
This workshop will consist of an interactive presentation of an ongoing research effort into the effect of the transition to emergency remote (online) teaching (ERT) during the pandemic. The research, conducted by the South African Society for Engineering Education and Stellenbosch University, seeks insights into the conditions, challenges and successes of the transition from engineering (and related) educators and postgraduate students at different institutions in different contexts.

Workshop participants will be invited to compare their own perceptions of online teaching in particular learning scenarios into their own context in an interactive format. The facilitators will then guide the participants through the framework and methodology used to productively interpret the qualitative data collected. The workshop will culminate with a comprehensive discussion on translating the analysed data into areas for potential action.

Presenters:
Karin Wolff (Stellenbosch University) and Johnson Carroll (University of Johannesburg)

Target Audience:
All engineering education related stakeholders (management, deans, lecturers, students, learning support staff)

2) Session: Mental Wellbeing Workshop

Topic:
Exhaustion and Authenticity in your career as an academic staff member

Overview:
Although wellbeing is a topic of much discussion within Higher Education, it is often seen as elusive and can be even harder to remain aware of your own wellbeing during the busiest times. This workshop facilitates participants' explorations of what working in Engineering Education Research means for them and how they can embed active wellbeing practices into their work life. Beginning by exploring two key factors in maintaining healthy levels of wellbeing, authenticity and exhaustion, participants are invited to reflect on their own experiences using this framing of wellbeing via Action Learning Sets and culminating in each participant devising their own strategies to ensure a healthy balance of wellbeing through a pledge they make to themselves. To embed sustainability into this practice of self-reflection and awareness of how they continue to embody their pledge in the future, the second part of the workshop focuses on developing simple personalised practical actions in support of this.

Presenters:
Lelanie Smith (University of Pretoria) and Rebecca Broadbent(Aston University, UK)

Target Audience:
All levels of faculty who are interested in exploring their awareness of their own wellbeing or exploring ways in which to help members of their team become aware of their wellbeing and master practices to maintain awareness.

3) Session: Ethics in Engineering Education Workshop

Topic:
Workshop on teaching ethics within engineering

Overview:
Session participants can expect to gain:

- the opportunity to engage with the different facets of teaching ethics including ethics as a skill, concept, knowledge, value and attitude
- the exploration of the difference between ethics as an individual and as a communal practice
- experience of online activities for the teaching of ethics to engineering students
- practical hands-on engagement with research ethics training and
- engagement with strategies to counter corruption in the public service.

Ethics within engineering can be seen as an individual practice and, as such, falls outside of professional discourse and processes. This workshop will reposition ethics as central to the practice of engineering and will engage with three key areas relating to research, the public sector and professional identity. Participants will go home with practical ideas for enhancing their own teaching of ethics to engineers. Participants will be engaged as students and teachers and expected to participate in and contribute to practical activities including scenarios.

Presenters:
Alison Gwynne-Evans, Marianne Camerer, Lyn Horn,Paula Saner (University of Cape Town) and Manimagalay Chetty (Durban University of Technology)

Target Audience:
All engineering education related stakeholders (management, deans, lecturers, learning support staff)

4) Session: Africa Engineering Education Research Network (EERN) Workshop

Topic:
Africa EER networking workshop

Overview:
EER is not well represented in Africa and although there is a growing interest to support African countries, Africa lacks representation in the global EER community. Many African Universities operate with limited resources and unique restrictions which leads to various innovative educational projects but they remain unpublished. This short workshop will act as a community building engagement as we move towards a sustainable EER network in Africa and to increase African representation globally in this field and showcase the contribution of Africa to EER. It will be informally organised to give scholars and practitioners the opportunity to connect, share experiences and their interests or potential links to EER.

Presenters:
Lelanie Smith (University of Pretoria), Esther Matemba (Curtin University), Aida Guerra(Aalborg University) and Mike Klassen (University of Toronto)

Target Audience:
Even though the focus is on African countries and building an EER community, anyone who has an interest in networking and collaborating is more than welcome.

Contents

Contents

Technical Papers

A case of implementation of an iPeer software tool to assess and develop engineering students' teamwork capabilities in a large class environment

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Abstract—**Due to the growing administrative challenges and addressing the need for creating an efficient large class learning environment, a peer review approach is introduced as a part of the Engineering Management module's teamwork assessment. The module is compulsory to all engineering disciplines and has an annual class size of ±1000 students in the University of Pretoria. As a result, the workload of academic staff has concurrently become unfeasible, especially concerning the student assessment and feedback. Furthermore, the industry feedback has indicated that the current system is not successfully producing the employability capabilities needed in the real world in terms of teamwork. This competency gap between students' actual teamwork skills and the skills required by the industry further sparked the need to revisit the teaching, learning and assessment practices of teamwork. Hence the technology-assisted peer review provided a solution to maintain the workload and the prospective to work smarter. This paper aspires to advance a better understanding regards the utilisation of peer review and its educational value in a large class size environment as the existing literature currently focus on small class size applications. This is an interactive mix methods study with a multiphase concurrent interdependent design. The emphasis is in the considerations of practical reality as the instructors in the high education institutions under the pressure of growing class sizes are in constant need of useful tools and new practical knowledge to better operate in their environment. The convenience sample includes 826 students forming 166 teams. After the completion, it became apparent that the peer review has a positive impact on students' self-awareness and that it can be used for assessment for a teamwork evaluation with certain limitations. This paper argues that the peer review, however, does not provide a 'quick fix' automatically improving students' teamwork capabilities but rather only assists in highlighting the problem areas when used in isolation. To enable actual cognitive learning and skills development, a more systematic approach involving curriculum development is required where teamwork skills are developed gradually through different modules from first to last year.**

Keywords—teamwork, team development, collaborative learning, peer assessment, large class

I. INTRODUCTION

The different fields of engineers are in high demand in South Africa as the country is suffering from an escalating skill shortage in most of its key economic sectors. Although South Africa's situation is acute, the country is nevertheless not alone, but nations all over are facing the same problem.

Consequently, the University of Pretoria's Faculty of Engineering, Built Environment and Information (EBIT) hosts the largest school of its kind in terms of student numbers in Southern Africa. Due to the growing administrative challenges and addressing the need for creating an efficient large class learning environment, EBIT introduced iPeer software tool as a part of its Engineering Management module's teamwork assessment.

This paper firstly aspires to advance a better understanding regards the utilisation of peer review and its educational value, as well as creating a greater awareness of the peer review technology available for super-sized classes, as the existing literature currently primarily focuses on small class size applications [1][2][3][4]. Furthermore, although eLearning can rightfully be claimed to be important and widely accepted, there is still, however, minimal high performing applications available [5][6]. This case demonstrates an implementation of iPeer software tool in assisting in the extensive class administration and assessment as well as in developing the student teamwork skills.

II. ENGINEERING EDUCATION ON TEAMWORK

The teamwork skills are among the top ten non-technical soft skills required in a modern workplace [7][8][9][10]. The employers actually, in most cases value the generic employability skills over the specific technical skills and hence, the educational practices should directly address the employability skills development [9][10][11]. The engineering professionals that learn well to the team would be more able to solve complex cross-disciplinary problems, align different cultures and viewpoints and to learn from multiple fronts, deliver a variety of outputs, and better manage a continually changing environment [12].

The Engineering Council of South Africa (ECSA) and the Accreditation Board for Engineering and Technology (ABET) emphasise the teamwork skills in their accreditation criteria for engineering and computing programmes [8][13][14], due to the professional profile of engineers having such a strong teamwork component [15]. Furthermore, the research on learning and education strongly continues to influence the engineering education; the set learning outcomes and the selected teaching approaches, more Profs using active learning methods, increasingly emphasising cooperative learning and increased student engagement [16][17][18]. Also, many instructors believe the importance of soft skills but most lack knowledge in developing these skills [19].

In most higher institutions, the use of teamwork is more related to lacking teaching or administrative resources rather than for the teaming skills improvement purposes [20]. Although the traditional approach is to place students together without further formal instruction and let them just 'work things out', it is, however, unlikely that any teamwork skills would be acquired through such an ad-hoc project experiment. There needs to be a more systematic approach towards the teaming and the

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development of students' teamwork competencies [19][21][22] through training and activities integrated into an active learning process [15][23]. Also, it is essential to note in a high technology environment, that a group of experts such as engineers do not necessarily naturally form an expert team [24] but quite the opposite. Typically engineers are well equipped in the technical skills needed for individual task performance. In contrast, the teamwork skills that are cognitive, behavioural and attitudinal aspects that an individual needs in order to function effectively as part of a team are left without much of attention and guidance [24].

According to Botha et al. [7], although the teamwork has such a high emphasis and a role in the higher education engineering programmes, the validity and reliability of the teamwork assessment is often questioned. In order to effectively assess the teamwork, both the final team deliverable and the process to develop that deliverable must be evaluated. Ideally, the feedback on teamwork leads to student's critical reflection and the development of the teamwork skills. In order to improve the teamwork skills, the assessment must support it as the learning is strongly influenced by the assessment [7].

Lingaard and Barkataki [21] aspired to find a more pragmatic and practical approach to teaching teamwork skills. They were driven by the need to establish criteria to measure the effectiveness of teaching these skills [21]. The teamwork should enforce the involvement of everyone in the team, both in the work and the assessment [25]. However, with this comes the challenge of how to assess the individual attendance and contribution to the team's results [20][23].

III. PEER ASSESSMENT

Botha et al. [8] emphasise that the assessment of teamwork should be based on both the output as well as on the deliverable to develop the output. This can be challenging since the teamwork typically takes place outside the formal classes where the lecturer cannot observe the team collaboration and contribution of the individual members. Peer participation evaluation (PPE) can cover this gap by allowing students to reflect their team dynamics and the respective teamwork skills by themselves. This feedback executed by the fellow team members regards the standard of work, and the overall team performance will enhance learning through improved understanding through self- regulation (monitoring of their learning) and self-correction, ultimately leading to metacognition [8]. In other words, PPE allows students to self-reflect and thus learn about themselves as well as about their role within the team [8][26].

Substantial research evidence suggests that peer assessment results in improved learning [26]. Peer assessment is a reliable and valid assessment approach to that conducted by an academic instructor and can complement other approaches such as cooperative learning [26]. Furthermore, an approach incorporating an element of peer assessment accounting for individual performance contributes positively towards the employability skills through learning as it increases the student responsibility and autonomy, provides insight to the assessment mechanisms and work expectations, advances deep learning, and motivates students to perform [11][27]. Regardless of the clear benefits and increasing implementation, many institutes still are not successful in incorporating the peer assessment to their formative or summative assessment [11]. There is also no clear consensus between the users regards the preferred peer assessment instrument [27]. However, the system should ideally be harmonised within the faculty, if not within the institution, in order to utilise the potential benefits fully. Some of the instruments currently available for peer- reviewing are Turnitin, PeerScholar, edx ORA, Canvas and iPeer [28].

iPeer is an open-source peer review application developed by the Centre for Instructional Support at the University of British Columbia [29] that enables the instructors to develop and distribute evaluations to the students online efficiently and to review and distribute the received student comments. iPeer offers three types of evaluations: (i) simple evaluations where students evaluate each other by distributing a set number of points among their team members, (ii) rubric evaluations where the students evaluate each other based on specific criteria, and (iii) mixed evaluations where the students evaluate each other by using a combination of the simple and rubric evaluations. Evaluations are based on anonymity, where the respondent students details are concealed and not shared with the other students in order to provide a platform for honest feedback. In all, iPeer facilitates customised evaluations in an automated and anonymous system environment, hence reducing instruction workload and overall logistics required, as well as efficiently distributing the assessments and receiving the feedback [30]. Furthermore, iPeer assists in establishing individual marks by allowing the team members to assess each other's participation and contribution to reaching the team's objective. Thus iPeer promotes not just effective teamwork but also individual learning.

IV. METHOD

The objective of this study seeks to create knowledge that guides practise through evaluating the outcomes and the overall experiences of iPeer implementation into a large class environment, especially from the students' teamwork skills development point of view. This study attempts to explore the concept of peer assessment inductively, and iPeer tool especially in order to answer to two questions: (i) what is the usability of iPeer in a large class environment as an assessment tool, and (ii) does peer review have an impact on students' teamwork skills development?

This is an interactive mix methods study that incorporates both qualitative and quantitative research approaches in order to provide more in-depth analysis and understanding of the research problem to guide the academic practitioners [31]. The different components are in constant interaction, and their outcomes are integrated throughout the study.

This study follows a multiphase concurrent interdependent design and the study is conducted in four phases. The implementation of each of the phases is not dependent on the results of data analysis of the other component. The integration of different approaches takes place both at the analysis and the discussion of results with a joint display of study findings and the merging of datasets. The quantitative approach is deemed as the principal and decisive core component, and the qualitative as the supplementary component in addressing the study objectives. The four phases of the study were as follows: (i) Phase 1: Project work assessment, (ii) Phase 2: Team peer review, (iii) Phase 3: iPeer feedback survey, and (iv) Phase 4: Meta inference.

The data collection is conducted as follows: (i) Phase 1: Obtaining all team project work assessment information (i.e. final marks for the teams) captured in the University of Pretoria's clickUP Learning

Management System, internationally also known as Blackboard, (ii) Phase 2: Obtaining all the individual peer assessment information (i.e. individual student evaluation marks) captured in iPeer, and (iii) Phase 3: Obtaining all the individual iPeer survey responses captured in Qualtrics.

The data analysis is conducted for both qualitative and quantitative datasets. The overall objective for quantitative data analysis is to convert the data into a readable format. The process starts with data preparation, including the validation (i.e. ensuring through a random sample of 5% that the correct procedures are followed and that the data is complete), editing (i.e. checking for errors and outliers) and coding (i.e. grouping and assigning values) of the quantitative data. The data preparation is followed by the data analysis, including the preparation of descriptive and inferential statistics and the execution of structural coding in order to identify broader topics, commonalities, relationships and indexing [32].

Following the preparation, qualitative content analysis is conducted. After the overall data analysis for both Phases 2 and 3 are completed, a meta inference, i.e. meta summary and synthesis for both quantitative and qualitative data analysis is completed in order to synthesise the results.

The sample for this study is all University of Pretoria's engineering students registered for the third year Engineering Management module in 2019. This convenience sample including 826 students of which formed 166 groups, is not further categorised according to sex, race or any other demographic factors. The peer review is compulsory for all the students when the participation in the following iPeer feedback questionnaire is voluntary.

All the 826 students are required to complete project work in auto-created teams (i.e. iPeer generated teams automatically based on random selection, only the maximum number of five team members were present) of which is assessed as follows: (i) the project work report is assessed by the academic personnel as the team deliverable and forms the basis of the overall team mark, and (ii) the peer assessment where the team members are assessing each other anonymously allocated the weight for each student. In other words, the project mark (i.e. overall team mark) x the individual student weight = the individual student mark for the project work. The student is assessed competent if the project work report is competent, and the peer assessment completed by the group members indicates that the student has contributed competently.

The 166 teams are instructed to submit their finalised project work reports within a set deadline, only after which the peer evaluation takes place. The project work report mark (i.e. the team mark) is used as a reflection point for criterion validity for this study where the project work report mark is compared predictively to the iPeer assessment mark.

iPeer is made available for students for seven days after the report submittal deadline closed. Each team has access to their event window in iPeer through clickUP where all the students are required to assess each of their team members as well as themselves as per the rubric provided. The rubric includes ten assessment criteria of which the assessment scale is pre-defined from the poor performance 'Not acceptable', through standard performance 'Effective', to finally to the highest performance level as 'Excellent'. Each student is required to fill in the assessment as well as to include a written comment for each of the ten criteria.

After all the students in a team have submitted their peer reviews, the assessment mark and the written feedback becomes available in the system. The assessment process is completed anonymously, and the students cannot identify who gave which assessment and feedback.

All the peer evaluation results are exported from iPeer as a dataset for descriptive and inferential statistics analysis preparation and qualitative coding by using a structural coding approach in order to identify initial patterns and connectors [32]. The categorisation is theoretically based on Topping [26] and Bannister et al. [33] where Topping [26] emphasises the importance of providing feedback as imperative in order to enable corrective actions and learning to take place. Thus the coding was following his main categorisation to confirmatory, suggestive and corrective feedback types. Furthermore, the feedback is also categorised according to the writing style from a general to very specific[26]. From another point of view, Bannister et al. [33] in their study present critical elements for effective teamwork of which four are applied for categorisation, namely communication, respect, leadership and engagement [33].

The iPeer feedback survey is released after the official module assessment process is finalised. The survey questionnaire is developed in Qualtrics, and the link together with the Quick Response Code to the survey is distributed to all the students via clickUP. The survey is made available for seven days and concluded before the actual marks are published in order to receive objective and unbiased feedback unassociated to the marks. The survey serves to record the usability of iPeer and to collect opinions and feedback regards the student learning component and is conducted anonymously. A descriptive and inferential statistical analysis is prepared and the qualitative data coding applied by using structural coding approach [32] where the comments six categories were formed, namely the iPeer experience (i.e. how did a student experience the use of iPeer in general), other emerging themes (i.e. other themes that were frequently emerging in the student comments), teamwork skills (i.e. teamwork skills and iPeer's possible impact on their development), assessment (i.e. how did the student experience being assessed, assessing others or self- assessing), peer comments (i.e. did the student go through the peer feedback), and peer assessment at the University of Pretoria (i.e. would the student support regular use of peer assessment in teamwork).

Lastly, a meta inference is conducted where all the different phases analysis outputs are reflecting each other.

V. RESULTS

In all, the written student peer comments can be categorised into two main segments: 75.2% confirmatory in nature, and 12.8% directly related to the overall communication, the other type of comments being presented in insignificant numbers. The role of a confirmatory response is to communicate the correctness or incorrectness of action or behaviour in a team, pointing out the positives and negatives. In contrast, the communication-related comments address the different ways to exchange information within the team and the overall interaction in a team's social context.

The segments that can be directly related to the development of teamwork skills and learning, namely the suggestive and very specific comments as well as the corrective comments, consist only 1.0% of all the comments of which as such is not a significant proportion. A suggestive comment by its definition includes a recommendation where the corrective comment provides a suggestion of corrective measure. As such both suggestive and corrective comments can be said directly providing a basis for the recipient to not just to better understand of his/hers capabilities but even more important to understand how to change for the better. Furthermore, a very specific comment provides the receiver with more detailed feedback and thus is also more valuable and useful from the learning point of view [26].

Consequently, these results, especially the significantly small proportion of feedback directly impacting on the learning and development of teamwork skills, bring up the question of the peer assessments actual capability in contributing in the development of students' teamwork skills as such but instead it contributes in identifying negative and positive individual attributes. Although from another point of view, it could be argued that confirmatory when presented as a negative comment, i.e. pointing out incorrect action or behaviour, could also indirectly provide a basis for learning and as such be corrective feedback in nature, and hence the proportion of feedback directly impacting on the learning and development of teamwork skills could be significant.

When analysing the frequencies in more detail, the confirmatory comments are evenly dispersed between all the assessment questions. In contrast, the communication comments are focused on the communication through text and voice 45.0%, and to the communication about the progress and challenges 29.9%. Furthermore, the question concerning the delivery on time received the highest number of corrective comments of all the questions. The students paid the closest attention to the manner of how their team members were communicating and felt that the matters of progress and the possible issues experienced that could hinder the execution of the project was the most critical information to communicate within the team.

When looking at the overall comments section that was made available for any open comments at the end of the peer assessment, its higher relative proportion of 12.3% of the overall comments together with the relatively higher number of corrective comments 6.4% and the significantly lowest amount of general comments 0.7% indicates that the students were quite willing to give a detailed and specific written feedback on their peers.

Overall, students' feedback is frank, direct and honest rather than just diplomatic, courteous and suggestive throughout the peer assessment questions.

The further statistical frequency analysis indicates that the criteria means are all in very close proximity to the maximum mark and that the standard deviation is small. Furthermore, the marks are clustering at the maximum end of the scale (negative skewness) and forming a heavy-tailed distribution (positive kurtosis); thus it can be concluded that the students have the tendency not only to award high marks to their peers but also to award the same marks to everyone.

The majority (80%) of the respondents' impression on the iPeer overall usability is positive. The application is found to be somewhat (26%) or very easy (43%) to use, where 70% of the respondents indicated that they did not need to use any instructions when navigating around the system.

All the respondents were unanimous that the teamwork skills are valuable for future employment and career. From the learning perspective majority of the students felt that iPeer had an impact on teamwork skills (84%), that iPeer experience was valuable (80%) and that it would be useful to have all the teamwork peer-assessed regularly (80%) at the University of Pretoria. Furthermore, 77% stated that they had read the peer comments made available to them.

As expected, the overall iPeer feedback survey comments are dominated by the feedback regards the overall iPeer experience, covering 29.3% of all the comments. Surprisingly the emerging themes form almost an equal relative proportion of 27.6% as a whole. In this category, the topic contributing the most is the students' improved ability to assess the individual performance in a group work situation 12.6% followed by the issues regarding the grading scale 5.7% where students suggested that the grading should allow zero assessment for peers that do not contribute, the positive feedback on overall anonymousity 5.3%, the concerns about the underlying motivations 3.7% and personal views affecting the assessment, and lastly the concerns of honesty 2.8% regards the self-assessment.

The segments that can be directly related to the development of teamwork skills and learning consist of 17.0% of all the feedback. The written feedback confirms the students to consider the peer assessment to be a positive experience and indeed to bring some positive value to the teamwork. However, the actual value to the learning is not considered significant. The students also consistently point out in the comments that the peer assessment itself does not as such build the teamwork skills but more point out the positives and negatives in students' performance and behaviour.

The final meta inference indicates that where the project report marks (assessed by the lecturers) have a normal distribution. In contrast, the peer assessment has a deviation from normal as the students are giving very high marks to all of their peers regardless of the contribution.

VI. CONCLUSIONS

The large class size of the Engineering Management module and the traditional, often manual, approaches applied had led to a situation where the management of the module had become overly strenuous, occupying the few academic resources mainly to administrative tasks and preventing the development and execution of a more efficient project work assessment of the students. Furthermore, the students received limited, superficial feedback of their performance that was based only on the project work report submitted by the student teams as their collective output. Thus, students did not have access to any individual feedback on their teamwork performance.

The iPeer project was initially started to ease the administration related to the assessment of ±1000 students through technology utilisation. Very early on the potential as an educational aid was also realised. Based on the data gathered, this study, however, argues that peer review itself will not automatically improve teamwork skills but rather only highlights the problem areas. To enable actual cognitive learning and skills development, a more systematic approach involving curriculum development is required where teamwork skills are developed gradually through different modules from first to last year. This would involve developing a teamwork teaching and study building block into the official LMS.

On the whole, students find the usability of the application to be so easy that they do not require any instructions to navigate around the system. Students also receive more individual feedback much quicker from their peers through iPeer than that what can be offered by the academic staff. Hence the iPeer offers a valuable solution in cases of constrained resources and minimal academic capacity. It is important to note, however, that the overall assessment should preferably be based on the students' comments than the marks given. For good quality feedback, it is advisable to have only a one general comment section at the end of each peer assessment as suggested by the students. In general, the comments provide a reliable source of information that further supports the overall assessment.

To conclude, this study advances the theoretical position of broader curriculum development as a prerequisite in enabling cognitive teamwork learning and skills development, especially in a large class environment. A systematic approach supporting both the teaching (academic staff) and learning (students) can best enhance the efficiency and successfulness of teamwork skills development. The broader implications of the research support the use of peer review software tools in a large class size environment, providing the assessment is based on the written comments.

This study had several limitations, which also offer avenues for future research. The data was based on a single case study where the students' team roles were not taken into account. Therefore, future research could explore the students' allocation to the teams based on their different characteristics and the impact on this to learning. Furthermore, the utilisation of more comprehensive CATME-B peer evaluation instrument for a more rigorous approach and a further study on group averages and the sampling of poor-performing students in a longitudinal study should be explored. Despite the limitations, this study reported on actual experiences from a super-sized class perspective, giving new insights to the limited literature in a large class size engineering education environment.

REFERENCES

[1] Brill, J. M. and Hodges, C. B. (2011). Investigating Peer Review as an Intentional Learning Strategy to Forster Collaborative Knowledge-Building in Students of Instructional Design. International Journal of Teaching and Learning in Higher Education. Vol. 23, No. 1. Pp. 114- 118.

[2] Nicol, D., Thomson, A. and Breslin, C. (2014). Rethinking Feedback Practices in Higher Education: A Peer Review Perspective. Assessment & Evaluation in Higher Education. Vol. 39, No. 1

[3] Ballantyne, R., Huges, K. and Mylonas, A. (2002). Developing Procedures for Implementing Peer Assessment in Large Classes Using an Action Research Process. Assessment & Evaluation in Higher Education. Vol. 27, No. 5. Pp. 102-122.

[4] Topping, K. (1998). Peer Assessment Between Students in Colleges and Universities. Review of Educational Research. Vol. 68, No. 3. Pp. 249-276.

[5] Islam, N., Beer, M. and Slack, F. (2015). E-Learning Challenges Faced by Academics in Higher Education - A Literature Review. Journal of Education and Training Studies. Vol. 3, No. 5.

[6] Kahiigi, E., Danielson, M., Hansson, H., Ekenberg, L., and Tusubira, F. F. (2009). Criticism of e-Learning Adoption and Use in Developing Country Context. IADIS International Conference e-Learning 2009.

[7] Botha, A., Bezuidenhout, S., du Plessis, L., Muller, E., Steyn, R., Weilbach, L., Janssen, R., Maritz, J. and Cronje T. (2019). Implementing an Online Tool for Teamwork - Assessment in Real Time: a Faculty Initiative Across Disciplines. In Remenyi, D. (ed.). The 5th e-Learning Excellence Awards: An Anthology of Case Histories. Reading: The United Kingdom. Academic Conferences and Publishing International Ltd. Pp. 21-40.

[8] Botha, A., Steyn, R., Weilbach, L. and Muller, E. (2018). Using the iPeer LMS Feature to Evaluate Peer Participation in Teamwork for Assessment "as Learning": Lessons Learned. Emerging Technologies for Education. Third International Symposium, SETE 2018.

[9] Pentland, A. (2012). The New Science of Building Great Teams. Harvard Business Review. April 2012 issue.

[10] Tarricone, P. and Luca, J. (2002). Successful Teamwork: A Case Study. Proceedings of 25th HERDSA Annual Conference. Perth, Australia, 7-10 July 2002.

[11] Cassidy, S. (2006). Developing Employability Skills: Peer Assessment in Higher Education. Education + Training. Vol. 48, No. 7.

[12] Edmondson, A. C. (2012). Teamwork on the fly. Harvard Business Review. April 2012 issue.

[13] ECSA (2019). Standards and Procedures System, South Africa.

[14] ABET (2019). Criteria for Accrediting Engineering Programmes. Online.

[15] García-Martín, J., Pérez-Martínez, P. and Sierra-Alonso, A. (2015). Teamwork, Motivational Profiles, and Academic Performance in Computer Science Engineering. IEEE Revista Iberoamericana de Technologias del Aprendizaje. Vol. 10, No. 2.

[16] Froyd, J. (2012). Five Major Shifts in 100 Years of Engineering Education. Proceedings of the IEEE. Vol. 100.

[17] Felder, R. M. (2006). Teaching Engineering in the 21st Century with a 12th Century Teaching Model: How Bright is That? Chemical Engineering Education. 40(2).

[18] Rugarcia, A., Felder, R. M., Woods, D. R. and Stice, J. E. (2000). The Future of Engineering Education I. A Vision for a New Century. Chemical Engineering Education. Vol. 34, No. 1.

[19] Woods, D. R., Felder, R. M. Rugarcia, A. and Stice, J. E. (2000). The Future of Engineering Education III. Developing Critical Skills. Chemical Engineering Education. Vol. 32, No. 2.

[20] Hilborn, R. B. (1994). Team Learning for Engineering Students. IEEE Transactions on Education. Vol. 37, No. 2.

[21] Brown, R. W. (1995). Autorating: Getting Individual Marks from Team Marks and Enhancing Teamwork. IEEE Frontiers in Education Conference.

[22] Lindgard, R. and Barkataki, S. (2011). Teaching Teamwork in Engineering and Computer Science. 41st ASEE/IEEE Frontiers in Education Conference.

[23] Budimac, Z., Putnik, Z., Ivanovic, M., Bothe, K. and Schuetzler, K. (2019). On the Assessment and Self-Assessment in a Students Teamwork Based Course on Software Engineering. Computer Applications in Engineering Education. Vol. 19, 1-9.

[24] Burke, C. S., Salas, E., Wilson-Donnelly, K. and Priest, H. (2004). How to Turn a Team of Experts into an Expert Medical Team: Guidance from the Aviation and Military Communities. Quality & Safe in Health Care. Vol. 13, No. 1.

[25] Bellamy, L., Evans, D. L., Linder, D. E., McNeill, B. W. and Raupp, G. (1994). Teams in Engineering Education. Arizona State University.

[26] Topping, K. J. (2009). Peer Assessment. Theory Into Practice. Vol. 48.

[27] Ohland, M. W., Loughry, M. L., Woehr, D. J., Bullard, L. G., Felder, R. M., Finelli, C. J., Layton, R. A., Pomeranz, H. R. and Schmucker, D. G. (2012). The Comprehensive Assessment of Team Member Effectiveness: Development of a Behaviorally Anchored Rating Scale for Self- and Peer Evaluation. Academy of Management Learning & Education. Vol. 11, No. 4.

[28] The University of British Columbia Learning Technology Support Hub (2019a). Peer-Based Assessments. The University of British Columbia. 14th May 2019. <https://lthub.ubc.ca/tech-uses/peer-based- assessments/>

[29] The University of British Columbia Learning Technology Support Hub (2019b). iPeer. The University of British Columbia. 14th May 2019. <https://lthub.ubc.ca/guides/ipeer/>

[30] The University of British Columbia Learning Technology Support Hub (2019c). What is iPeer. The University of British Columbia. 14th May 2019. <http://ipeer.ctlt.ubc.ca/wiki/whatis>

[31] Schoonenboom, J. and Johanson, R. B. (2017). How to Construct a Mixed methods Research Design. Köln Z Soziol. Suppl 2, 69.

[32] Saldaña, J. (2016). The Coding Manual for Qualitative Researchers. SAGE.

[33] Bannister, S. L., Wickenheiser, H. M., and Keegan, D. A. (2013). Key Elements of Highly Effective Teams. Paediatrics. January 2014.

Technical Papers

Project management of global project-based learning course for innovation and sustainable development

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***Abstract*—Since 2013, we have been implementing a global project-based learning (PBL) course of our own design. The global PBL course is an engineering education project for fostering innovation and global-mindedness among engineers and scientists. The course is multidisciplinary and multinational, involving industry–academia collaboration in project-focused learning. Project themes are related to sustainable development goals and real-world industry problems. Global PBL programs include two project types: faculty projects and student projects. To implement the global PBL program, the faculty must perform certain project activities such as designing an educational program to improve the international learning environment while implementing, controlling, and continuously improving educational activities. Project deliverables and activities are organized as a work breakdown structure (WBS) prior to the commencement of the project. This process involves defining faculty member roles, preparing a schedule for the preparation phase, and implementing the global PBL program. The faculty plans, executes, monitors, and controls the project. At the end of each year's global PBL course, the Keep–Problem–Try (KPT) method is used to implement continuous improvement of the course. At the end of the course, the faculty describes the KPTs in line with the WBS items. The KPTs are then collected and shared among the faculty, leading to continuous improvement.**

Keywords—Project-based Learning, Global, Innovation, SDGs, Multidisciplinary, Project Management

I. INTRODUCTION

In recent years, engineering education has changed due to society's expectation that education promote student awareness and understanding of social issues while offering knowledge and technology related to specific fields. During the Fifth World Engineers Conference and Convention 2015 (WECC 2015), the Kyoto Declaration was adopted, including the statement that engineers must not only work to advance specialized knowledge of science, technology, and engineering, but also consider societal concerns [1].

For engineers, higher education is a main venue for education in innovation. Innovation education is crucial in engineering, helping link pure engineering with societal needs. Teamwork among people of differing specialties and backgrounds is important, and methodologies that integrate knowledge and technology are clearly needed. Implementation of innovation in an engineering context can involve the following processes: exploring social issues, creating solution concepts and prototypes, maintaining a discussion centered on society, and introducing prototypes that establish new services while obtaining user evaluation.

We observe that innovation education, including methodology and practical training to create new value, is necessary for all engineers and engineering students. Moreover, we believe that such education should be conducted during each stage of both undergraduate and graduate education. In line with these trends, science and engineering educational institutions have developed various project-based learning (PBL) educational programs taught by diverse teams [2] [3] [4].

Since 2013, the authors have been implementing global PBL programs for students from Japan and Southeast Asian countries, with the goal of developing individuals who can promote discovery and innovate to solve social problems across fields. Global PBL programs also include faculty and staff projects for designing educational programs and environments, maintaining learning environments, and coordinating with industry and the community. In this paper, both student projects and faculty and staff projects are described.

II. GLOBAL PROJECT-BASED LEARNING (PBL)

A. Overview of global project-based learning (PBL)

Each year, the Shibaura Institute of Technology (SIT) conducts 80 global PBL programs at home and abroad. Each PBL program consists of a unit specific to a field such as mechanical engineering, electrical and electronic information engineering, or civil engineering. A cross-disciplinary PBL unit is also offered in which students participate from across multiple fields.

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In the global PBL programs implemented around the world in Asia, Europe, and other locales, students and faculty from Japan stay at partner universities, where students from those partner universities and visiting Japanese students conduct intensive activities for approximately ten days. These activities include problem discovery as well as solution design, prototyping, and presentation. In contrast, for global PBL programs in Japan, students from around the world are invited to Japan and implement a multinational global PBL program there.

Cross-disciplinary global PBL programs concern social problems such as sustainable development goals (SDGs) and real industry and community problems. Program themes cover a variety of topics such as energy, transportation, environment, poverty, natural disasters, and education. In cross-disciplinary PBL programs, students from different departments cooperate to define problems, set tasks, propose solutions, and produce prototypes [5] [6] [7].

B. Cross-disciplinary global project-based learning (PBL)

The first global PBL program was held in Bangkok, Thailand, in February 2013 in a collaboration between SIT and Thailand's King Mongkut's University of Technology Thonburi (KMUTT). The following year, Indonesia's Institut Teknologi Sepuluh Nopember (ITS) joined the global PBL effort. This program has since continued while making improvements and adding participating institutions, with the global PBL program taking place in February 2020.

In 2015 SIT initiated a multinational global PBL program, partnering with KMUTT, ITS, and other Japanese, Asian, and European universities on SIT's Omiya campus.

C. Global project-based learning (PBL) program with complex project management

Global PBL program that include multidiscipline, academia-industry collaboration, and multinationality, and require immense administrative tasks for inviting international students and faculty. Moreover, overnight trip for an intensive project camp needs complex project management.

A global PBL program implemented at SIT's Omiya campus in Saitama Prefecture and Nasu town, Tochigi Prefecture is described. This global PBL program was implemented for 10 days: December 5–14, 2018 (Figure 1). Seventy one students and six teaching assistants participated in the PBL course, with participating students coming from 21 universities in 11 countries (Figure 2). Of the students participating in the global PBL course, 34 hailed from Japanese universities (SIT, Ehime University, and Tokyo Denki University); 16 students hailed from Thai universities (KMUTT, Suranaree University of Technology, Thai-Nichi Institute of Technology, and Nakhon Ratchasima Rajabhat University), and five students hailed from Vietnamese universities (Hanoi University of Science and Technology, Ho Chi Minh City University of Technology, and the Posts and Telecommunications Institute of Technology in Vietnam). Additional participants from Indonesia, Malaysia, China, Taiwan, Mongolia, Ireland, Germany, and India included three students from ITS; three from Universiti Teknologi Malaysia and Universiti Utara Malaysia; three from the Wuhan University of Technology and the China University of Geosciences; two from Ming Chi University of Technology and Tamkang University; two from Mongol Koosen College of Technology; one from the Waterford Institute of Technology; one from Clausthal University of Technology; and one attended from K.L.S. Gogte Institute of Technology.

The PBL also includes academia-industry collaboration with more than ten local industries and government.

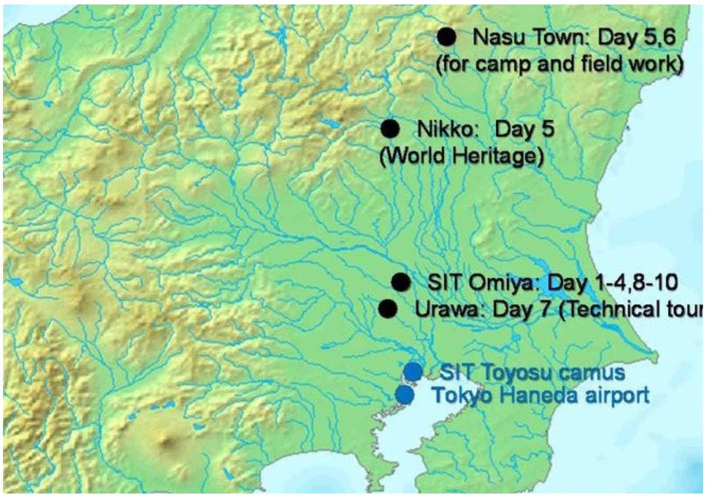

***FIGURE 1** gPBL2018 venue, Kanto, Japan*

***FIGURE 2** Participants in gPBL2018 at SIT Omiya*

III. AIM AND RESEARCH QUESTION

The burden and degree of difficulty of conducting a global PBL course can vary substantially depending on course location, number of participating students, presence or absence of industry–academia collaboration, and scope of the participating students. The program placing the least burden on faculty and staff would be a small-scale PBL course between two university laboratories, focused on a single technological field, with no industry–academia collaboration. In contrast, the most burdensome and difficult program would be one with students of various specialties from many countries and universities, covering multiple technological fields, with extensive university–industry collaboration (Figure 3).

The challenge is managing the complexity of the project and ensuring project success.

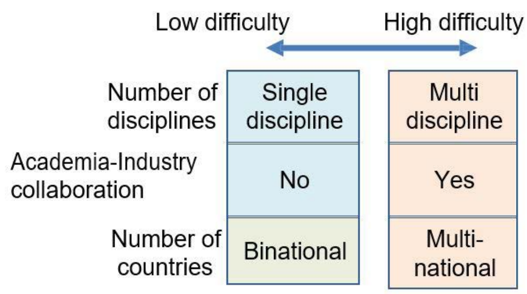

***FIGURE 3** Factors influencing the difficulty levels in designing and implementing global PBL*

IV. METHODOLOGY

A. Stakeholders and scope of global project-based learning (PBL)

Implementing the global PBL program required faculty and staff to create project activities and a learning environment . Project activities included designing an educational program, improving the international learning environment, and implementing, controlling, and continuously improving educational activities. This international collaboration project conducted by faculty and staff enabled students to conduct active learning in Japan and abroad.

The global PBL program has extensive stakeholders, including students, faculty, and staff from each university, teaching assistants (TAs) from universities in Japan and elsewhere, such as cooperating companies and local governments, grant-related funders, and government ministries and embassies. Staff include teachers in charge of courses, staff from the International Division, staff from the Academic Affairs Division, and staff from the University–Academia Collaboration Division.

From the faculty and staff perspective, the global PBL project's scope included various tasks (Table I) : the design of a PBL educational program; management of cooperation with industry and local governments; participant selection and recruitment; recruitment, development, and management of TAs; arrangement of participants' travel and lodging; facilitating cultural exchange among students; enabling coordination among faculty members from participating countries; assessing tool development and procurement of learning outcomes; sending out evaluation results of learning outcomes to participating universities in Japan and abroad; designing and implementing an award system with participation by domestic and foreign students and teachers. These tasks involved dealing with staff illnesses and injuries; budgeting; fundraising; and expense processing and reporting to government agencies, partner companies and local governments and groups.

B. Project management of project-based learning (PBL) by Work Break Down Strucutre (WBS) and Keep-Problem - Try (KPT) method

Project deliverables and activities are organized as a WBS prior to the start of each project [8] [9]. This process involves defining faculty and staff member roles and preparing a schedule for the preparation and implementation phases of the global PBL program. Faculty and staff plan, execute, monitor, and control the project, and at the end of each year's global PBL course, they use the Keep–Problem–Try (KPT) method to implement continuous improvement. The KPT method, a mental framework used to determine improvement actions, proceeds in the following order: K = Keep (items that were good and should be continued), P = Problem (areas that need improvement), T = Try (new ideas). At the end of the course, faculty and staff describe KPTs in line with WBS items. The KPTs are then collected and shared among the faculty and staff, prompting continuous improvement.

TABLE I *Scope of Global Project-Based Learning (PBL)*

Designing global PBL as an educational program	• Design of educational objectives, curriculum and evaluation of learning outcomes • Development and arrangement of tools for assessment of learning outcomes • Award system design and implementation • Sending of evaluation results to participating schools in Japan and abroad
Participants and stakeholders	• Domestic and international participant recruitment and selection of participants • Recruitment and training of teaching assistants (TAs) • Coordination among the faculty members of the participating countries • Collaboration with industry and local governments • Cultural exchange between students
Support services	• Arrangement of travel and accommodation for participants (Visa application, air ticket and accommodation arrangements) • Arrangement of chartered buses for domestic transportation and transportation to and from the airport • Preparing for a welcome party, etc.
Crisis management	• Public safety, illness and injury of participating domestic and foreign students and faculty
Finance and accounting	• Budget planning, grant applications, collection of donations, and expense processing
Reporting	• Reporting to government agencies, partner companies, local governments and organizations

C. Industry-academia collaboration with local companies

The global PBL course implemented in Thailand has included collaborations with Honda Automobile (2014), Ajinomoto Thailand (2015), Isuzu Motors (2016), EXEDY Friction Material (2017, 2018), YKK (2019), and various Japanese-affiliated companies. Factory tours and exchanges of opinions with company executives have helped students understand manufacturing, design, research and development localization, and methods for communicating among multinational employees. Additionally, in 2016 a local connector manufacturer provided a global PBL theme related to manufacturing and product testing. Two student teams worked on issues connected with this theme, visiting the local factory's production line. Based on engineer interviews, multinational and multidisciplinary student team we used characteristics and suggested concrete solutions to fit the local situation. The teams' solutions were given strong evaluations by the company.

V. RESULTS

A. Student behavior and teacher involvement

Participating students from Southeast Asia hail from the top technical universities in their respective countries and excel at using their expertise to solve determinate problems. However, these students have little experience with finding problems or with working on problems lacking a predetermined answer. In addition, Japanese students tend to believe that environmental, hygiene, and transportation issues, among others, in Southeast Asian countries have already been solved in Japan, and that those issues can be solved elsewhere using the same means. Thus, the goal is for these students to come up with new solutions as a multinational team. The teacher's role is to set up multinational and multidisciplinary student teams to promote creative activities that are not limited to easy solutions.

B. *Global project-based learning outcomes and quality assurance*

Learning outcomes were assessed for students, and results were fed back to participating universities. Learning outcome assessment included design of a rubric (evaluation-level table) for individual learning results and project achievements, as well as individual self-evaluation at the start and end of the program in accordance with learning objectives. Self- assessment and mutual evaluation among students were conducted with respect to study results and teacher evaluation, and inter-group evaluations were carried out concerning project results (Table II) [10] [11].

***TABLE II** Learning Outcomes and Quality Assurance of Global PBL*

	Learning outcomes and assessment methods
1	Rubric for individual learning outcomes (used for student self-evaluation and student peer evaluation)
2	Rubric for results of team activities (peer evaluation between teams and evaluation by teachers)
3	Engineering communication skills (developed a CEFR-based Can-Do list)
4	Intercultural ability
5	Generic skills (PROG applied to global talent evaluation)

Additionally, a multi-lingual introductory Progress Report on Generic Skills (PROG) [12] [16] for evaluating generic skills in adults was conducted. The PROG consisted of a literacy test measuring knowledge-based generic skills and a competency test measuring experience-based generic skills. In 2013, an English-language version of both PROG examinations was prepared and used with Japanese and Thai students. The scores in the literacy test, which consisted of long sentences, were lower for students of lower foreign language proficiency. Starting in 2014, to maintain accurate evaluation and fairness, competency examinations using short problem sentences were standardized in English regardless of student nationality, while long-sentence literacy examinations for Japanese and Thai students were conducted in their native languages.

C. *Collaboration expansion in global project-based learning*

It is desirable that faculty members create project plans and make full use of the implemented global PBL program and that many universities and companies participate and share their results (Table III). Global PBL links education, research, and industry–academia collaboration, strengthening joint research and industry–academia collaboration among faculty from various universities (Figure 4).

***TABLE III** Collaboration in Global Project-based Learning*

Benefits	• Economies of scale (project planning, logistics) • Diversity (different universities, majors, and cultures) • Learning from each other about good practices in PBL
Expertise	• Multidiscipline • Single discipline
Collaboration	• Domestic universities • Industry- academia • International universities
Location	• Japan and abroad
Student projects	• Practical issues of industry and community • Social issues, SDGs • Simulated issues
Period	• two weeks intensive, quarter, semester, 1 year
Implementation costs	• Self- funding, • On-campus budget, • On-campus scholarships • Government scholarships
Sharing of teaching and assessment methods, joint development	• PBL instructional design • Assessment methods for learning outcomes • Credit approval and grading • Credit transfer

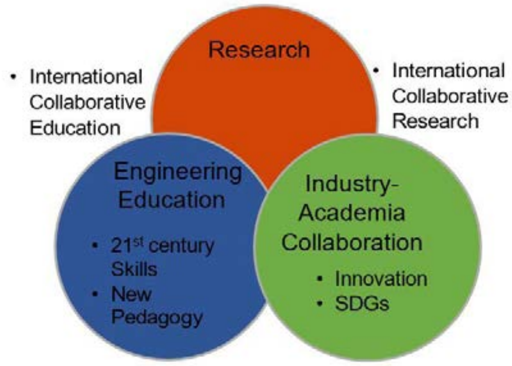

***FIGURE 4** Expanding global project-based learning collaboration*

D. *Global technology initiative consoutium*

SIT established the Global Technology Initiative (GTI) Consortium in 2015 [13]. The Consortium is a platform in which universities, industries, and government agencies cooperate, with the purpose of generating innovation and developing human resources. In collaboration with universities, companies, and government agencies, the GTI Consortium co-hosts global PBL, international internships, international joint research, inter-governmental cooperation projects, inter-university international collaborations, and the GTI Consortium Symposium (Figure 5) (Table 2).

The cross-disciplinary international PBL program described in this paper began in February 2013 and was regarded as a precedent for establishing the GTI Consortium. To implement global PBL programs, it is necessary to train faculty and staff who can plan, implement, and control PBL activities. The joint use of global PBL by the GTI Consortium enables many university faculty and staff to experience global PBL. Training for operating global PBL programs is also being formulated.

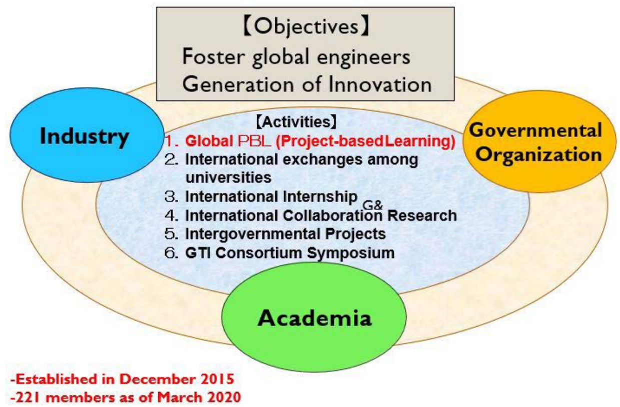

***FIGURE 5** Global Technology Initiative*

TABLE IV *Increase in GPBL Programs*

Field	Outbound			Inbound		
	Programs	Students		Programs	Students	
		Japan	International		Japan	International
Mechanical Engineering	8	117	77	3	30	40
Material & Chemistry	2	32	32	2	40	30
Electrical, Electronic & Computer Engineering	17	217	218	4	65	42
Civil Eng. & Architecture	16	183	181	6	67	71
Design & Engineering	5	75	150	7	145	141
Mathematics	2	5	5	1	10	5
Multi-disciplinary	3	79	73	1	40	40
Total	53	708	736	24	397	369

VI. SUMMARY

In 2013, a global PBL course was designed and it has been executed ever since. The global PBL course is an engineering education project for fostering innovation and global- mindedness in engineers and scientists. The course is multidisciplinary and multinational, and it involves industry– academia collaboration in project-focused learning. Participating students have come from Japan, Thailand, Indonesia, Cambodia, China, India, Malaysia, Mongolia, Vietnam and others countries, and participants have included third- and fourth-year undergraduate students and first-year graduate students. Project themes are related to SDGs and real problems in industry, covering a wide range of topics such as energy, transportation, the environment, poverty, natural disasters, and education. Multinational student teams find and define social, technical, and interdisciplinary problems and then design and prototype solutions. Global PBL programs involve two project types: those for students and those for faculty and staff. Faculty and staff develop educational curricula, implement the PBL program, develop the environment, and coordinate cooperation with industry and the community. Students develop their own project plans and then execute and control them in an environment of global collaboration. The education program's quality assurance has been achieved by assessing learning outcomes based on rubrics and a test known as the PROG Skills. Based on these experiences, the GTI Consortium was established in 2015 as a platform for collaboration among universities, industries and government organizations in Japan and Southeast Asian countries. The GTI Consortium aims to create innovation and develop human resources based on global industry–academia collaboration.

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REFERENCES

[1] Kyoto Declaration,(2015), The Fifth World Engineering Conference and Convention, available from: http://www.jfes.or.jp/wecc2015/about/pdf/kyoto_declaration.pdf.

[2] Segalàs, J, Benson, P, Esbrí, ME(2011), European Project Semester: 30 ECTS of PBL in Sustainability with Multicultural and Multidisciplinary Bachelor Students Groups, International Conference on Engineering Education.

[3] Servant, V, (2013), The many roads to Problem-Based Learning: A Cross-Disciplinary: Overview of PBL in Asian Institutions, The 4th International Research Symposium on Problem-Based Learning (IRSPBL), pp.395-403.

[4] Inoue, M, Hasegawa, H, Mano, K, Furukawa, Y, Yamazaki, A, and Khantachawana, A (2015), Development of an Engineering Education Program for Innovation in Global Environment, The World Engineering Conference and Convention (WECC2015).

[5] Inoue, M, and Hasegawa, H (2008), Evolutional Project-Based Learning of Systems Engineering and Project Management, 4th International Project Management Conference, pp. 519-525.

[6] Inoue, M (2011), Outcome Design an Assessment for Interdisciplinary Education, Proceedings of International Conference on Engineering Education, ICEE-2011.

[7] Inoue, M, Hasegawa, H, Mano, K, Furukawa, Y, Yamazaki, A, Khantachawana A, and Tachibana, M (2014), Systems Engineering Design Education based on Multidisciplinary and Global Project Based Learning, International Conference on Advanced Design Research and Education, ICADRE14 2014, pp.53-61.

[8] Project Management Institute (2019), Practice Standard for Work Breakdown Structures Third Edition, Project Management Institute.

[9] Project Management Institute (2017), A Guide to the Project Management Body of Knowledge (PMBOK Guide) Sixth Edition, Project Management Institute.

[10] Oda, S, Yamazaki, A, and Inoue, M (2017), Assessment of Global Competency in Engineering Students in Multicultural and Multidisciplinary Project Based Learning Course, The 7th World Engineering Education Forum (WEEF).

[11] Oda, S, Yamazaki, A, and Inoue, M (2018), A COMPARATIVE STUDY ON PERCEPTIONS OF CULTURAL DIVERSITY IN ENGINEERING STUDENTS, EDULEARN18, 10th International Conference on Education and New Learning Technologies, IATED, Palma de Mallorca.

[12] Progress Report On Generic Skill (2018), http://www.riasec.co.jp/prog_hp/

[13] Global Technology Initiative (GTI) Consortium (2020), http://plus.shibaura-it.ac.jp/gti/en/

[14] iEARN project (2020), https://iearn.org/

[15] Beemt, A, MacLeod, M, Veen, J, Ven, A, Baalen, S, Klaassen, R, and Boon, M (2020), Interdisciplinary engineering education: A review of vision, teaching, and support, JEE, 109 (3), July, pp. 508-555.

[16] Inoue, M, Matsumura, N, Oda, S, Yamazaki, A, Khantachawana, A (2020), Engineering Project to Foster Global Competency and Assessment of Learning Outcomes Using the PROG Test, The 48th SEFI Annual Conference, September 20-24.

Technical Papers

Engineering students' perspectives on the use of group work peer assessment in two undergraduate Industrial Engineering modules

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***Abstract*—Group work is commonly used in undergraduate engineering curricula as it cultivates attributes that make graduates work-ready. However, freeloading behaviour, frequently observed at university level, spoils learning benefits and can deepen marginalisation and prejudice. Therefore, conversations about how to fairly credit individual contribution in group work are ongoing in literature and practice. Peer assessment is a popular mechanism for distinguishing individual marks, but it is not without its criticisms. This study evaluates students' perspectives regarding the use of mark-influencing peer assessment in two junior-level Industrial Engineering courses at the University of Pretoria. The findings show that students acknowledge the learning benefits of group work but group work overuse and freeloading mars their experience. They support the use of mark- influencing peer assessment in general, regardless of whether groups are self-selected or allocated. The study's findings offer practical insights for engineering educators and broader inputs to the development of assessment policies.**

Keywords—peer assessment, group work, freeloading, individual contribution

I. INTRODUCTION

Engineering educators use group projects in their undergraduate courses to prepare graduates for the workplace. Project-based learning (PBL) is a favoured pedagogy, primarily because it emulates so well the professional environments of engineers in industry [1]–[3]. Facilitating PBL in a group setting — i.e. group work — has also risen to prominence as employers and accreditation bodies place more emphasis on the importance of teamwork and effective communication skills [4]–[7].

At the University of Pretoria (UP), high-stakes group projects are common in many of the third year (junior) and fourth year (senior) courses in the Bachelors degree in Industrial Engineering (IE). In conversation with colleagues, it is clear that developing work-ready graduates is a primary motivator for using group projects. But some have com- mented that there is a secondary, more pragmatic, motivator — workload balancing. We hope that the synergy of group work would reduce individual workload and introduce more enjoyment in the learning process. But, the informal feedback we have received from students over the years indicates that our altruistic notions seem to benefit the lazy and burden the diligent through *freeloading*.

The problem of freeloading (or *social loafing)* in university-level group work is pervasive [4], [7]–[9] and deeply harmful. Not only does freeloading erode the developmental benefits of positive interdependence advocated by cooperative learning proponents like Colbeck et al. [4], it can deepen marginalisation in the classroom [7]. When hardworking students mitigate freeloading by avoiding "slackers" [4], it further inculcates a culture that already avoids weaker students or students regarded as "other than us" [7]. In fact, in a culture that expects freeloading, it can become a scapegoat or smoke-screen for other harmful group dynamics, for example when more dominant or "diligent" students ignore or deliberately squash the earnest contributions of others in pursuit of a higher mark. After repeated experience, freeloading antagonises students to group work altogether and fosters resentment towards those educators who require it. Although freeloading is not the only root cause of negative group dynamics, literature highlights it as a significant one that requires proactive measures. We agree with authors like Mellor [7] who contend that freeloading is not innocuous, and thus it is our duty as educators to implement good group work practice by proactively combatting it.

Concerned about the negative impact of freeloading, we implemented mark-influencing peer assessment of group projects in two junior IE modules, namely Operations research (BOZ 312) and Simulation modelling (BUY 321). This technique is a practical and efficient approach for large classes in a resource-constrained environment. But it is not without its criticisms. Therefore, we wanted to investigate students' perceptions about its use. Our research question is:

"What are students' perspectives on the use of peer assessment in BOZ 312 and BUY 321?"

This paper presents survey results from four student cohorts collected in 2017 and 2018. Our findings provide recommendations to engineering educators who currently use group work but are frustrated by perceived freeloading behaviour. The insights from the student perspective also add to the conversations that formulate assessment policies in engineering schools.

The following section explains the rationale for mark- influencing peer assessment in this study. Section III outlines how data was acquired and analysed. Sections IV and V present findings of student perspectives regarding group work in general and peer assessment, respectively. Section VI answers the research question with suggestions for educators and administrators.

II. ASSESSING INDIVIDUAL CONTRIBUTION IN GROUP PROJECTS

A common source of tension in group work is due to reward interdependence [4] — i.e. everyone receives the same mark. Reward interdependence is a reality in professional settings. Thus

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if group work is to prepare graduates for industry, they must learn how to constructively navigate this interdependence and not avoid it. Herein lies a paradox that each educator faces. We embrace this paradox in our own practice as follows: While we endeavour to coach students in developing constructive group work attitudes, we need to scale reward interdependence in the context of time-constrained, outcomes-focused modules where the primary learning objectives are not related to cultivating teamwork attitudes.

Recognising individual contribution is the most popular way of scaling back reward interdependence in higher education. Although it could be argued that this is a more superficial approach to developing teamwork skills, many have found it effective in promoting fairness and better group dynamics [6], [8]–[11] within curricular constraints.

The question of how to measure individual contribution across diverse scenarios is not trivial [6]. The many creative approaches to assessing individual contribution found in literature and practice can be divided into three overlapping themes: explicit identification of individual work, lecturer assessment through observation and disclosure, and peer assessment. Hayes et al. [6] state that these assessment approaches should aspire to be fair, consistent, reflect educational objectives, provide feedback, encourage students, not allow mark inflation, and be easy on the assessor. We have not found evidence of any approach that meets all these criteria.

Peer assessment holds two advantages over techniques that rely on the lecturer: it lightens lecturer workload and has the potential to be more accurate. Group members could, arguably, have a more precise view of individual contributions than any outsider.

Concerns regarding peer assessment are fairness and honesty & impartiality in the face of social pressure [11] or stereotyping [9]. Sridharan et al. [11] show that when peer assessment is used in a formative sense, it is remarkably accurate and consistent. In contrast, when peer assessment is used summatively, influencing the final mark, the results are significantly less so. Despite this drawback, mark-influencing peer assessment remains a widely used technique, and students do seem to prefer it to the alternative where everyone receives the same mark [6], [8], [9]. Therefore, educators suggest strategies to increase the integrity of such peer assessment such as anonymity [8], including self assessment in the scoring [12], and coaching students in class to reduce the influence of social pressure and stereotypes [7]. Some also note that students grow in their ability to assess and thus experience may improve their judgements [11].

We were aware of the potential drawbacks of mark-influencing peer assessment when we implemented it, but in light of resource-scarcity, we hoped that it would still be effective in quashing freeloading.

III. DATA AND METHODS

Both BOZ 312 and BUY 321 teach mathematical modelling techniques used to represent, study, and ultimately improve industrial systems. It is critical that students learn how to apply these modelling techniques to real-world problems. The co-authors of this study, Prof Johan W Joubert and Dr Wilna L Bean, have presented BUY 321 and BOZ 312, respectively, at least since 2016. As these courses are closely related, Joubert and Bean often discuss and align pedagogical strategies.

From 2016 to 2018, both courses included a mandatory group project that formed a substantive portion of a student's final mark. The rubrics used to assess the academic merit of the project focussed on educational objectives related to various Engineering Council of South Africa (ECSA) outcomes. The rubrics used for peer assessment asked each student to rate their group members in terms of their attendance, participation, autonomy, and value-add. For each one of these criteria, students could select one of four competence levels: competence not achieved, towards required competence, competence achieved, or exceeds required competence. Each one of these competence levels had criteria-specific descriptions that were discussed in class at the outset of the module.

Since 2016, Joubert and Bean let the peer assessment influence the final mark. How the peer assessment influenced the final mark, differed slightly between the modules and is described alongside relevant results in Section IV. The authors' observations indicated that the approach held promise to reduce freeloading. Thus, in 2017 and 2018 (the study period), they obtained ethical clearance to administer a voluntary student survey for the purpose of this study.

In BOZ 312, the survey was administered after the project and peer assessment was finalised, but before students received their marks. In BUY 321, students completed two peer as- sessments — one after each major deliverable. The survey was conducted after the first peer assessment, but before they received their mark for the deliverable. We wanted to conduct the survey while the group work and peer assessment was still fresh in students' minds, thus we chose not to wait a few weeks until their marks were available.

There were four student cohorts in this study: BOZ312-2017, BOZ312-2018, BUY321-2017, and BUY321-2018. The number of survey respondents, respectively, were 61 (47%), 125 (85%), 77 (53%), and 115 (85%). BOZ 312 is presented in the first semester of the junior year and BUY 321 in the second. It is thus likely that respondents participated in two surveys (or more, if they repeated a course). We believe student perceptions can evolve, thus we prefer to include all responses. Besides, anonymity prevents any attempt to remove second or third responses.

The surveys were identical with the exception of two of the twenty-three questions (see Appendix A). Eight of these questions gauged students' opinions on the goals of using group work in the IE curriculum (Q1–Q7, Q16). These questions were included to explore whether students held the same opinion as us about the goals of group work. In the same vein, one question surveyed the suitability of group projects in the courses (Q8). A question about group formation was also included as this seems to be a contentious issue among our students and colleagues (Q17). Central to this study, two questions related to freeloading (Q9, Q10), five related to the importance and fairness of peer assessment in these courses (Q11, Q18–Q21), and four related to the appropriateness of the criteria used in the peer assessment (Q12–Q15). All these questions used a 5-point Likert scale (Strongly Disagree (SD), Disagree (D), Neither Agree or Disagree (N), Agree (A), Strongly Agree (SA)) and provided a Not Applicable (N/A) option.

The two last questions were included only for BUY321- 2017 and BUY321-2018. One surveyed whether students thought their peers had sufficient knowledge of all aspects of the project (TRUE/ FALSE) (Q22), the other allowed general comments (Q23).

Mann-Whitney hypothesis tests could not, in nearly all cases, reject the null hypothesis that the survey responses were similar between the four cohorts. Thus we combine the responses of the cohorts in this paper. In the few exceptional cases where the null hypothesis was rejected, we visually inspected the response distributions and were comfortable that combining the cohorts would not distort the findings.

One shortcoming of this study was our lack of expertise in survey design. While sincere thought was applied, we realised later that the wording of the questions limited the degree to which we could study connections and causalities. The findings and assertions that follow are mindful of this limitation.

IV. STUDENT PERSPECTIVES ON GROUP WORK

A. *The goals of group work*

We were pleasantly surprised that a majority of students shared our perspectives regarding the goals of group work. Table I presents the relevant responses. These questions were asked in a general sense — not specifically relating to the two courses. When answering these questions, students would have been involved in group projects in courses other than BOZ 312 and BUY 321. Q2–Q5 show that the students recognised the educational goals of group work, while Q1 illustrates their belief that quality of learning improves. Q6 confirmed the informal feedback that students were not overly convinced that group work assisted in workload balancing.

TABLE I *Survey Responses: Goals of Group Work N = 378*

	Question abbreviation[a]	N/A	SD	D	N	A	SA
Q1	Learning quality	<1%	5%	11%	17%	57%	10%
Q2	Teamwork skills	0%	2%	7%	9%	64%	18%
Q3	Analytical skills	0%	2%	5%	5%	61%	23%
Q4	Collaboration skills	0%	2%	5%	8%	61%	24%
Q5	Organisational skills	0%	2%	8%	10%	54%	26%
Q6	Workload balancing	0%	15%	21%	20%	32%	12%
Q7	Workload (lecturer)	<1%	7%	19%	42%	21%	10%
Q9	General freeloading	0%	1%	11%	24%	43%	22%
Q16	Group work overuse	<1%	6%	19%	26%	21%	27%

a *See Appendix A for survey questions.*

When asked about the goal of reducing lecturer workload, students were more neutral than we anticipated. From our perspective, group work does reduce the marking burden, but increases the administrative burden. Reducing lecturer workload is not a dominant goal for us, but we appreciate that students would not have sufficient knowledge about our workload to recognise that.

While students shared our perspective on the educational benefits of group work, Q16 indicated that nearly half of them believed group work was overused in the IE curriculum. Combined with the strong agreement that "group work results in freeloading" (Table I, Q9), there is a potential for resentment towards lecturers who use group work.

Sharpening the focus on this study, more than half of students agreed or strongly agreed that BUY 321 was better-suited to group work than individual work (Q8). The majority of these BUY 321 respondents (55% in 2017, 71% in 2018) also believed that all their group members had sufficient knowledge of the project's elements to defend it in an exam (Q22). This is curious when compared to their response about workload balancing (Q6). We considered that balanced workload and balanced exposure to the project elements were correlated, but this was not the case.

For BOZ 312, only the BOZ312-2018 survey included the question regarding appropriateness (Q8). Here, the students felt differently. More than 36% either disagreed or strongly disagreed with only 21% agreeing or strongly agreeing.

Overall, students recognised the learning benefits that group work offered, but their experience of group work overuse and freeloading must be addressed. Next, we explore students' perspectives about group formation.

B. *Group formation*

In BOZ 312 and BUY 321, students were allowed to select their own groups to a maximum of four members. There was no minimum which meant that students could choose to work individually. Very few chose individual projects and the majority of groups had three or four members. Three reasons are offered: the lecturers' strong discouragement of individual projects was convincing, students were optimistic about group work's benefits (refer Q1–Q5), and they were willing to work in groups they selected.

Whether to allow students to select their own groups or enforce random/lecturer allocation is not an obvious choice among our colleagues. Random/lecturer allocation better reflects industry where one seldom gets to pick one's project members. But students greatly preferred selecting their own groups. In response to the statement "[w]hen group work is assessed, I want to choose my own group members. . . ", nearly three quarters agreed or strongly agreed (Q17). Our experience suggests that students select groups based on their friendship circles, academic performance and to avoid slack- ers. One reason for allowing self-selection was to leverage the social contracts in place (friendships) so that students could progress swiftly through the "forming", "storming", and "norming" stages of group work to the "performing" stage [13]. Another reason was that we were actually indifferent and believed that this "granted autonomy" would make students more positive towards group work. Only after engaging with literature for this study did we realise the unintended harm of giving students what they want. Self-selection has the potential to deepen marginalisation and prejudice [7]. These realities make eradicating freeloading behaviour in our student culture even more urgent for us. We believe that be removing the expectation of freeloading behaviour, students may be more generous during group formation. Mark-influencing peer assessment may be one way to achieve this.

V. STUDENT PERSPECTIVES ON PEER ASSESSMENT

Two survey questions starkly reflect the perceived importance of peer assessment in generally regulating group dynamics. While peer assessment is preferred in self-selected groups (Table II, Q18), students regarded it an absolute necessity (66% strongly agree) when they did not get to choose (Q19). The less control students had over who was in their group, the greater their need for an incentive to control group dynamics. The majority of students also agreed that this peer assessment should influence the final mark (Q20). The responses to Q10 (N = 255: N/A 13%, SD 20%, D 31%, N 14%, A 16%, SA 7%) regarding freeloading in these two courses compared to group work in general (Table III, Q9) do imply that group dynamics were improved. This view that mark-influencing peer assessment promoted better group dynamics aligns with literature [11].

TABLE II *Survey Responses: Peer Assessment in General N = 378*

	Question abbreviation[a]	N/A	SD	D	N	A	SA
Q18	Peer assessment (self-selected)	<1%	3%	11%	13%	46%	28%
Q19	Q19 Peer assessment (allocated)	0%	0%	1%	4%	29%	66%
Q20	Q20 Should influence mark	<1%	2%	11%	13%	41%	33%

a See Appendix A for survey questions.

A. Peer assessment in BOZ 312 and BUY 321

The peer assessment rubrics in all four cohorts were identical. The rubrics asked students to rate themselves and all their group members according to four equally weighted criteria: attendance, participation, autonomy, and value-add. A student's peer assessment mark was an equally weighted average of his self assessment and his peers' assessments of him. Including the self assessment avoided the scenario where over-generous students inadvertently penalise themselves [12]. It also allowed students to calibrate their opinion of their peers against their own contribution, and highlighted problematic group dynamics. Both courses aligned with good educational practice [6], [7], [12] by being transparent about the rationale for peer assessment, criteria, scoring mechanism, and influence on the final mark by discussing these elements in class and in the course study guides. Thus it heartened us that students predominantly disagreed that the criteria were vague and unclear (Table III, Q11).

Table III, Q12–Q15, show students' opinions on the importance of the four criteria in the peer assessment. Using a Mann-Whitney hypothesis test, the null hypothesis that the response distributions for Q12 (attendance) and Q13 (participation) were similar, was rejected ($p < 0.05$), implying that participation is a more important criteria to measure than attendance. The null hypothesis that the response distributions for Q14 (autonomy) and Q15 (value-add) were similar failed to be rejected. But the p-value of 0.057 suggest that this is a borderline result. These findings merit weighting participation and value-add more than attendance and autonomy in future.

TABLE III *Survey Responses: Peer Assessment in the Courses N = 378*

	Question abbreviation[a]	N/A	SD	D	N	A	SA
Q11	Criteria vague/unclear	<1%	18%	54%	19%	8%	2%
Q12	Attendance criterion	0%	<1%	8%	13%	48%	31%
Q13	Participation criterion	0%	<1%	2%	4%	48%	46%
Q14	Autonomy criterion	0%	<1%	4%	13%	50%	33%
Q15	Value-add criterion	0%	<1%	3%	6%	54%	36%
Q21	Procedural fairness	6%	2%	3%	16%	46%	26%

a See Appendix A for survey questions.

How the peer assessment was incorporated into a student's individual project mark differed between BOZ 312 and BUY 321. In BOZ 312, the group mark was multiplied by the student's peer assessment score. This multiplicative approach is preferred to the approach that simply adds the peer assessment score as a contributing criterion in the project mark because it better reflects the purpose of scaling the overall mark to reflect personal contribution [8]. For BUY 321, a type of normalisation scheme was adopted. If all group members' peer assessment scores were similar, everyone received the broader the scaling of the group mark among the group members. Unlike BOZ 312, it was possible for students to achieve 110% of their group's mark in BUY 321 if their peer assessment score stood out.

The fact that most students agreed that these approaches were fair (Table III, Q21) could be misleading. They had not yet seen their final mark when they completed the survey. In hindsight, we believe both scaling mechanisms require revision. The scheme in BOZ 312 was unduly punitive. For students to receive the full group project mark, they had to "exceed expectations" in each criteria. Instead, the approach followed by Goldfinch and Raeside [8] seems more fair where students can earn more than 100% of the group mark if their contributions exceeded expectations. The scheme in BUY 321 made it possible for groups to 'game the system' by ensuring everyone received similar peer assessment scores. Yet, students believed, at least in theory, that these flawed approaches were more fair than no approach at all.

Students felt strongly about including mark-influencing peer assessment regardless of how the groups were formed and seemed positive about the way in which peer assessment was implemented in the courses. The next section summarises the most useful findings of this study.

VI. CONCLUSION

Student perspectives regarding the use of peer assessment in two junior-level IE courses were collected from four cohorts in 2017 and 2018 using a Likert-style survey. Survey questions covered five broad topics: students' general perceptions of the goals of group work, students' experiences of freeloading, students' preferences regarding group formation, the importance of peer assessment, and the fairness of the mark-influencing peer assessment approaches used in BOZ 312 and BUY 321.

Some of the study's insights should be considered by those developing assessment policies within our engineering school. Firstly, our students appreciated the learning benefits of group work, but group work overuse in the IE curriculum and freeloading behaviour potentially eroded these benefits. Secondly, despite its criticisms, students supported mark- influencing peer assessment as a necessity in distinguishing in- dividual contribution. Thus, in our view, mark-influencing peer assessment remains a viable alternative to address freeloading at our institution. However, care should be taken when decid- ing how peer assessment influences final marks.

As engineering educators, we have gained practical insights through this study. Firstly, group work should be used spar- ingly in our curriculum. Secondly, students prefer it when explicit strategies are implemented to reduce freeloading. Thirdly, we should be cognisant of the subtle social im- plications of group formation protocols and seek to reduce marginalisation.

REFERENCES

[1] G. Heitmann, "Project-oriented study and project-organized curricula: A brief review of intentions and solutions," European Journal of Engineering Education, vol. 21, no. 2, pp. 121–131, 1996.

[2] M. Jollands, L. Jolly, and T. Molyneaux, "Project-based learning as a contributing factor to graduates work readiness," European Journal of Engineering Education, vol. 37, no. 2, pp. 143–154, 2012.

[3] J. E. Mills and D. F. Treagust, "Engineering education — is problem-based or project-based learning the answer," Australasian journal of engineering education, vol. 3, no. 2, pp. 2–16, 2003.

[4] C. Colbeck, S. Campbell, and S. Bjorklund, "Grouping in the dark: What college students learn from group projects," The Journal of Higher Education, vol. 71, no. 1, pp. 60–83, 2000.

[5] H. A. Hadim and S. K. Esche, "Enhancing the engineering curriculum through project-based learning," in 32nd Annual Frontiers in Education, vol. 2. IEEE, 2002, pp. F3F–F3F.

[6] J. H. Hayes, T. C. Lethbridge, and D. Port, "Evaluating individual contribution toward group software engineering projects," in 25th International Conference on Software Engineering, 2003. Proceedings. IEEE, 2003, pp. 622–627.

[7] T. Mellor, "Group work assessment: some key considerations in developing good practice," Planet, vol. 25, no. 1, pp. 16–20, 2012.

[8] J. Goldfinch and R. Raeside, "Development of a peer assessment technique for obtaining individual marks on a group project," Assessment and evaluation in Higher Education, vol. 15, no. 3, pp. 210–231, 1990.

[9] G. Thondhlana and D. Z. Belluigi, "Students reception of peer assessment of group-work contributions: Problematics in terms of race and gender emerging from a South African case study," Assessment & Evaluation in Higher Education, vol. 42, no. 7, pp. 1118–1131, 2017.

[10] A. C. Alves, D. Mesquita, F. Moreira, and S. Fernandes, "Teamwork in project-based learning: engineering students perceptions of strengths and weaknesses," in Proceedings of the Fourth International Symposium on Project Approaches in Engineering Education (PAEE2012),. Paee2012, 2012, pp. 23–32.

[11] B. Sridharan, J. Tai, and D. Boud, "Does the use of summative peer assessment in collaborative group work inhibit good judgement?" Higher Education, vol. 77, no. 5, pp. 853–870, 2019.

[12] J. Goldfinch, "Further developments in peer assessment of group projects," Assessment & Evaluation in Higher Education, vol. 19, no. 1, pp. 29–35, 1994.

[13] B. Tuckman and M. Jensen, "Stages of small-group development revisited," Group & Organization Studies, vol. 2, no. 4, pp. 419–427, 1977.

APPENDIX SURVEY QUESTIONS

Q1 Group work, as part of formal assessment, allows that peer learning takes place. Consequently, the overall quality of student learning improves.

Q2 I learn teamwork skills when given group work that helps me work efficiently within team dynamics.

Q3 When doing group work I learn specific analytical and cognitive skills like questioning others, critical thinking, and evaluating the contribution of others.

Q4 When given group work, I learn collaboration skills about conflict management and resolution, accepting criticism, and about negotiation and compromise.

Q5 Group work taught me better organisational and time management skills. I had to fit in with others' schedules, and had to plan better to work jointly subject to multiple individuals' schedules.

Q6 Group work allows us as group members to better apportion the workload. Group work is less effort for the student compared to individual assignments.

Q7 Group work is easier for the lecturer to assess. It is an easy-out for the lecturer.

Q8 The course BUY 321 (Simulation modelling) [BOZ 312 *(Operations research)*] lends itself more towards group work than individual assessment. [*Error in data collection for BOZ312-2017, responses excluded.*]

Q9 In general I think group work results in freeloading: some students just tag along as dead wood.

Q10 We experienced freeloading in our BUY 321 (Simulation modelling) [BOZ 312 *(Operations research)*] group. The contribution was unequal. [*Question mistakenly omitted for BOZ312-2018.*]

Q11 The criteria for peer assessment in this module is vague and unclear.

Q12 'Attendance' is important in peer assessment, and it should be specifically assessed.

Q13 'Participation' is important in peer assessment, and it should be specifically assessed.

Q14 'Autonomy' is important in peer assessment because students must still work on their own (even in a group setting), and it should be specifically assessed.

Q15 'Value-add' is important in peer assessment, and it should be specifically assessed. Q16 I believe group work is overused in our Industrial Engineering curriculum.

Q17 When group work is assessed, I want to choose my own group members (as opposed to groups being set up by the lecturer).

Q18 When we choose our own groups, peer assessment is necessary. Q19 When the lecturer sets up the groups, peer assessment is necessary. Q20 The peer assessment should influence the group mark.

Q21 I believe the procedure followed, in BUY 321 (Simulation modelling) [BOZ 312 (Operations research)], in which peer assessment influences the group work (and group mark) is sound and fair.

Q22 With regards to your BUY 321 semester project, do you believe that each member has sufficient knowledge about all aspects of the project (data analyses, modelling, reporting) that they can defend it in an examination? [*Not included in BOZ 312 survey*]

Technical Papers

Work-in-progress: Exploring the transition-to-university experiences of South African engineering students

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***Abstract*—Using a narrative approach, this research will explore the factors that were influential to engineering students as they transitioned from high school to a well-resourced South African university, and how digital literacy competence influenced their transition. We define our use of the term digital literacy and draw on theories of first-generation students, intersectionality and transitions to university. This work-in-progress paper describes the theoretical framework that will be used to analyze data. A sample narrative analysis is given, based on the personal narrative of the second author, who is a final-year engineering student.**

Keywords— transition, narrative, digital literacy, intersectionality, student success

I. INTRODUCTION

South Africa is a hugely unequal country due to various social factors that resulted from the Apartheid governing system. Schools reserved for white students under apartheid have become desegregated and continue to be functional, but schools formerly reserved for Black students continue to be under-resourced and achieve lower educational outcomes [1, 2]. Universities have been and are still fighting the battle of inequality through various programs to reduce the gap [3].

Under-resourced and mostly dysfunctional schools make up 75% of the schooling system in South Africa [4]. Students who come from these schools have little or no familiarity with the usage of computers, in contrast to their counterparts who come from the wealthier schools. With overcrowded classrooms, limited resources, and no technical labs, under- resourced schools may manage to produce two or three “star” students each year. Some teachers disregard government directives to teach in the language of instruction (which is English in over 80% of schools) from Grade 4 and instead teach science and mathematics concepts using native language examples for better chances of understanding.

One of the ways inequality is evident is in the additional time needed by some students to quickly acquire digital literacy skills in order to navigate their start of university. Digital literacy also impacts the educational trajectory of the fortunate few students from such schools that get to go to university. The engagements that school students have with technology are typically on social media platforms such as Facebook, WhatsApp and Instagram. However, in tertiary institutions, the acceptance letter, registration details and even the welcome by faculty are all communicated via email. The university student is expected to know how to use a computer but for students who have little or no previous encounters with computers, a small task like checking email can take a couple of days to discover. As the first year progresses, factors such as efficiency in technology use and proficiency in English can impact grades [5], some right through the end of their degree or to the point where they eventually drop out.

The purpose of this research is to better understand how the university community of lecturers, support staff and present students can help to make the adjustment to university easier for future students.

II. THEORETICAL FRAMEWORK

The following theories frame this research.

A. Digital literacy in higher education students

There is no single definition of digital literacy used in research literature. The term can simply mean being technologically fluent, or being able to locate, extract, organise, manage, present and evaluate digital information, or being competent in issues such as online safety, privacy, ethical use and reuse of digital media [6]. We consider digital literacy in broader terms since students without a knowledge of the need for password security might become a victim of hackers and this could jeopardise their progress at university. This research will add rich qualitative data to international research that explores the impact on humans of not being digitally literate [6].

There is an expectation that ‘digital natives’ who were born into a highly digital world are more comfortable and competent with technology than older ‘digital immigrants’ [7]. However, the end-user focus in social media, with no attention given to how the technology works, may distort students’ view of what makes for effective communication and disadvantage them in the long run.

B. First-generation students and intersectionality

First-generation or ‘first in family’ students face challenges which are not usually singular. These could be lower socioeconomic status, poverty, language, not knowing how to navigate a university or the expectations from lecturers of students. The theory of intersectionality [8] recognises that there are multiple facets of identity that may compound struggles [9]. For example, students who are first-generation at university in South Africa are often Black, often come from lower socio-economic backgrounds, are typically studying in a language that is not their home language and may be grappling with how to fit in with others who are more economically advantaged.

Groves and O’Shea [5] found that first-generation students who were able to successfully complete their degrees at universities had some common behaviours: they engaged more with lecturers, tutors, and university counsellors, and were not shy or quiet about their struggles. This intentional involvement helped them build

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relationships and find support for whenever they encountered hurdles, which could include digital literacy problems. Making the structures in the university more transparent to students in order for students to find the right people to engage with is a recommendation from an international review [10], which also suggested that support for first-generation students should not be through exclusive programmes only open to first-generation students.

C. Transition to university

1) Emotional transitions

Succeeding academically at university affects more than just the rate at which credits are gathered. A study in the United Kingdom [11] showed that academic factors are critical to students' emotional experiences in their transition to higher education. Higher levels of negative emotionality, primarily stress, is associated with greater inclination to plagiarize [12]. Therefore, it is in the interests of universities to help students to manage their academic studies in ways that keep stress levels low. Keeping track of digital communication for all their courses in a time-efficient manner is a vital skill for students to master as soon as possible.

2) Transition to university extends beyond first year

The transition to university is usually considered to be exclusive to first year students but Groves and O'Shea [5] suggest that since more first in family students consider leaving studies in their second and third years, the transition process takes longer than the first year. They advise that "drawing upon learners' reflections of their participation across the whole of the student life cycle usefully offers new insights into how [first in family students] manage their transition into the new community." [5: p.50]. The implication of [5] is that it justifies using a methodology that allows for gathering experiences from final year students, and perhaps also students who did not complete degrees.

Many international studies (for example [13, 14]) investigate the transition to university in terms of the academic preparedness of students. The South African context adds richness to international studies due to the extreme resource differences between the wealthiest 25% and the poorest 75% of schools [4].

In summary, the theories of digital literacy, first-generation students, intersectionality and transition to university provide a framework from which the research questions were posed. This theoretical framework will direct the collection and interpretation of the data for the purpose of answering the research questions. In this work-in-progress study, we present the research questions, methods and methodology that will be pursued, together with a sample narrative analysis of the experience of the second author.

III. RESEARCH QUESTIONS

This research explores the influence of society and culture on the retention and attrition of engineering students in universities. We will explore how transition experiences and digital literacy competence (specifically email, word processing, spreadsheets, internet browsing, online learning system navigation) plays a role in the student's ability to complete their engineering studies.

The research questions are:

1. What factors were influential to engineering students as they transitioned from high school to a well-resourced South African university?
2. Were there overlaps in the identified factors between students who attended poorer and wealthier South African high schools?
3. How does digital literacy competence influence engineering students in their transition to a well- resourced South African university?

Related questions that are beyond the scope of this study but are suggested for future research are:

- How competent in digital literacy are university students in general, and how do engineering students compare with other students, internationally and in South Africa?
- Is there evidence that engineering students, who are typically top achievers with higher levels of technological understanding, have more digital literacy competence, and therefore that peer-help support systems in engineering may work better than in other disciplines?

IV. METHODS AND METHODOLOGY

A. Research design

A qualitative research approach will be taken using narrative analysis. Narrative analysis is a research method that involves carefully looking through the words from interviews or stories people have shared and deducing themes that link to the theories in the theoretical framework. (See [15] for a good summary of narrative research applied in an engineering education context.)

Final-year engineering students from disadvantaged schools as well as students from well-resourced schools will be identified. After ethical clearance is obtained, students will be interviewed on WhatsApp or Zoom about their experiences and progress in university and how their digital literacy competence affected them at different stages in their transition into university. Interviews will be semi-structured, using open-ended questions such as: 'What was your school experience like? Describe your first days at university.' Follow-up questions will be used to expand more on the participants' stories, for example: 'How did you keep up with course announcements?' Interviews will be recorded, transcribed and anonymised before being coded and analysed by thematic analysis [16] using the software NVivo.

As the second author is herself a final-year engineering student, the research method of scholarly personal narrative [17] provides an additional research method and source of data. The personal narrative extracts that follow give an example of the narrative analysis method.

V. SINDISWA'S STORY

Sindiswa attended one of the 75% of poorly resourced South African schools. Her science teacher found ways to make students understand concepts despite the lack of resources.

> The person I probably still consider the best teacher I ever had was my science teacher, he had a talent for making you imagine things you'd never seen. The elements and concepts we learnt about in chemistry particularly, we'd never seen. We had no labs to conduct experiments, but 10 years since I left high school, I still remember the concepts. I credit that to his examples which were made up of things we did know and that were explained in the native language.

A reliance on her vernacular language of isiXhosa at school may have made her early transition to university more challenging.

> This might have helped me gain impressive marks in high school however it was not beneficial for me when I got to university where the language of instruction is strictly English. Before I could grapple with the complex concepts of courses, I first needed to translate the lecture in my head which only made the learning process longer. Sometimes, I would miss things completely and when realising that my peers didn't, there would be embarrassment to admit such. However, the experience wasn't all doom and gloom because you do improve in English as you go along.

Recalling the experiences of friends, Sindiswa noticed that language use affected students in different ways.

> I have a friend who was also from a vernacular language school like myself. He was incredibly smart. The experience of not fitting in and the delivery of all courses in English took a toll on him so much that he ended up dropping out. He went to the University of KwaZulu- Natal which he'd heard would be more accommodating to Zulu-speaking pupils like himself.

The impact of feeling a sense of fitting in is noted in the failure and subsequent success of a student who moved from the University of the Western Cape (UWC) to the University of Cape Town (UCT) and back again. The demographics of UCT and UWC are quite different. UWC was established in 1959 as a college for Black students [18] and has a greater proportion of Black students when compared to UCT.

> … a friend who came to UCT after a year at UWC doing Computer Science. He didn't do well at UCT, except in Computer Science. For example, he failed first year electrical engineering three times until he decided to go back to UWC and continue with his Computer Science degree. He finished last year and is working now.

The final narrative extract shows the benefit Sindiswa experienced from making connections with lecturers and teaching assistants, which confirms the findings of [5].

> What was probably the turning point for me was joining the ASPECT extended program. I had lecturers I wasn't scared to approach, people whom it was easy to believe that were there for you. When you gain such support, then you start believing in yourself again and your grades start to improve. I have come to realise that I do better when I feel seen, when I do not feel like I'm lost in the big numbers of University classes. When people in positions like lecturers, teacher's assistance support you, you want to do better not just for yourself but to be able to share your successes with them too.

VI. FUTURE RESEARCH AND IMPLICATIONS

We anticipate a number of findings from this research. Firstly, if stories of students from low resourced schools point to areas of difficulty in the transition into university, such as specific difficulties with gaining familiarity with the necessary digital literacies needed at university, this knowledge may suggest focussed areas in which to provide targeted support for engineering students adjusting between their school education and university education. Support may take the form of development of online or face-to-face mentoring by students or staff from diverse backgrounds. The findings could contribute to a design-based research project in which researchers work with students from high schools and university to identify and overcome obstacles to the transition to engineering studies at university.

Secondly, we expect the narrative stories may suggest ways to manage diverse levels of digital literacy competence that provides needed support without making the supported students feel stereotyped, second-class, or weak. The outcomes of this study will be interesting and relevant to countries with similar problems.

A limitation of the qualitative approach for this research is that only a small number of participants will be interviewed and consequently the results will not be generalizable. However, the depth that qualitative research brings complements larger qualitative studies that produce more easily generalizable results.

We anticipate that the results of this research will further reduce the gap and increase interest, participation and success of students in STEM programs.

VII. ACKNOWLEDGMENT

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VIII. REFERENCES

[1] B. S. Ndimande, From Bantu Education to the fight for socially just education, Equity & Excellence in Education, 46:1, 2013, pp. 20-35, DOI: 10.1080/10665684.2013.750199

[2] M.M. Mlachila and T. Moeletsi, Struggling to make the grade: A review of the causes and consequences of the weak outcomes of South Africa's education system. International Monetary Fund; 2019.

[3] I. Scott, Academic development in South Africa. In: Blitzer, E (ed.). Higher Education in South Africa: A Scholarly Look Behind the Scenes. Stellenbosch: Stellenbosch University Press, 2009.

[4] N. Spaull, Poverty and privilege: Primary school inequality in South Africa. International Journal of Educational Development 33(5), 2013, pp.436-447.

[5] O. Groves and S. O'Shea, Learning to 'be' a university student: First in family students negotiating membership of the university community. International Journal of Educational Research, 98, 2019, pp.48-54.

[6] E. M. Meyers, I. Erickson and R. V. Small, Digital literacy and informal learning environments: an introduction. Learning, media and technology, 38(4), 2013, pp.355-367.

[7] M. Prensky, Digital natives, digital immigrants. On the horizon.Nov;9(5), 2001. file:///C:/Users/01430073/Downloads/article_104264.pdf

[8] S. Cho, K. W. Crenshaw and L. McCall, Toward a field of intersectionality studies: Theory, applications, and praxis. Signs: Journal of Women in Culture and Society, 38(4), 2013, pp. 787– 810.

[9] S. Nichols and G. Stahl, Intersectionality in higher education research: a systematic literature review. Higher Education Research & Development, 38(6), 2019, pp.1255-1268.

[10]] T. Spiegler and A. Bednarek, First-generation students: what we ask, what we know and what it means: an international review of the state of research. International Studies in Sociology of Education, 23(4), 2013, pp.318-337.

[11] E. Young, R. Thompson, J. Sharp and D. Bosmans, Emotional transitions? Exploring the student experience of entering higher education in a widening-participation HE-in-FE setting. Journal of Further and Higher Education, 2019, pp.1-15.

[12] I. K. Tindall and G. J. Curtis, Negative emotionality predicts attitudes toward plagiarism. Journal of Academic Ethics, 18(1), 2020, pp.89-102.

[13] A. G. Nortvedt and A. Siqveland, Are beginning calculus and engineering students adequately prepared for higher education? An assessment of students' basic mathematical knowledge, Int J Math Edu Sci Technol, 50(3), 2019, pp. 325-343, DOI: 10.1080/0020739X.2018.1501826

[14] M. Hourigan, J. O'Donoghue, Mathematical under- preparedness: The influence of the pre-tertiary mathematics experience on students' ability to make a successful transition to tertiary level mathematics courses in Ireland. Int J Math Edu Sci Technol. 38(4), 2007 pp. 461–476. DOI: 10.1080/00207390601129279

[15] M. Scheidt and A. Godwin, A narrative approach to understanding underrepresented students' pathways into engineering. In 2017 IEEE Frontiers in Education Conference, 2017, pp. 1-5.

[16] L. S. Nowell, J. M. Norris, D. E. White, and N. J. Moules, Thematic analysis: Striving to meet the trustworthiness criteria. International Journal of Qualitative Methods, 16(1), 2017. DOI:10.1177/1609406917733847.

[17] D. L. Bradley, R. Nash, Mesearch and research: A guide for writing scholarly personal narrative manuscripts. IAP; 2011.

[18] World University Rankings, University of the Western Cape https://www.timeshighereducation.com/world-university-rankings/university-western-cape

Technical Papers

Reflecting on the success of a peer mentorship programme – A scholarly personal narrative

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***Abstract*—Peer mentorship programmes exist where senior students offer support to first year students to help them transition from high school into a university environment. The implementation of such programmes requires extensive resources and a proper management structure. In general, both the mentor and mentee benefits, as the mentee is helped to settle into the university while the mentor develops important social skills. However, different authors have different perspectives on measuring the success of such programmes. Some measure the success based on the academic performance, decrease in dropout rates and better social integration of the mentees. What may be considered as a successful programme at one university may not be considered so at another university. Furthermore, what tangible benefits accrue to the mentors? The purpose of this paper is to present a scholarly personal perspective of the benefits and challenges of a peer mentorship programme that was introduced at a university of technology in South Africa in 2014. The author was employed as a teaching and learning assistance in the faculty of engineering and information technology for a period of one year, thereby validating her perspectives based on personal involvement with the mentors. A scholarly personal perspective is used that may be linked to a constructivist research methodology that recognizes the validity and usefulness of a researcher's personal experiences in a specific discipline. Critical subsections on the success of this programme relates to the selection criteria for mentors, the structure and management of weekly sessions between mentors and mentees and developmental sessions for the mentors. It is recommended that universities should continue offering support to first year student through peer mentorship programmes, as it assists mentees to settle into university life, while allowing further personal development.**

Keywords—Benefits, mentors, mentees, reflection

I. INTRODUCTION

"Successful peer mentoring in university settings is the result of relationships among students, mentors, and instructors". These words, by Colvin and Ashman [1] , brings to our attention that the success of peer mentoring hinges upon the successful interactions between all stakeholders. Johnson, Niemi, Green and Gentry [2] claims that implementation of a successful peer mentorship program is a process that requires extensive resources and the proper management structure and maintenance of a thriving environment. In view of this, reflecting on the structure and maintenance of an existing peer mentorship programme should be encouraged in order to determine possible benefits and challenges, which may need to be addressed. According to Deakin University [3] it is important to note that reflective writing is not a summary of something that one has observed. It is important to describe, analyse and evaluate experiences that enable one to develop new insights and perspectives.

Research so far has indicated that scholarly writing is important because there is an increasing use of learning journals in higher education which are on reflective writing and they enable individuals to relate personal experiences to active learning [4]. Moreover, Strivens [5] brings to our attention that reflective writing is supported by a broader literature on reflection which illustrates how writing down a record of an event followed by conscious analysis helps one to learn from that event. A study conducted in engineering education showed how personal narrative reflections can be used in a way to support professional development [6].For example an academic in engineering used personal narratives to demonstrate how developing a comprehensive portfolio provided tangible evidence of good teaching, personal experience and acquired skills [2]. Therefore, in student peer mentoring programme a scholarly narrative may be used to present its benefits, challenges and successes.

According to Yomtov, Plunkett, Efrat and Marin [8] student peer mentoring is a process whereby a mentor who is a senior student provides guidance, support and advice to a mentee. In this study, the mentee is a first-year student who is close in age and shares common characteristics or experiences. Many authors have reflected on different peer mentorship programmes, having arrived at different conclusions.

For example, Crisp and Cruz [9] points out that such a programme benefits mentees in terms of psychological and emotional support, goal setting and career path, academic subject knowledge support and having a role model. Mentors also benefit in the process of helping mentees. For example, Beltman and Schaeben [10] point out that benefits derived by mentors includes developing interpersonal skills such as communication and leadership. Yomtov, Plunkett, Efrat and Marin [6] further state that such programmes have become a prominent tool in higher education as it enhances personal and professional development among both mentees and mentors. Despite these benefits, there are challenges that are faced by some mentors, such as a lack of self-confidence or having trouble with interpersonal skills [11]. Moreover, a peer mentorship programme can become a challenge when mentors are unable to communicate with their mentees on a regular basis or get them engaged during contact sessions.

The purpose of this paper is to present a scholarly personal narrative of the benefits and challenges of a peer mentorship

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programme that was introduced at a university of technology in South Africa in 2014. According to Nash [12] a scholarly personal narrative (SPN) is where the author explores some part of his or her personal life, weaving experiences into a fabric of scholarly research from other sources, as a way of reaching insights. Moreover, Nash and Bradley [13] remind us that a SPN structure makes use of the first person, because the author relates to personal experiences, critically reflecting on them. Killen and Gallagher [14] describes a SPN as an emerging methodology which is accurate and worthy of being recognised.

A SPN challenges researchers to apply theoretical concepts to personal and professional experiences. It seems that Brookfield [15] dispute Killen and Gallaghers's [14] claim that autobiographies do not make scholarship. The author suggests that scholarships of personal narratives, as initiated by Nash, can be scholarship if it consists of two elements which are used in research; a theoretical literature and a continuous attempt to construct theory from generalised elements of certain events, contradictions and actions. Ng and Carney [16] emphasises that a SPN challenges researchers to link theoretical concepts to personal and professional experiences. Drawing on the experiences of the author during 2016 and 2017, as a teaching and learning assistant in a faculty of engineering and information technology, validates the author's perspective based on personal involvement and experiences with the mentors.

This SPN will cover the author's experiences with regard to the selection criteria for mentors, the structure and management of weekly sessions between mentors and mentees and developmental sessions for mentors. The author was personally involved with these aspects of the peer mentorship programme on a weekly basis for almost one year. Other aspects, such as budget allocation, management of funding resources, compiling the reports for university management and conduct with mentees will not be discussed, as the author was not personally involved with them. The paper firstly considers some of the benefits and challenges of a peer mentorship in higher education, along with the author's experiences in this regard.

II. PEER MENTORSHIP PROGRAMME

Colvin and Ashman [17] define peer mentorship programme (PMP) as relationship whereby a more experienced student assists a less experienced student to improve their overall academic performance, by providing advice, support, and knowledge to the mentee. Peer mentorship programme relates to the concepts of peer support and learning whereby a mentor helps in enhancing the university experience of an individual student or a group of students [18]. Moreover, in general, a peer mentor is slightly more advanced in their studies than mentees and they use their experiences to help new students to settle into and succeed at the university, building lasting relationships that last through the first-year and beyond [19]. It seems that both authors agree with one another that peer mentorship is all about experienced students supporting in-experienced first- year students to settle into, and succeed at the university, by building lasting relationships. For example, the author received a mentor's monthly report in which stated that one of the mentees had lost his father in death and was subsequently facing many emotional challenges. I quote "the entire family (Myself and all the mentees) gave support during the entire week till the funeral day. We bought a sympathy card and we all signed and bought roses as a sign of one's love. She was so touched, and she replied how much we mean to her and how we changed her life completely."

A PMP further assists first-year students to adapt to a higher education institution, resulting in positive outcomes such as enhancing academic performance, self-efficacy and well-being [19]. These programmes have increased the retention of diverse groups of students [20]. Another key benefit lies in mentors who desire to give support to other students [19], thereby building their interpersonal and intra- personal skills. A study conducted by Andrew and Clarks [21] revealed that participating in peer mentorship benefits students to attain valuable transferable employability skills, such as self-management, leadership and communication skills. In addition, mentors experience personal and social benefits, which include personal satisfaction in helping others and the opportunity to 'give something back'.
However, disadvantages or challenges of such programmes do exist. For example, Bunting, Dye, Pinnegar and Robinson [22] argues that even if there are large numbers of experienced students on college campus, it does not guarantee that all of them will chose to participate in such programmes. Research findings by Andrew and Clarks [21] shows that one of the challenges in PMP is communication within the between mentors and the institution, especially in regard to reporting. One key aspect relating to communication that should be transparent to all is the criteria for selecting mentors for a PMP.

III. SELECTION AND INTERVIEW PROCESS

Every year in September the teaching and learning assistant (TLA) in the faculty of engineering and information technology at Central University of Technology (CUT) places an advert for students to apply to be mentors in the following year. The advert has the information regarding the PMP and outlines what is expected out of the mentors. Furthermore, information of all the documents that should be submitted are also included on the poster. Students who are applying to become mentors would personally contact the TLA in the faculty via email, attaching all relevant documentation. The attached documents would include the CV of the student, copy of ID, statement of results and a motivation letter stating the reason for applying to be a peer mentor. The TLA then checks the academic results of the applicants, selecting only those who had passed all of their first-year modules. A file is then created for every student for record-keeping purposes. After this initial screening process, the applicants would be interviewed by the TLA in order to ascertain why they want to be a mentor and what contribution that may make towards the success of the PMP. The interview will take place in the TLA office and last for about 45 minutes during the month of October. After two weeks of conducting interviews, the TLA informs all students via email of the outcome of their application.

A briefing session is then held in November with all successful applicants where the TLA informs the mentors of the required forms and documents that they should submit to finalize the appointment. In addition, they are informed of the activities which are planned for the new year. Mentors need to submit these forms before the end of January of the new year to the TLA, as it needs to be submitted to the Human Resources Department for payroll purposes. According to Nowell, Norris, Mrklas and White [23] a PMP incurs costs and requires expenditure in order to operate successfully, which includes a stipend to mentors for the work which they do. It is the responsibility of the TLA to make sure that all the forms are filled in correctly and submitted to Human Resources Department in order for mentors to be paid.

The submission and screening of the applicant's documents was done by me. This gave me the opportunity to review the motivational letters of the students in order to find out why they want to be mentors and how they would benefit from it. Zaniewski and Reinholz [20] verifies that potential mentors were screened through a written application process. Most of students who applied for the position where mentees and indicated that they have benefited from the programme in the past. Jackling and McDowall [24] noted some reasons why students want to be mentors, which include wanting to make a difference and wanting to help other students, while learning life skills and improving their self-confidence. This really equates to ploughing back into the community. In this regard, it shows that these applicants had a good experience with their mentor, and this can be regarded as one of the success stories of PMP as they were positively influenced by their mentor. The screening process assisted me to understand student's intentions of being a mentor and to select potential mentors for an interview. Although the screening process verifies potential mentors, it was labour intensive and time consuming for me. I had to review over 120 applications from which I selected 100.

I found the interview process transparent as I was able to evaluate if the applicant would be a good mentor. My evaluation was based on the applicants being able to answer the interview questions satisfactorily. While most of the students were keen in being mentors, I found that many of them lacked a desire and willingness to fulfil the responsibilities of a mentor which they were familiar with. The interview process also gave me an opportunity to interact with the applicants and determine which ones would be better suited to become mentors based on their communication skills. Some of the applicants were not able to express their thoughts very well, despite performing well academically. However, I tried to obtain a holistic view of the applicants by not considering if any of their strengths may offset this perceived weakness. For example, I had a student who did not express himself well when answering interview questions and at the end of the year he was one of the committed mentors and his communication skills had improved. This provides evidence that a PMP enhances mentor's communication skills, which is collaborated by Hall and Jaugietis [25]. Instead of just focusing on the applicant's communication skills, or lack thereof, I would focus on other characteristics such as a willingness and a desire to be a mentor and on their previous experiences as a mentee.

The interviews also enabled me to get to know the names of the mentors that I will be working with. It is always good to learn student's names and address them by their names as it builds relationships between individuals. Glenz [26] brings to our attention that learning student's names is the first step in knowing who they are and calling them by their name communicates respect and makes them feel recognised as individuals. Furthermore, it helps to draw out and include shy students in the discussion. Learning student names is important in developing a long-lasting relationship and helps establish a sense of belonging for students in the PMP.

IV. STRUCTURE AND MANAGEMENT OF WEEKLY SESSIONS

Every week mentors meet with mentees for mentorship sessions to discuss different topics. Prior to these meetings, a Meet and Greet session is held. The TLA initiated this activity in response to a challenge raised by previous year's mentors who stated that they had difficulty in contacting their mentees before the weekly sessions commenced. The purpose of this activity was for the mentor and mentee to start establishing a working relationship. It was the first time that such an activity was held in the Faculty.

After the initial Meet and Greet activity, the first session was held with mentees. Details about such sessions were communicated between the mentor and the mentees using a WhatsUp group (social media). One mentor was assigned to ten mentees who collaboratively decided on a venue and time slot. The sessions were held once a week with mentees, some of the topics including goal setting, time management, study skills, budgeting, revision methods and stress management. The purpose of these topics was for mentors to share their own ideas and experiences with mentees in order to help them adapt to university life and to help them cope with their academic workload.

A register was kept for each session and photos were often taken for inclusion into official reports and student portfolios. The TLA took note of mentors who had not submitted their monthly reports and attempted to follow up with them as to why this was so. In some cases, mentors did not meet their mentees due to time limitations or timetable clashes.

I considered the Meet and Greet activity to be effective as many mentors and mentees supported it, enthusiastically engaging with each other for more than two hours. This activity furthermore stressed the importance of attending mentorship sessions in the faculty and in helping mentees gets to know the TLA.

Although the activity was effective in helping to build relationships, I noted that many of our first- year students did not attend the activity, despite being aware of it. This awareness was created by using posters and by visiting first-year students in their classes. Rodger and Tremblay [27] brings to our attention that the level of participation in PMP activities differs as it is voluntary.

I also noted that it was difficult for the mentor and mentees to reach consensus on the venue and time slot for the weekly sessions due to their different timetables. This led to some mentors having two groups of mentees per week. Then at the end of the month the mentor submits a report together with the register to the TLA. In the past the institution considered the time from 12:30-13:30 as a lunch hour and there were no classes between those times. Mentors often used that period for these sessions, which no longer was possible, as the lunch hour was removed in 2016.

In view of this, it is suggested that there should be a specific time slot allocated to mentorship activities on the timetable of first-year students. This would enhance mentees attendance for PMP sessions. Consequently, a lack of dedicated time for mentorship sessions is considered as a major problem for an effective PMP [25].

V. DEVELOPMENTAL ACTIVITIES FOR MENTORS

Three specific PMP developmental activities are stipulated to assist and empower mentors which are grouped as follows: training; meetings; and support.

Training; this is required to empower mentors to acquire mentoring skills in order to implement effective mentoring sessions with mentees [20]. In this regard, training is a process where a mentor is being nurtured by the TLA, who also encourages the mentors to develop their personal and professional skills. PMP training is usually held for two days where the mentors are capacitated with knowledge and skills on how to conduct PMP sessions with mentees. Life skills, such as teamwork, problem solving, time management and communication are also discussed. This training further assisted mentors to work together in a team and to get to know each other better. Other PMP training sessions are also incorporated into the semester, such as the graduate attributes workshop. This workshop usually lasts for one day and is facilitated by one of the PMP administrative staff. The purpose of the workshop is to help mentors in the faculty to be able to identify and understand the ten graduate attributes adopted by CUT. After this workshop, a paper entitled assessing senior engineering student's ability to identify graduate attributes was presented at the 2018 International Conference on Multidisciplinary Research [27].

Meetings; these are important because they help coordinate activities and provide accountability [2]. In addition, they provide a supportive organizational structure with committed individuals to assist with supervision to keeps track of individuals. Johnson, Niemi, Green and Gentry [2] stresses that this is accomplished through conducting training and bi-weekly meetings. These were held twice per month enabling the TLA to announce any upcoming PMP activities and for mentors to raise any challenges they were facing with their mentees. Possible solutions to these challenges were then discussed by all in attendance. In this way, the mentors learned from each other. In the beginning of the year, the TLA suggested that the PMP should have a leadership team. The mentors welcomed the idea and elected a Chairperson, a Deputy Chairperson, a Secretary, a Public Relations Officer and a Finance Officer. The committee usually liaises with the TLA to discuss future meeting agendas. These meetings also serve to identify and plan other PMP activities that were specifically geared towards mentor development.

Support; this is to be provided by the TLA to the mentors in the program. Foster, Ooms and Marks-Maran [28] are of the view that universities can better support mentors through regular mentor updates, study days for mentors and assessment of mentors. The TLA held one on one consultations in an effort to help support mentors in identifying and addressing any concerns or challenges that they may have encountered. The consultations also provided the opportunity for the TLA to check on the mentor's academic performance and if they were managing to balance PMP activities with their academic work.

I found the training as informative activity in that it empowered mentors with specific knowledge and skills to effectively help their mentees. During training mentors are empowered to be professional, understanding, confident and approachable. Training was conducted during the last week of January to prepare the mentors for the semester's activities with their mentees. A few mentors did not attend the training as they were still on holiday. I therefore had to arrange another training session for them. The training that I provided to the mentors better equipped them to deal with their responsibilities, especially in writing their monthly reports which helped me to compile my report to senior management.

The bi-weekly meetings were very interactive, being led by a chairperson appointed by the mentors. Mentors took ownership during meetings by engaging in the discussions and making it easier for other mentors to raise any challenges they were facing with their mentees.

Meetings also served as a platform for mentors to be updated with upcoming PMP activities and share any accomplishments that they may have experienced with their mentees.

I really enjoyed the experience of supporting the mentors during our one-on-one consultation. For example, one mentors pointed out that she was not coping with academic and PMP work, but she loves being a mentor. We came up with solutions together on how to manage her time so that she can balance both works. I also found that specific mentors had developed a sense of self-esteem with different abilities such as being professional and understanding to their mentees. Many of the mentors thanked me at the end of the year for the regular consultations by giving me small gifts as a token of their appreciation. One mentor stated: "thank you for the impact that you had in my life" while another said "Thank you for making me the best mentor I can be".

This has taught me that whatever I am involved with in my life should be related to the development of others, and not only to doing a good job. To date, I am still in contact with many of the mentors and they share their life's challenges and progress with me. I still try to advise and guide them where possible. All these images are evidence of the gifts that I received from mentors and conversations that I have with them. Others have graduated while others are on experiential trainings and others are still on campus. I have also formed relationships with mentors and to date some of them consider me as their mentor and we are still in contact beyond PMP.

VI. CONCLUSIONS

The purpose of this paper was to present a scholarly personal narrative of the benefits and challenges of a PMP that was introduced at a university of technology in South Africa in 2014. It is limited to a singular academic perspective of the author as it reflects a personal experience of working in a PMP as a TLA. The author's scholarly personal narrative also includes illustrating the benefits and challenges of a PMP, as perceived by herself during 2016 and 2017. Table I illustrates aspects in the PMP that worked with benefits and challenges.

Key benefits noted by the author for mentors include creating a platform for them to unleash their full potential, through different leadership roles, by being role models and by building relationships. Providing mentors support was one of the most rewarding experiences because it resulted into positive effects such as focusing on mentor's development and building lasting relationship with them. A platform was created for the TLA to give a feedback to mentor's performance, showing appreciation and checking if mentors were balancing their academic work with their PMP activities. The conversations were constructive, and quite social with laughter. Constructive feedback is necessary for mentor's development and this helps mentors to recognise their challenges in PMP. Feedback focused on all aspects of PMP activities and academic work. Thus, for mentors to balance activities and work they have to acquire time management skills and be able to plan activities in time.

TABLE I *Aspects in the PMP that worked and their benefits and challenges*

Aspects	What worked with its benefits	Challenges
Selection Criteria	*Documents* Submission of relevant documents finalised the appointment of mentors enabling them to be paid a stipend. It also served as a motivation to mentors and helped with record keeping for HR and office administration purposes. *Interviews* Interviews created a platform for the TLA to interact with the mentors, getting to know their names and building professional relationships with them.	*Documents* They were time consuming as they had to be filled in correctly and submitted with all relevant supporting documents which are a copy of identity document, appointment forms and proof of bank account. Some mentors take time in submitting the relevant documents and it delays payment. Sometimes it will take me the whole day sorting out more than 50 mentors' documents and delayed me to do some of the office duties. This emphasizes the need for students to be called all at once so that they can be guided when filling in the forms to avoid delays. More than 120 applications were reviewed and 100 were selected for interview. *Interviews* About ten applicants were not able to express their thoughts well during the interview even though they had good academic results. This led to the interview exceeding hour duration. Interviews therefore serve to get to know students and to determine where they need to develop.
Structure and management of weekly sessions between a mentor and the mentees	*Meet and greet* This activity was a highlight of the PMP as it was the first time being held in the faculty where mentors had a chance to meet their mentees face to face before conducting their PMP sessions. *Mentorship Sessions* Sessions were held once a week and mentors prepare topics for discussions and sometimes, they ask mentees to come up with topics for discussion. Sessions provided mentees with academic and social support.	*Meet and greet* Not all mentees attended the event despite being made aware of it by posters and classroom visits. About 50% of mentees attended the event. I had identified that mentees have their own preferred mentors and they were already assigned to their mentors before they came to event. It was therefore essential for me to motivate mentees. *Mentorship Sessions* In some cases, it was hard for some mentors to meet with all their mentees at the same time for their sessions. This led to some mentors having more than one session per week which impacted on their balancing their various activities. Sometimes a mentor will meet with two mentees out of ten today and tomorrow it will the others. I came to realize that there is a need for mentorship slot in the timetable where all mentees go for sessions at the same time.
Developmental activities for mentors	*Training of Mentors* Training was held during the last week of January to provide mentors with skills and knowledge on how to effectively execute their duties. This helped the TLA to better execute her duties during the semester, especially in terms of reporting to senior management. *Graduate attribute workshop* A workshop was held for mentors in order for them to be able to understand and identify graduate attributes. This led to mentors being able to identify graduate attributes which they could not communicate to their mentees. This was also a flagship activity that enabled me to write my first conference paper. *Meetings* Meetings were interesting as they were led by the mentors and it was easy for them engage with one another. It primarily addressed challenges that they may be facing with their mentees. *Mentors support by the TLA* Mentors support is very important as it is regarded as a developmental tool for mentors. It also emphasises the importance of balancing PMP activities and academic work. It also builds trust between the TLA and the mentor. *Relationships with Mentors* The warm cheerful attitude of the TLA would have made a lasting impression on many mentors, as many of them showed gratitude by giving small gifts of appreciation.	*Training of Mentors* It turned out that some of the mentors were not able to attend the training due to family matters. The first training 60 mentors attended which was most mentors. The TLA had to conduct a second training session in February and 12 mentors attended. *Graduate attribute workshop* Most of the mentors attended the workshop and can understand and identify graduate attributes. Out of 72 mentors only 51 attended the workshop. However, 60% struggled to identify technical and conceptual competence and 80% numeracy as there is no word in the definition that may be linked to the name of the attribute. *Meetings* Some mentors were engaging so much with one another during the meeting, that it went overtime with one hour. This led to some mentors losing interest and leaving the meeting. Average time for meetings was an hour. *Mentors support by the TLA* This was, time consuming at times, as the TLA had to meet with almost 80 students each week. Sometimes it would take an hour to complete one consultation with one mentor and at the end of the week I did not do other office duties as most of the time was spend on mentors support. I would even have to work overtime to attend to other office duties. *Relationships with Mentors* Building relationships with mentees made it easier for TLA to be approachable and made mentors to be free. However, there was a point when some mentors would just come to the office without a valid reason. About 11% would not respond well to the direction given.

Mentors faced challenges when they had to meet with their mentees for sessions as there is no specific provision in the university timetable for this type of activity. Therefore, there is a need for a time slot for a PMP in the institutional timetable to accommodate all mentees to attend these contact sessions. A PMP can create a platform for mentors to assist a mentee. It is recommended that a good relationship be maintained between the TLA, mentors and mentees for a PMP to be successful. My experience can help other in this field to improve on their mentorship work.

REFERENCES

[1] J. W. Colvin and M. Ashman, "Roles, risks, and benefits of peer mentoring relationships in higher education.," Mentoring & Tutoring: Partnership in Learning, vol. 18, no. 2, pp. 121-134, 2010.

[2] J. Johnson, A. Niemi, M. Green and L. Gentry, "Management and Assessment of a Successful Peer Mentor Program For Increasing Freshmen Retention," in 121st ASEE Annual Conference and Exposition, Indianapolis, 2014

[3] A. Moore, "Deakin University," 12 September 2018. [Online]. Available: http://www.deakin.edu.au/students/studying/study-support/academic-skills/reflective-writing. [Accessed 10 November 2018].

[4] J. Stapleford, L. Beasley and S. Palmer, "Developing PDP to support employability:An institutional perspective.," in Personal developmentplanning and employability., York, Higher Education Academy, 2009, pp. 38-46.

[5] J. Strivens, "From the inside:Supporting and assesing personal development.," in Personal development planning and employability , York, Higher Education Academy, 2009, pp. 31-37 .

[6] G. Epstein and Y. V. Zastavker, "Uneasy stories: Critical reflection narratives in engineering education," in Creative ways of knowing in engineering, B. Diana and E. Michele, Eds., Cham, Springer, 2016, pp. 173-196.

[7] A. J. Swart, "Developing a comprehensive teaching portfolio—A scholarly personal narrative," in IEEE Global Engineering Education Conference (EDUCON), Santa Cruz de Tenerife, 2018.

[8] D. Yomtov, S. W. Plunkett, R. Efrat and A. G. Marin, "Can Peer Mentors Improve First-Year Experinces of University Students?," Journal of College Student Retention, vol. 19, no. 1, pp. 25-44, 2017.

[9] G. Crisp and I. Cruz, "Mentoring college students: A critical review of the literature between 1990 and 2007.," Research in Higher Education, vol. 50, no. 6, pp. 525-545, 2009.

[10] S. Beltman and M. Schaeben, "Institution-wide peer mentoring: Benefits for mentors.," The International Journal of the First Year in Higher Education, vol. 3, no. 2, pp. 33-44, 2012.

[11] F. Gunn, S. H. Lee and M. Steed, "Student Perceptions of Benefits and Challenges of Peer Mentoring Programs: Divergent Perspectives From Mentors and Mentees," Marketing Education Review, vol. 27, no. 1, pp. 15-26, 2017.

[12] R. Nash, "Librating scholarly writing: The power odf personal narrative," Teachers College Press, New York, 2004.

[13] R. Nash and L. Bradley, "Me-search and re-search: A guide for writting scholarly personal narrative manuscripts .," Charlotte, NC:Age, 2011.

[14] P. O. Killen and E. V. Gallagher, "Sketching the contours of the schorship of teaching and learning in theology and religion," Teaching Theology and Religion, vol. 16, no. 2, pp. 107-124, 2013.

[15] Brookfield, "Scholarly personal narrative as anew direction for the scholarship of teaching and learning," Teaching Theology and Religion, vol. 16, no. 2, pp. 127-128, 2013.

[16] L. Ng and M. Carney, "Scholarly personal narrative in the SOTL tent.," Teaching and Learning In quiry, vol. 5, no. 1, pp. 1-10, 2017.

[17] J. W. Colvin and A. Marinda, "Roles, Risks, and Benefitsof Peer Mentoring Relationships in Higher Education, Mentoring and Tutoring," Partnership in Learning, vol. 18, no. 2, pp. 121-134, 2015.

[18] R. Clark and C. Robin, "How Peer Mentoring Enhances Student Success in Higher Education," Aston University, London, 2011.

[19] J. Andrews, R. Clark and K. Davies, "Peer mentoring works! How Peer Mentoring Enhances Student Success in Higher Education," Aston University, London, 2011.

[20] A. Chester, S. Xenos and L. J. Burton, "Peer mentoring: An embedded model to support first-year psychology students," Teaching Psychology Around the World, vol. 3, pp. 133-150, 2012.

[21] A. M. Zaniewski and D. Reinholz, "Increasing STEM success: a near-peer mentoring program in the physical sciences," International Journal of STEM Education, vol. 3, no. 14, pp. 2-12, 2016.

[22] B. Bunting, B. Dye, S. Pinnegar and K. Robinson, "Understanding the dynamics of peer mentor learning: Anarrative study.," Journal of the FIRST- Year Experience and Students in Transition, vol. 24, no. 1, p. 61=78, 2012.

[23] L. Nowell, J. M. Norris, K. Mrklas and D. E. White, "A literature review of mentorship programs in academic nursing," Journal of Professional Nursing, vol. 33, no. 15, pp. 334-344, 2017.

[24] B. Jackling and T. McDowell, "Peer mentoring in an accounting setting :a case study of mentor skill development," Accounting Education, vol. 17, no. 4, pp. 447-462, 2008.

[25] R. Hall and Z. Jaugietis, "Developing peer mentoring through evaluation," Innovative Higher Education, vol. 36, no. 1, pp. 41-52, 2011.

[26] T. Glenz, "The Importance of Learning Students' Names," Journal of Best Teaching Practices, vol. 1, no. 1, pp. 21-22, 2014.

[27] S. Rodger and P. F. Tremblay, "The effects of a peer mentoring program on academic success among first year university students," Canadian Journal of Higher Education, vol. 33, no. 3, pp. 1-7, 2003.

[28] M. Lefera and J. A. Swart, "Assesing senior engineering student's ability to identify graduate attributtes," in International Conference on Multidisciplinary Research, Ponteaux Piments, 2018.

[29] H. Foster, A. Ooms and D. Mark-Maran, "Nursing students expectations and experinces of mentorship," Nurses Education Today, vol. 35, no. 1, pp. 18-24, 2015.

Technical Papers

Modes of entry as predictors of academic performance of engineering students in a Nigerian university

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Abstract—**The four modes of entry into Faculties of Engineering and Technology in Nigerian universities are: passing the Unified Tertiary Matriculation Examination (UTME) to gain admission into the first year of a five-year engineering degree programme; passing through a one year Remedial programme before coming in as first year students; Direct entry admission into the second year (200 Level) of the degree programme; and Direct entry admission into third year (300 Level). Data on the modes of entry and Cumulative Grade Point Average (CGPA) at the time of graduation obtained from the ten departments in Faculty of Engineering and Technology at University of Ilorin, for students who graduated in 2018/2019 session, were analysed. Out of the 471 students, 24 graduated with first class honours with 22 of them being UTME students and two being Remedial students. The number of UTME, Remedial, Direct Entry students at 200 Level, and Direct Entry students at 300 level were: 377, 66, 26, and 2 and the averages of their CGPA were: 3.58, 3.27, 3.60, and 3.52, respectively. There was statistically significant difference between the CGPAs of graduates who were admitted through UTME, Remedial and Direct Entry at 200 level. It is recommended that the admission quota of Direct Entry candidates be increased and the UTME candidates should continue to have the highest percentage of admission spaces.**

Keywords— modes of entry, academic performance, engineering, students

I. INTRODUCTION

There is increasing demand for spaces in Faculties of Engineering and Technology in Nigeria due to increasing turn out of applicants who have completed secondary education, as a result of population growth in the country. The four modes of entry into Faculties of Engineering and Technology in Nigerian universities are: passing the Unified Tertiary Matriculation Examination (UTME) organized by the Joint Admissions and Matriculation Board (JAMB) to gain admission into the first year of a five-year engineering degree programme; passing through a one year pre-degree programme also known as Remedial programme before writing UTME to come in as first year students; Direct entry admission into the second year (200 Level) of the degree programme for students who have successfully completed Advanced Level or National Diploma programme in a polytechnic (DE-200L); and Direct entry admission into third year (300 Level) for students who have successfully completed a Higher National Diploma (HND) programme in a polytechnic (DE-300L).

To qualify for admission through UTME, DE-200L or DE- 300L, a student must have at least 5 credits pass at one or two sittings in ordinary level or school certificate examination conducted by West African Examination Council (WAEC) or any of the two national examination bodies. The 5 credits must include Mathematics, Physics, Chemistry and English Language. The UTME candidates for engineering programmes write their examination conducted by JAMB in these four subjects and they are expected to score reasonably high marks.

Remedial candidates may or may not have 5 credits required at one or two sittings because they are admitted to a one session pre-degree programme in which the ordinary level curriculum is covered in Mathematics, Physics, Chemistry, Biology and English Language before proceeding to the first year. During the Remedial year they are expected to take UTME but scoring high marks is not demanded of them as for UTME candidates. For this mode of entry, the entry requirements are reduced to give room for students from educationally disadvantaged places to have opportunity to enroll in engineering programmes.

All applicants for admission are also subjected to Post- UTME computer-based test in which they are expected to score above 60 or 70% for most engineering degree programmes.

One of the factors that can affect the academic performance of students in the university is the mode of entry.

Academic performance was defined by Ballotpedia [1] as the "measurement of student achievement across various academic subjects". It is usually measured by using classroom performance, graduation rates, and results from standardized tests and it is used to determine how well an individual can assimilate, retain, recall and communicate what has been learned [2,3].

Some researchers have worked on the effect of mode of entry on academic performance in Higher Education Institution. Evroro

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[4] from his investigation of the relationship between the mode of entry and academic performance of a sample of 300 students in Faculty of Education at Delta State University, Abraka, Nigeria, found that the academic performance at the point of graduation of the students had no relationship with their mode of entry.

Ojo [5] stated that direct entry students were superior to their remedial and UTME students in academic achievement. From their statistical analysis, there was a significant difference between students who were admitted through UTME and Direct Entry into the various departments in the Institute of Education during the reviewed sessions. [5]

Lawal [6] reported in her work that both the UTME and Direct Entry students from the five Science Education programmes studied did not perform equally; the differences in their performance in different programmes could be attributed to various factors other than the mode of entry.

Olorunmaiye et al., [7] from their work reported that students admitted through UTME performed better than those who were admitted through remedial, for engineering students at the end of their first year with dropout rates of 36% and 63% for UTME and Remedial students, respectively.. Joe et al., [3] stated in their work, that the students admitted through UTME performed significantly better than those admitted through Preliminary programme in the Faculty of Engineering.

Irtwange and Agbe, [8] in their work, reported that there was a significant difference between the achievement of Remedial and UTME students with the Remedial students performing better than UTME students.

Most of the works done on investigating the influence of mode entering on academic performance were carried out for degree programmes faculty of Education [4, 5, 6]. Joe et al. [3] and Irtwange and Agbe [8] who carried out such investigation for engineering degree programmes considered only the two modes of entry into the first year of engineering degree programmes; they did not consider direct entry modes. Since they were interested in studying the influence of mode of entry on academic performance at the end of the first year, Olorunmaiye et al. [7] also considered only the two modes of entry into the first year.

This work is an extension of the earlier work considering engineering programmes and also the direct entry modes at the second and third years, in addition to the two modes of entry in the first year.

Therefore, the aim of this work is to study the effect of modes of entry in the first, second and third years of the five- year engineering degree programmes, on the academic performance of engineering students at the time of graduation.

This study addresses the following questions:

i. What percentage of students that graduated came in through each of the four modes of entry in the faculty?
ii. What percentage of all the students in the faculty graduated with first class, second class upper, second class lower and third class degrees?
iii. What percentage of UTME, remedial, DE-200L and DE-300L candidates graduated with first class and second class upper degrees?
iv. Is there significant difference in the academic performance of students who came in by different modes of entry?

II. METHODOLOGY

A. Data Collection

Copies of corrected spreadsheet of the results of the students in faculty of engineering and technology, University of Ilorin, who graduated in 2018/2019 session from the ten engineering programmes were obtain from the faculty officer and two of the heads of department, after the university senate had approved the result. The name, matriculation number, mode of entry, cumulative grade point average (CGPA) and class of degree are among the pieces of information on the spreadsheet of each student.

B. Hypothesis

The null hypothesis to be tested is Ho: There is no significant difference in the academic performance of students who came in by different modes of entry.

C. Statistical Analysis

Data on matriculation number of students, CGPA and class of degree were entered into a Microsoft Excel 2010 worksheet for each of the 10 departments. Statistical analyses on the data provided information on the maximum, minimum, mean, and standard deviation values of CGPA for each mode of entry for the 10 Departments. To test the null hypotheses, Chi-Square Test was used to analyze the data. The computed values were compared with the tabulated values at 5 % level of significance.

III. RESULTS AND DISCUSSION

Table 1 shows the total number of students in all the ten departments in the faculty, maximum, minimum and mean CGPA and standard deviation values for each mode of entry.

TABLE I *Modes of Entry, Numbers of Students and CGPA Values and Standard Deviations*

Mode of Entry	Number of Students	Max CGPA	Min CGPA	Mean CGPA	STD
UTME	377	4.87	2.30	3.58	0.57
Remedial	66	4.73	2.37	3.27	0.55
DE–200L	26	4.37	2.82	3.60	0.42
DE–300L	2	3.56	3.47	3.52	-

The number of students that came in through UTME, Remedial, DE-200L, and DE-300L were 377, 66, 26, and 2, respectively. The highest average CGPA was produced by DE-200L group followed by UTME, DE-300L and Remedial with average CGPAs of 3.58, 3.52, and 3.27, respectively. However, the result of the UTME group is considered the best because they produced 22 first class candidates out of the total of 24 first class students.

The percentages of first class, second class upper, second class lower and third class candidates for each mode of entry, respectively are: UTME—5.8, 51.5, 42.2,and 0.5; Remedial— 3.0, 30.3, 65.2, and 1.5; DE-200L—0.0, 65.4, 34.6, and 0,0; and DE-300L –0.0, 50,0, 50,0, and 0,0. The better performance of UTME students over remedial students observed at the point of graduation in this work is in agreement with the better performance observed at the end of first year of study by the same set of students reported earlier in [7]. In the earlier work, it was found that the success rates of UTME and remedial students were 64% and 37% respectively [7]. The better performance of UTME students over the remedial students observed in this work is in agreement with the result obtained by Joe et al. [3] in which they found that the CGPA of the 128 UTME students who graduated in 2009/2010 and 2010/2011 academic session was significantly difference (better than) from the result of 45 students admitted through School of Science Laboratory Technology (SSLT) program.

The DE-300L mode of entry was not considered in Table II used for computation of chi-square because there were only two students in this category. The DE 300L candidates were few in this work because the HND holders who could have applied to enter degree programmes through this route had an alternative route in which they could spend four semesters to obtain postgraduate diploma in engineering which qualifies them for registration as engineers. Council for the Regulation of Engineering in Nigeria (COREN) has canceled this route. More recently, some universities introduced another route called "top-up programme" for HND holders to spend four semesters to obtain Bachelor's degree in Engineering.

Considering a 3 x 4 contingency table, the degrees of freedom (d.f.) = (3-1) x (4-1) = 2 x 3 = 6.

TABLE II *Summary of CGPA distribution among three modes of entry*

Mode of Entry	Class of Degree				
	3rd Class	2nd Class Lower	2nd Class Upper	1st Class	Total
Remedial	1	43	20	2	66
UTME	2	159	194	22	377
DE-200L	0	9	17	0	26
Total	**3**	**211**	**231**	**24**	**469**

Note: *1st Class 4.50 ≤ CGPA ≤ 5.00, 2nd Class Upper 3.50 ≤ CGPA ≤ 4.49 2nd Class Lower 2.40 ≤ CGPA ≤ 3.49, 3rd Class 1.50 ≤ CGPA ≤ 2.39*

Calculations were done to obtain the expected frequencies table corresponding to Table II, following the procedure outlined in reference [9], to obtain Table III below.

The value of chi-square computed was 17.107. Since the calculated value of χ2 (17.107) is greater than the tabulated value ຮ for 6 degrees of freedom (12.59), the null hypothesis is rejected at 5% level of significance. Therefore, there is statistically significant difference between the CGPAs of graduates who were admitted through the three modes of entry in the faculty.

TABLE III *Corresponding expected frequencies*

Mode of Entry	Class of Degree				
	3rd Class	2nd Class Lower	2nd Class Upper	1st Class	Total
Remedial	0.422	29.693	32.508	3.377	66
UTME	2.412	169.610	185.687	19.292	377
DE-200L	0.166	11.697	12.806	1.331	26
Total	**3**	**211**	**231**	**24**	**469**

IV. CONCLUSION

The students admitted through UTME are better than the other students admitted through Remedial Programme and Direct Entry. The academic performances of students admitted through different modes of entry are significantly different. If the computation of the percentages of students graduating with different classes of degree for each mode of entry which was done in this work, is carried out for many years, the average percentages can be used to predict the distribution of students over various classes of degrees at the point of graduation even before the students get to their final year. The sample size for this work can be extended by considering several graduating sets of engineering students at University of Ilorin. Another way to extend the sample size is to consider engineering graduate of a particular session from several Nigerian Universities. The admission quota of direct entry candidates should be increased and UTME mode of entry should continue to have the highest admission quota based on the results obtained in this work.

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REFERENCES

[1] Ballotpedia (2019) "Academic Performance", https://ballotpedia.org/Academic_performance accessed 13/12/2019.

[2] B. L. Edo, O. M. Chukwusa, and F. O. Uzoma, "Quality Management Strategies and Students' Academic Performance in the Nigerian Universities," International Journal of Innovative Development & Policy Studies, vol. 6 no.1, pp. 21-26, January – March 2018, www.seahipaj.org.

[3] A. I. Joe, P. J. Kpolovie, K. E. Osonwa, and C. E. Iderima, "Modes of Admission and Academic Performance in Nigerian Universities," Merit Research Journal of Education and Review, vol. 2 no. 9, pp. 203 – 230, 2014, http://www.meritresearchjournals.org/er/index.htm.

[4] E. S. Evroro, "Mode of Entry and Degree Performance of Delta State University Undergraduates," Journal of Research in National Development, vol. 7 no. 1, June 2009, https://www.transcampus.org/JORINDV7Jun2009/JournalsV7NO1Ju n200936.html, accessed on 14/1/2020.

[5] F. Ojo, "Nigerian Universities and high level manpower development", H.R.R.V research series. Lagos: University press. 21-23, 2005.

[6] T. E. Lawal, "Comparative Study of Academic Performance of UME and Direct Entry Students at Graduation in Science Education Section, Ahmadu Bello University, Zaria, Nigeria", International Journal of Educational Science and Research, vol. 4, issue 1, February 2014, pp. 63-68..

[7] J. A. Olorunmaiye, J. O. Olaoye, A. A. Ajayi-Banji, and T. Yahaya, "Influence of Mode of Entry on Academic Performance of First Year Engineering Students in a Nigerian University", 6th African Engineering Education Association (AEEA) Conference Proceedings, Central University of Technology, Free State, Main Campus, Bloemfontein, South Africa, pp. 17-23, September 20 – 22, 2016.

[8] S. V. Irtwange, and N. N. Agbe, "Comparative analysis of academic achievement of UME and ex-remedial students: Case study of University of Agriculture, Makurdi, Nigeria", Journal of Education Administration and Policy Studies, vol. 2 no. 1, pp. 009-030, February, 2010. http://www.academicjournals.org/JEAPS.

[9] S. C. Gupta, Fundamentals of Statistics, 7th ed., pp. 18.20 – 18.21, Himalaya Publishing House: Mumbai, 2013.

Technical Papers

Engineering student attitudes to e-reading in remote teaching environments

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***Abstract*—Rational:** Academic libraries are increasingly offering online e-books because they provide convenient access for students, cost savings, logistical advantages and significant portability. Current research suggests that this trend will continue in the future. In parallel with the growth of the e-book market and the development of e-book library collections, librarians and information scientists have conducted a number of research studies to investigate the impact of e-books on collection development: specifically, relating to the challenges and questions of e-book management and service. Consequently, researchers have considered it pertinent to explore the behaviours and strategies of e-book readers.

Scope: In January 2020, institutions around the globe faced significant disruption due to COVID-19. Many universities accelerated their adoption of online/e-learning approaches in response to the COVID-19 epidemic. Though e-books were at an early stage of adoption and the culture of using them in academia was slowly growing, they suddenly became the preferred option, if not the sole option because libraries were closed. Accordingly, some of the popular publishers; for example, Cambridge University Press, have offered online higher education textbooks as free-to-access. Over 700 textbooks were available for more than 2 months, regardless of whether those textbooks had previously been purchased. Furthermore, MIT Press offered complimentary access to its catalogue of e-books to support faculty and students who were working and learning remotely.

Methodology: Despite increasing interest from librarians and learning technologists, prior to 2020, there were few well conducted studies investigating the habits of e-book users, especially amongst engineering students. Notwithstanding the challenges arising from the COVID-19 pandemic, an opportunity has arisen to survey student attitudes regarding the adoption of e-reading in an academic context. In this paper, a case study is presented that investigates the impact of the mandatory use of an e-book textbook in a final year undergraduate engineering module at the University of Nottingham Ningbo China. The paper investigates Science and Engineering students' usage and attitudes towards e-books when using their available e-readers, which include PCs or portable devices. A cross-sectional survey containing 5 nominal questions, 2 open questions and 17 Likert questions was developed and deployed to final year students from two programmes: Electrical and Electronic Engineering and Mechatronics Engineering. These students were attending the module titled Integrated Circuits and Systems.

Findings: The results of this study highlight approaches for improving support for e-reading in an academic environment.

Of particular interest to librarians are student attitudes after their adjustment to e-books, which have implications for future purchasing decisions. Furthermore, student strategies for adjusting their learning techniques as a result of forced engagement with e-books illustrate preferences that can inform educators.

In conclusion, the forced adoption of e-books has presented the opportunity to investigate student acceptance and strategies. This research provides evidence for purchasing decisions and strategies for adopting e-books in wider Higher Education syllabi.

Keywords— E-reading, E-book, Engineering education, Textbook, E-learning

I. INTRODUCTION

The coronavirus outbreak, later known as COVID-19, became a serious issue in China during December 2019 [1]. By January 2020, the pandemic had raised considerable concern within China. Strict measures were immediately implemented by the Chinese government that included restriction on people's migration, which led to an extension of the national holiday, and winter vacation of all schools and universities. This placed major challenges on both institutions and students, firstly in China, and later internationally when COVID-19 was announced as a global pandemic [2]. In order to face the challenge, the University of Nottingham Ningbo China (UNNC) implemented remote teaching after firstly extending the winter break by two weeks.

The university library helped students by providing e-books as replacements of physical textbooks because no students were allowed to return to campus during the majority of the spring semester. Module convenors were also encouraged to offer more reference choices to the library to expand the electronic reading list. All e-books provided by the library were available on the university library platform NUsearch, with an option to integrate a specific reading list of a module into the learning management platform, which is *Moodle* [3].

In this paper, a survey was developed that was based on the findings of a specific study to investigate UCLA undergraduates' reading format preferences, and a more global study among university students worldwide [4, 5].

This paper is structured as follows: Section II gives an overview of the literature review. Section III introduces the methodology. Section IV presents the students' survey and reflects on the findings, and Section V concludes.

II. LITERATURE REVIEW

In recent years, e-reading has seen widespread adoption, especially in consumer/leisure contexts with the introduction of dedicated e-reading devices such as Amazon's Kindle[1] and the Nook[2] by Barnes & Noble. It is expected that this trend of adoption will continue in the coming years [6]. E-reading has a number of advantages over traditional print media, including cost, portability, instant availability of content, inline digital notetaking, backlit reading, customizable font and layout, accessibility features and the ability to easily copy or quote materials [5-8]. Despite its numerous advantages and the promise of widespread adoption, the enthusiasm for e- reading in the education sector has been underwhelming, to date [9]. A number of studies have set out to investigate why students, in general, tend to prefer traditional printed reading materials over e-reading.

The context in which the reading occurs has been found to affect student's preference of reading medium. Students reported a preference for e-reading materials that are shorter, and leisure focused [7, 10]. Numerous studies have reported a preference amongst students, at all levels of study, for reading lengthier, academic materials in printed form [5, 7]. Preference for e-reading appears to be informed by level of study, with Wang and Bai reporting that senior undergraduates were more likely to utilise e-reading for academic pursuits relative to their fellow junior peers [7].

Similarly, Lamothe reported doctorial students to be the biggest user groups of electronic resources and most likely to utilize them for academic purposes [8]. Awareness of the availability of e-resources is another relevant factor for consideration in this discussion, with research generally indicating that the majority of students are aware of the availability of e-books through their libraries. However, studies have indicated that faculty staff might be less likely to advertise or promote the availability of e-books for their courses [11, 12].

A number of usability studies have investigated e-reading behaviours. Navigating e-books has been highlighted as unsatisfactory by students with many citing the ability to quickly "flick" or "skim" through material to identify relevant content as being lacking in e-reading environments [9]. Navigation in e-reading contexts remains an active area of research in the *human computer interaction* (HCI) community to date [13]. Furthermore, human factors that include eyestrain, distractions and familiarity with the relevant technologies are compounding factors that detract from the e-reading experience [14]. Mizrachi et al. performed a large (10,000+ students) worldwide survey of student reading format preference [5]. The survey found that there was little relationship between the student's country of origin and the stated preference of reading format. Mizrachi et al. also contributed a multi-faceted survey to interrogate reading preferences in an academic context, the basis for which we use in the work presented in this paper. To the best of our knowledge, no existing studies have explored the response and attitudes of students to a situation where they are required to utilise e-reading resources, as was the situation that resulted from the COVID-19 pandemic. The novelty and contribution of the study presented here includes the impact of circumstance on student attitudes to e-reading when volition has been restricted.

III. METHODOLOGY

In this paper, a survey consisting of four dimensions was given to final year engineering students attending an optional module. The survey was developed based upon a specific study that was used to investigate UCLA undergraduates' reading format preferences, and a more global study among university students worldwide [4, 5]. A specific dimension of this study was dedicated to investigating the impact of disruptive education on the students' reading behaviours.

Students answered questions on four different themes, including format preferences, learning engagement, language influence on material format, and the impact of COVID-19 on their reading behaviour. The survey consisted of 17 Likert questions, 5 nominal questions and 2 open questions. The questionnaire was given to all 23 students enrolled in the module and it was completed by 16 participants. This reduction is responses was considered to be due to normal questionnaire attrition.

The survey was built and analysed using Qualtrics. The invitation to participate in the survey was sent to all students as an announcement on MS-Teams. A reminder was also sent through the students' class representative to encourage greater participation. The responses were analysed using simple statistics together with the student responses from the open question fields to derive meaning from the results.

IV. FINDINGS

The survey questionnaire responses are categorized according to theme and will be described in the following paragraphs.

A. Format Preference

The investigators were firstly interested to know if students would prefer to read the teaching material in printed format and whether this had subjectively affected their comprehension. Using a Likert scale question, students were asked to respond to the following statements (with 10 for highly likely and 1 for least likely):

> I prefer to have my course materials in print format.

> It is more convenient to read my assigned readings electronically than to read them in print.

> I remember information from my course better when I read them from printed pages.

1 Amazon Kindle - http://amazon.com/kindle

2 Nook by Barnes & Noble - https://www.barnesandnoble.com/b/nook/_/N-1pbl

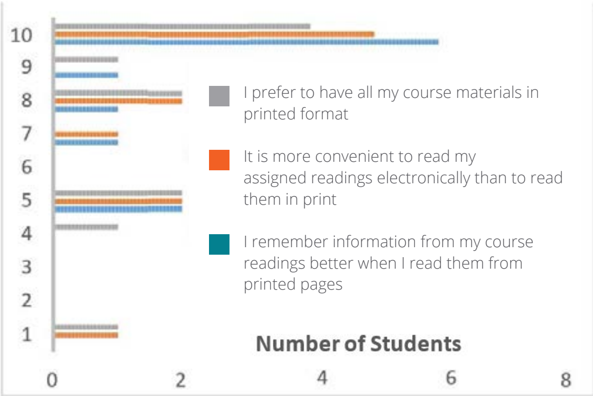

FIGURE 1 Course material reading preference

Figure 1 demonstrates that students felt that they remembered more information when reading from printed pages; however, students simultaneously appreciated the convenience of e-readers. Against this juxtaposition, it was interesting to see that students preferred to have printed course materials as opposed to using the e-books.

In an intervention designed to investigate the influence of reading length on the preferred reading format, the students were asked for their responses to the following two statements:

If an assigned reading is 7 pages or more, I prefer to read it in printed format.

If an assigned reading is less than 7 pages, I prefer to read it electronically.

Figure 2 shows the response of the students. These responses were consistent with previous studies showing the preference of having electronic readings of shorter length [4, 15]. The preference for reading texts of greater than 7 pages was inconclusive based on this data.

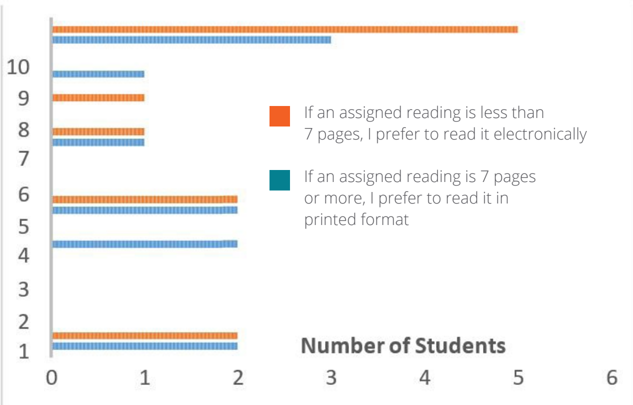

FIGURE 2 Influence of document length on reading format

In a second intervention that attempted to generalise the previous result and also to understand the effect on reading comprehension, the students were asked to give their response to the following statements:

I prefer electronic textbooks over printed/physical textbooks.

I can focus on the material better when I read it in print.

I prefer to read my course readings electronically.

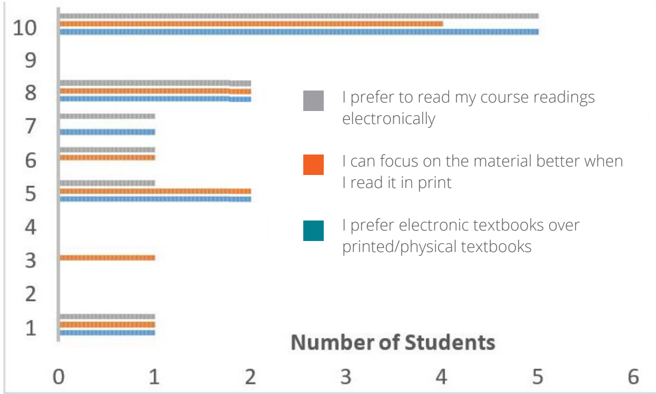

FIGURE 3 Preference of electronic readings over printed document

In Figure 3, it can be seen that some students indicate that they can better focus on printed material as opposed to e- books; however, they preferred to have both their course readings and their textbooks available to them electronically. This could possibly be because they prefer to store them electronically and read them in print. It is interesting to note that there are few discernible differences in the responses to the questions.

B. Learning Engagement

In order to investigate the influence of the reading format on learning engagement, the students were asked the following Likert scale questions:

I usually highlight and annotate my printed course readings.

I usually highlight and annotate my electronic readings.

The response is shown in Figure 4, which shows that students are similarly motivated to annotate both. It was expected that the search option of all electronic readers would reduce the annotation on these devices, but it appears that the decision to annotate might be due to the learning preferences of the student and not due to the medium used to read.

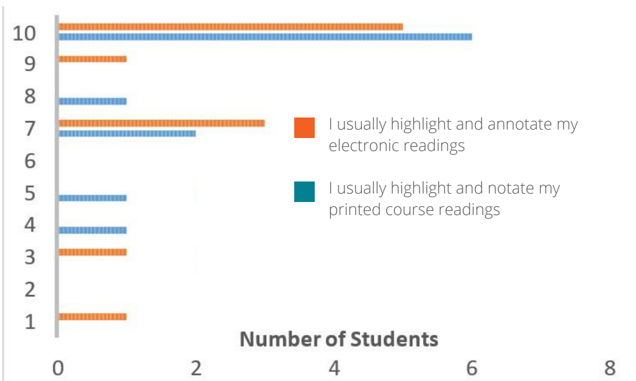

FIGURE 4 Annotation of readings

In order to investigate if having both the print and electronic reading formats would subjectively improve learning efficacy, the students were asked to provide their response to the following two statements:

I prefer to print out my course readings rather than to read them electronically.

I like to make digital copies of my printed course materials.

The response is illustrated in Figure 5 in which the students appear mildly more motivated to make digital copies of printed course material than printing electronic materials. What cannot be understood is why students make digital copies of printed media and print digital media. In Section IV.A it as suggested that students like to store course materials digitally for convenience and then some like to print those materials for learning. However, this is merely an assumption that warrants further investigation.

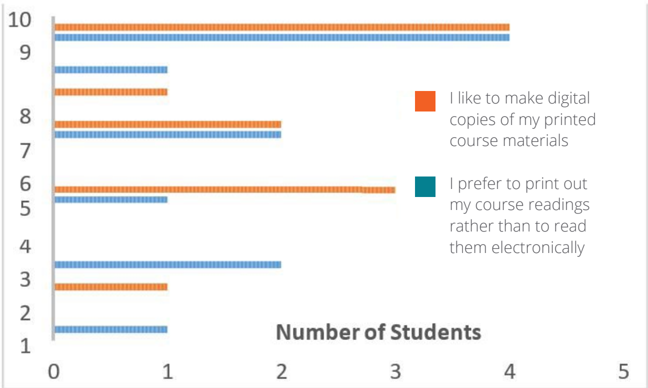

FIGURE 5 *Students preference of having both of the in print and electronic formats*

C. Language Influence

To investigate the effect of the reader's language on the media preference, the students were asked to give their responses to the three following statements:
I prefer to read course readings which are in my native language in electronic format rather than in printed format.

I prefer reading foreign language material in printed rather than electronic format.

My preferred reading format, either electronic or printed, depends on the language I am reading.

Figure 6 clearly shows that students strongly prefer e-reading of their learning material when it's offered in their native language. On the other hand, student preferences were divided on the choice of media when reading foreign language material.

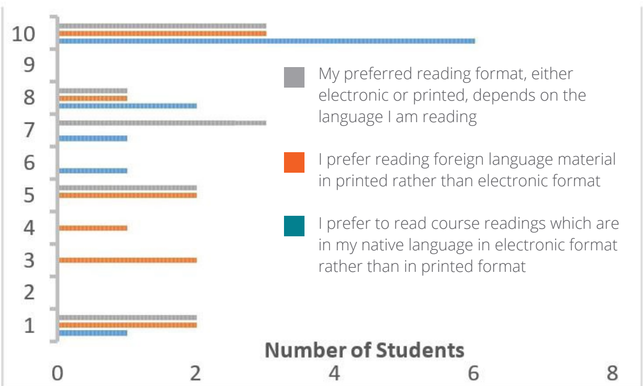

FIGURE 6 *Influence of language on the preferred reading format*

D. Impact of COVID-19 on Reading Behaviour

To understand the changes in students' reading behaviour due to the COVID-19 outbreak, a fourth theme was included in this study that posed five questions. The students were asked:

On average, how often did you use an e-book this semester?

The response of students to this question is shown in Figure 7. It was found that 56% of the students used their e-book daily, 27% used e-books twice a week and 10% used them occasionally. It is assumed that the high engagement with e- books was because of the limited availability of a physical book.

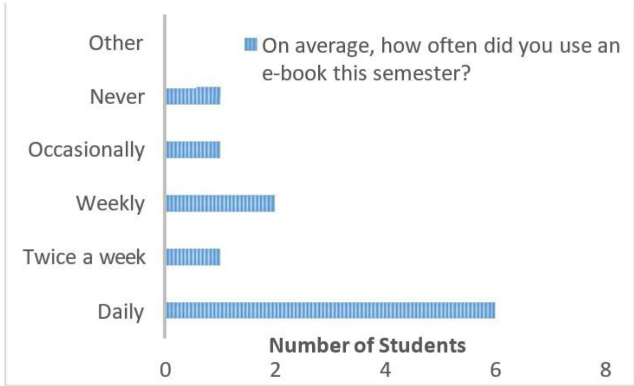

FIGURE 7 *Frequency of usage of e-books during the outbreak*

To emphasise the change of reading behaviour during the COVID-19 outbreak, the students were asked to give their response to the following statement on a Likert scale:

The COVID-19 situation required that I change my reading behaviour to be more e-reading centric.

The response to this statement is shown in Figure 8 in which, 73% of the students strongly agreed and ranked the statement between 7 and 10, with more than 36% of the students responding with a rank of 10.

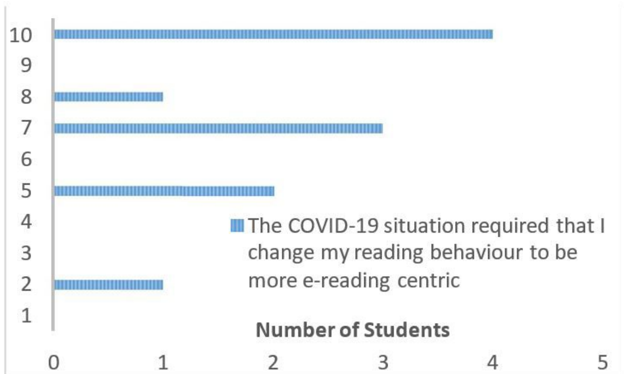

FIGURE 8 *Transfer to e-reading due to COVID-19*

In an open question designed to investigate how students discovered e-books and how they accessed them, the students were asked:

Please tell us what resources you would use to find an e- book?

According to their responses, students mainly preferred to use *Google*, *Baidu*, or the university library search engine: *NUsearch*. Some students would ask senior students, their friends or use *Moodle*.

To investigate if students intended to continue using e- books after they returned to campus, despite the availability of physical books in the library, the students were asked the following three questions:

Have you returned to campus?

Have you continued to use e-books?

Do you intend to continue to use e-books when you return?

The response is shown on Table I.

TABLE I *Usage of e-book after campus return*

Survey Question	Yes	No
Have you returned to campus?	72.73%	27.27
Have you continued to use e-books?	100%	0%
Do you intend to continue to use e-books when you return?	66.67%	33.33%

It was found that all students who had returned to campus by the time this survey was distributed had continued using e-books despite physical books being available in the library. Table I indicates that the majority of the students who were still offsite said they would continue to use e-books; although, these results cannot discover if a change in attitude had occurred.

Finally, the investigators were interested in discovering student opinion for the purposes of informing future policy. To this end, the students were asked:

If you were given an e-reading device (for example, a Kindle) would you prefer to use that instead of using a physical textbook?

The response to this question is shown in Figure 9.

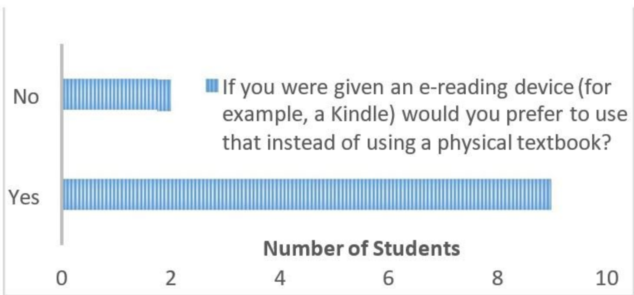

FIGURE 9 *Students' view of e-books replacing physical textbooks*

In this case, the majority of the students (~82%) would prefer to use e-readers; however, this investigation had no pre- disruption data hence it is not possible to predict how students might have answered before COVID-19. It is not inconceivable that student answers were swayed by the thought of receiving a free Kindle.

V. CONCLUSION

The paper has outlined the understanding that has come about from a series of sudden changes brought about by unpredicted circumstances. The students' attitudes to electronic reading have been investigated during a semester where their normal way of study was interrupted and remote teaching became a necessity.

The findings have suggested that engineering students do not have a preference for a specific type of reading media. The results indicate that the students appear to be evenly divided between those who prefer e-books and those who prefer physical media. Hence, future policy makers ought to make provision for both types of media in libraries. It can also be seen that students are likely to digitise their physical media and might print digital media for the purpose of reading, depending on their preferences. This is understandable if students are working from a frame of convenience. It is simple to store course materials on a cloud, which improves accessibility and possibly safety. Then, when necessary, those materials can be printed. Few students indicated that they would not use a Kindle if they were provided with one, but this remains an avenue of further investigation without current conclusion.

One threat to validity is that students were sympathetic and may have given high evaluations because of the abrupt change difficult circumstances. However, the results indicate a subtle shift in student attitudes towards electronic reading, which is a phenomenon to be monitored in the post COVID-19 future.

REFERENCES

[1] World Health Organization, Novel Coronavirus(2019-nCoV), Situation Report – 11. Available at https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200131-sitrep-11- ncov.pdf?sfvrsn=de7c0f7_4 (Last accessed June 2020).

[2] WHO declares COVID-19 outbreak a pandemic. Available at https://www.who.int/dg/speeches/detail/who-director-general-s- opening-remarks-at-the-media-briefing-on-covid-19 11-march-2020 (Last accessed June 2020).

[3] UNNC online library. Available at: https://www.nottingham.edu.cn/en/library/finding- resources/nusearch.aspx. (Last accessed August 2020).

[4] Mizrachi D., "Undergraduates Academic Reading Format Preferences and Behaviors," J Acad Librariansh. JAI, vol. 41, pp. 301-311, 2015;

[5] Mizrachi D, Salaz AM, Kurbanoglu S, Boustany J, "Academic reading format preferences and behaviors among university students worldwide: A comparative survey analysis," PLoS ONE, vol. 13:5, May 2018.

[6] Coopers, P. (2011). Turning the page. The Future of eBooks.

[7] Wang, S., & Bai, X., "University students awareness, usage and attitude towards e-books: Experience from China," The Journal of Academic Librarianship, vol. 42:3, pp. 247-258, 2016.

[8] Lamothe, A. R., "Electronic book usage patterns as observed at an academic library: searches and viewings. Partnership," The Canadian Journal of Library and Information Practice and Research, vol. 5:1, 2010.

[9] Carlock, D. M., & Perry, A. M., "Exploring faculty experiences with e-books: a focus group," Library hi tech, 2008.

[10] Croft, R., & Davis, C., "E-books revisited: Surveying student e-book usage in a distributed learning academic library 6 years later," Journal of Library Administration, vol. 50:5-6, pp. 543-569, 2010.

[11] Lenares, D., Smith, S., & Boissy, R. W., "Ebook use and acceptance in an undergraduate institution," Springer ebooks, vol. 22:09, 2014.

[12] Rowlands, I., Nicholas, D., Jamali, H. R., & Huntington, P., "What do faculty and students really think about e-books?," Aslib proceedings. Emerald Group Publishing Limited, vol. 59:6, pp. 489-511, November 2007.

[13] Bailey, G., Sahoo, D., & Jones, M., "Paper for E-paper: Towards paper like tangible experience using E-paper," Proceedings of the 2017 ACM International Conference on Interactive Surfaces and Spaces, pp. 446-449, October 2017.

[14] Brunson, K. W., "Electronic textbooks: An empirical study of adoption potential," The Liberty Business Review, vol. 1:1, pp. 44-55, 2008.

[15] Li C, Poe F, Potter M, Quigley B, Wilson J. UC Libraries Academic e- Book Usage Survey. 2011.

Technical Papers

The utilization of augmented reality technologies within the engineering curricula – opportunities and challenges

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Abstract—**Augmented Reality (AR) is technology that combines videos, photos, texts, and location data of the real world with computer-generated data. Recently, an increased interest from both academia and industry has grown to study and deploy AR technology. Current literature shows that AR has been successfully integrated into many fields of the industry, like navigation, tourism, engineering, entertainment, and automotive. However, its deployment in education and specifically in high education seems to be limited as more research is required to find ways to overcome the associated implementation barriers. This paper aims to explore the potential use of AR in the engineering education sector by highlighting its importance and evaluating the factors that would enable augmented reality application and identifying the associated challenges accordingly. To achieve this, several previous research papers on the potential use of AR applications within the engineering discipline, including the challenges and barriers facing their integration in this discipline were reviewed. This paper, therefore, reports on the findings of this study, providing key foundations towards establishing better-designed AR systems and applications that will increase the acceptance and implementation potential of AR technology in the education industry.**

Keywords— Augmented Reality; Education; learning methods and styles, factors and barriers, advantages.

I. INTRODUCTION

Across the developing world, new technologies are introduced regularly in which they are considered as a great resource for education, connectivity, and health. Recently, technology adoption in education is becoming a vibrant area of interest across global education [1]. ICT has facilitated education by improving its efficiency and effectiveness at all levels. Education is enhanced by improving the student learning experience by altering classrooms and teaching methods. One of the recent technological advancements is Augmented Reality (AR) which combines the real and virtual world, provide real-time interactivity and 3D registration [2]. To elaborate, AR combines computer-generated information with a physical real-world environment to enhance the user's real experience. AR is different from Virtual Reality (VR) in the sense that it superimposes digital data upon the real world instead of totally immersing the user in virtual world. Both AR and VR are part of the Reality – Virtuality Continuum, shown in figure 1, which is a range of all technological classifications starting from completely real environments that do not encounter any technological enhancement towards completely virtual environments that are solely generated by the computer. Augmented Reality (AR) and Augmented Virtuality (AV) reside in between as they combine both real and virtual environments. The main difference is that AR enhances the real world by adding computer-generated information while AV performs the opposite by merging real- world objects into virtual settings.

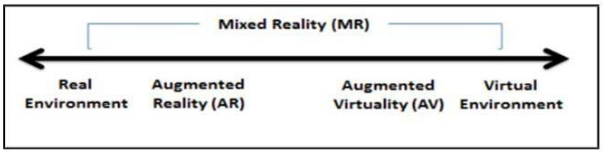

FIGURE 1 *Virtuality-reality continuum [3].*

The AR has been adopted by various industrial fields like navigation, tourism, entertainment, and engineering. Its main importance resides in its capability of enabling many tasks to be achieved efficiently. For example, in navigation & tourism, AR apps were used to display real-time visual information and directions to help tourists find their destination. This is easily achieved by using a smartphone's GPS and camera. Another application is utilizing image processing to identify historical landmark places and virtually reconstructing their ancient ruins to display them as to how they originally looked in the past [4]. AR was also used widely in the entertainment industry as it provides a unique experience. One example is "Nintendogs + Cats" game that utilizes a portable device's camera to augment virtual pets onto an AR card. Players can then communicate with their pets through verbal commands and various controls [5]. In engineering applications, AR was widely used in mechanical, civil, and architecture fields. In mechanical engineering, AR was deployed to display 3D data that identifies the heat distribution during a mechanical activity and in supporting factory layout planning. In civil engineering, AR was utilized to superimpose a simulated steel structure model in an outdoor location. This enables the engineers to look up the model from different angles where the CAD model of steel structure was fixed as the engineer moves. In architecture, AR was utilized to see 3D models of the existing architectural facility and thus help engineers in developing an understanding of buildings from a 3D perspective [6]. One of the biggest industries when it comes to augmented reality is the auto industry. For example, Jaguar, a well-known automobile company, is implementing this technology to provide its clients with a driving experience using the AR application. Moreover, the German motor brand (BMW) is utilizing AR in technical applications such as maintenance, repair, and it can be used further for development purposes [7].

In education. professionals and researchers have been developing theories and ways to apply and migrate AR environment into classrooms. AR is used to illustrate system mechanisms or machinery functionality and other complicated theories. In

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[8], students utilized AR to examine 3D illustration of camshaft arrangement along with a set of real engine components. Also, AR technologies enable users to experience scientific phenomena that are not possible in the real world, such as certain chemical reactions, making inaccessible subject matter available to students [9]. Another area where the implementation of AR becomes very useful is in Physics. Dynamic representations of velocity and acceleration using AR, where we have changes over time, are now being assessed by researchers. Besides, AR technology can be used in estimating experimental outcomes which are adding great value to the learning objectives and making physics more interesting for students. Furthermore, the healthcare industry is one area that can utilize AR technology in providing training for medical students. AR would enhance the learning experience and can allow students to present the model of the human body in 3-dimensions for a better understanding of the anatomy and physiology of our bodies. The demonstration of the human body will give the students the chance to practice performing surgeries and create a similar environment to the real one. Therefore, AR would provide the students with a wide range of different scenarios that may be faced by medical students in real life [10]. In [11], authors explored ways of integrating AR and VR instruments into academic mining education. The European funded project aims to apply this integration in the mining field through developing mining manuals as a digital and electronic standard. Such methodology can be applied during lectures using several hardware instruments such as VR headsets, specialized software, AR-compatible smartphones, and internet connection. One more area where the AR concept can be applied is Welding. In the welding field, AR can be used to provide the welding operators with proper and efficient training. The training is based on providing the operators with helmets that contain sensors that will help in capturing the images of the instruments and devices and transfer them to a simulator to create 3-dimensional pictures of metal workpieces, weld arcs, and weld beads and integrate them into a real-life setting. The AR environment created using the helmets will be displayed for the operators on a panel which allows them to work and use the welding gun. Also, with the help of software, the operators will be able to practice and perform welding exercises which will further develop their skills, and for the trainer, he will be able to monitor the work of the operators and evaluate their progress. Besides, AR is not only enhancing the learning experience but saves a lot of resources since no real materials are being consumed [12].

Accordingly, AR potential in education is recently being explored and researchers are working with educators to explore the best methods to apply AR in education. Research shows that AR utilization would enhance the learning process as it simplifies complex information and increases student's motivation and engagement [2]. Therefore, institutions and schools need to understand its significant potential and its effectiveness compared with traditional methods. Consequently, we will review previous research on AR advantages and highlight its importance in education. Also, we will identify the required factors to be taken into consideration while designing an AR system. Our work is based on the following questions:

- Why should AR be implemented in educational settings? What are the challenges associated with the current educational system? How AR will enhance education?
- What are the important factors that need to be taken into consideration in order to successfully implement AR solutions in educational settings?
- What are the associated barriers related to those factors?

II. IMPORTANCE OF AR IN EDUCATION

Multiple challenges have been associated with the present educational system. Lack of application of theoretical knowledge into practical work is one of the biggest challenges. AR with the relevant software technologies can be used to supply the students with a practical learning setting which can prepare the students for practice in addition to the knowledge base. Also, planning field visiting trips would be possible only to a limited extent and in small groups and thus it is not very practical. AR provides solutions that can substitute field visits and thus save time. Another challenge is that static calculations can be simulated, but not actually tested. With AR, students will be able to see the impact and test their calculations [11].

Explaining why and how AR is an effective tool in education is made by understanding how learning occurs according to learning theories and styles. Kolb's experiential theory is one of the most familiar learning theories [13]. It was stated by Kolb that learning involves acquiring abstract concepts that can be flexibly applied in a variety of situations. The principle of this theory is characterized by a four-stage learning cycle. Those are: firstly, concrete experience: a new experience or reinterpretation of existing experience. Secondly, reflective observation of the new experience. Thirdly, abstract conceptualization reflection: construction of new abstract concepts or adjustment of existing ones after analysis and formation of conclusions. Lastly, active experimentation- the stage where ideas are applied to be observed and tested. Successful learning is achieved when someone passes the four-stage cycle respectively [14].

Kolb's learning theory identifies four learning styles, which are based on the four-stage learning cycle [13]. It is important that each student identify the best approach for processing, learning, and retaining new information as this makes them better leaners by using the respective strategy associated with that learning style. It could be that students prefer one learning style over the other or use a combination of them. Fleming and Mills came up with one of the learning styles theories that account for differences in individuals' learning preferences known as VARK, which stands for Visual, Aural, Read/Write, and Kinesthetic (hands-on) [15]. Visual learners learn best by observing visual representation like diagrams, charts, graphs, symbols, illustrated textbooks, videos, flipcharts and mind maps, and other visualizations of information hierarchy. A number of study strategies can be followed for visual learners like highlighting key words, creating flashcards, using technology for visual illustration, turning words and notes into visual diagram or pictures, and color-code. Aural learners prefer learning by verbal communication which could be through verbal lessons, discussions, listening to others. They process information through hearing and based on that the most useful learning strategies are reading written notes out loud to themselves, listening to recorded information or audio books, work in groups or study partners, using mnemonic devices, and repetition. Read/write learners prefer word-based input and output. They learn best by writing down notes and materials, providing handouts, arrange words into hierarchies and points, online research, and PowerPoint slide presentations [16]. Lastly, Kinesthetic learners are physical learners. That means they learn best by being physically active in the learning process and figuring out things by hand. The most useful learning strategies are moving around while reading or studying, creating hands-on learning experience when possible like simulating a practical lesson, and performing lab experiments or projects [17].

Augmented reality medium enhances the learning process since it can be used as a teaching tool that supports and provides a unique combination of all learning styles, visual, aural, read/write, and kinesthetic. Considering the conventional learning system, it has mostly relied on static visualization such as texts and diagrams. Utilizing AR would provide interactive content instead. Static images become animated, 2D representations can be illustrated in 3D format and text can be converted to audio. It is also notable that the current educational system does not support kinesthetic learners as they easily get distracted by their desire to move and perform an activity when they are required to stay still for long periods. All these changes in teaching tools can be educationally effective because they ease the process of grasping new information and makes learning more appealing to different learners [13]. In [14], authors conducted an experiment to test children's learning performance with three types of teaching materials, including a picture book, physical interactions, and an AR graphic book. Results showed that children preferred the AR graphic book over the other teaching material as it provides a practical and hands-on learning experience.

Powerful teaching requires motivation in addition to experiential learning. Keller represented the ARCS Model, which is a four-dimensions model. Attention (curiosities and interests of the people should be encouraged and upheld), Relevance (people must believe that the discipline relates and connects to their goals and objectives), Confidence, and Satisfaction. Based on Keller's concept, people must successfully experience those four models in order to be properly motivated [18].

Attention and satisfaction motivational factors were evaluated better among the AR system than the traditional learning environment. A usability study has presented acceptance of middle-school students towards the AR technology although it is considered not mature enough to be widely used in education. AR improves the students' motivation through the application of the ARCS Model [19].

Since AR makes the learning experience more fun and enjoyable, it increases student's engagement in classrooms and make students more motivated towards learning. As was reported by several studies on integrating AR in educational environment [20-23], it was shown that AR improves the learning skills and abilities and enhances student's memorization by enabling students to physically enact the educational concepts. It also improves the cognition of information-identification-recognition and understanding of things since physical activity is linked to conceptual understanding of educational content. Also, it makes courses easier to understand and increases the brainpower and creativity of students. All these advantages increase student motivation.

III. AR IMPLEMENTATION FACTORS AND BARRIERS TO ADOPTION IN ENGINEERING EDUCATION

After identifying the importance and emphasizing the need to implement AR technology in educational settings, we will investigate the factors concerning AR implementations and the associated barriers and how to overcome them. The factors are classified into six categories which are AR applicability, stakeholders' perception, technology knowledge level, psychological, human and technical.

AR applicability can be measured by how much the technology is suited for the context of its use. This is made by deciding on the learning courses that is to be augmented and the learning material or syllabus. AR applicability is important because otherwise the technology is not worth the investment as it does not add any value. To decide on which courses to augment, researchers decided to choose the most important course for that major of study. For example, researchers in [19], chose engineering graphics course since it represents the foundation for engineering profession, and it is essential for almost every technical faculty at the private and state universities in the country. In another study concerned with implementing AR in computer science major, discrete mathematics subject was chosen as it is the most important basic course in this major since its concept are applied in many courses like algorithms, data structure, and computer networks [23].

Additionally, the evaluation of AR applicability to each courses' topics must be studied as well. the decision on which subjects to augment in that chosen course depends on the students' exams results in previous years. By detecting the success rates of students by subject, a priority is given to the subjects that students are less successful in. Lastly, before implementing AR in any course or field, it is important to identify the learning objectives and goals that the educator is trying to achieve, and then seek the best way to accomplish them through AR applications. Accordingly, AR designers must communicate with instructors to understand how to create experiences that integrate into classroom pedagogy. Examples include designing AR content in a way it can be integrated into multiple points along the curriculum, designing a multiplayer AR experiences to facilitate student's collaboration, designing smart applications that monitor student progress, and adapt accordingly. Doing so will help teachers achieve their syllabus's learning objectives [21]. An example of achieving the learning syllabus by using AR is elaborated in [2]. Authors depicted an interactive and engaging user experience in chemistry related application. Cards were used to represent different chemical elements and AR was integrated to play audio files to pronounce the names of the chemical elements upon detection, and augment 3D scenes on top of the physical card.

After the experience, students developed an understanding of collision concepts that trigger the chemical reaction between elements.

The Second factor is perception and opinions towards integrating AR in classrooms. In [24], authors examined junior high school student's conception of learning science by AR through a survey. Results showed that students mostly exhibited positive beliefs towards learning science by AR as they think it will increase their motivation to learn and improve their interaction with the learning material. However, students also expressed some negative conceptions in which they belief AR diminishes their imagination about the scientific content in the paper book. Therefore, it is necessary to incorporate active learning practices like scientific cues or prompts instead of providing concrete augmented information. This way, students' negative conception regarding diminishing their imagination will be reduced.

It is notable that students and faculty perception about AR is based on their knowledge level of its concept, applications, and technologies.

Therefore, determining their knowledge level is another factor that needs to be taken into consideration. It is important to determine to what extent student and faculty are familiar with it so that they will be able to realize its importance in classrooms or the ways in which it can be used. if their initial perception is negative, then making them try it and explaining to them its concepts, devices, and applications, would help in familiarizing them more and thus changing their perception. A research study was made with the intent to explore instructors' opinions about using AR in classrooms. Results showed that candidates had good knowledge in technological devices like smartphones and laptop computers, but their knowledge about AR technology was limited to the term only.

They did not know enough details about the technology and its possible applications. The authors then examined the teachers' opinions after using augmented reality material. Candidates were very excited and stated that it is a promising technology with high potential use in teaching and learning materials and they would like to see AR technology in their lessons and learning environments. In [25], the same study was performed on students to get their perception on the use of augmented reality, which produced the similar results.
People also might perceive AR as an ineffective tool and refuse to update the current educational systems due to some psychological factors. To elaborate, some people are connected to the old way and have developed a fear of change. Also, they might be misunderstanding and under- evaluating the need for change [16]. Another psychological factor is developed anxiety. That is, users think AR will make learning difficult, causes boredom, and they will find it difficult to use. So, a solution would be by providing training and appropriate assistant when needed. Also, by providing previous successful examples of AR implementation [26].

Human factors also play a vital role in designing an effective computing system. Human factors are explored from different perspectives with attempts to propose design guidelines. Cognitive issues are identified as an important category of human factors in AR. These issues are related to users' cognitive process for understanding an AR environment when interacting with the system. In [27], researchers identified and examined three primary categories of cognitive issues in mobile AR interaction: information presentation, physical interaction, and shared experience. Factors like amount, placement of information determine the impact of information presentation on cognitive functioning in mobile AR. It is important to represent a considerable amount of information in order to avoid cognitive overloading and technical problems that would hinder the cognitive functioning. Presenting a large volume of information can cause information interference in a single display. Additionally, proper Information placement is required as it helps users to connect the meaning of virtual information with the real-world view and thus impact the understandability of information. The second category is physical interaction, which is represented by the physical actions engaged by users in mobile AR. Interaction learning motivates users to perform self-exploratory activities and enhance their spatial awareness of physical spaces. The increasing level of physical participation can shape user experiences and affect their understanding of the world.

Lastly, the technological factor also affects the success of AR applications. The difficulties and obstacles of using AR technology can be classified into physical obstacles and technical obstacles [21]. Physical obstacles are related to AR platform in terms of tools or devices used to deploy the AR application. Examples of physical obstacles are data security, data storage, and scalability. Technical obstacles are related to digital content, its appearance, and its stability while interacting. Examples of technical obstacles are response time of the application, contrast (correctly matching the brightness of both virtual and real objects), Registration (the proper alignment of the virtual and real objects in regard to their interrelation and in regard to the surrounding environment) and Occlusion (the overlapping of virtual and real objects in the AR systems). By understanding the underlying technological factors that augmented reality can leverage in educational experiences, designers and educators can make use of the specific affordances of the AR medium in order to construct effective learning experiences.

IV. CONCLUSION

Applying AR in education will improve the teaching process and help students in understanding and analyzing engineering concepts on a deeper level as well as enhance their skills. Its importance was highlighted by explaining its benefits with regard to learning theories. Kolb's, VARK and ARCS theories were discussed where it shows that AR supports the concepts of these theories and provides features to overcome challenges associated with the current educational system. This was also proved from previous research studies. To answer the second research question, results showed that the main factors are categorized as AR applicability, perception, knowledge level, psychological, human, and technical factors. These factors should be taken into consideration while proposing the design guidelines to yield a successful implementation of AR system in education.

REFERENCES

[1] "Technology enhanced learning | Advance HE," Heacademy.ac.uk. [Online]. Available: https://www.heacademy.ac.uk/individuals/strategic- priorities/technology-enhanced-learning. [Accessed: 14-Aug-2020].

[2] R. T. Azuma, "A survey of augmented reality," Presence (Camb.), vol. 6, no. 4, pp. 1-9, 1997.

[3] Yuen, S. C. Y., Yaoyuneyong, G., & Johnson, E. (2011). Augmented reality: An overview and five directions for AR in education. Journal of Educational Technology Development and Exchange (JETDE), 4(1), 11..

[4] A. Saenz, "Augmented reality does time travel tourism," Singularityhub.com, 19-Nov-2009. [Online]. Available: https://singularityhub.com/2009/11/19/augmented-reality-does-time-travel-tourism/. [Accessed: 15-Aug-2020].

[5] "nintendogs + cats: Golden Retriever & New Friends for Nintendo 3DS - Nintendo Game Details," Nintendo.com. [Online]. Available: http://nintendogspluscats.nintendo.com/pose/. [Accessed: 17-Aug-2020].

[6] Pejić, P., Rizov, T., Krasić, S., & Stajić, B. (2014, October). Augmented reality application in engineering. In 3rd international congress, SMAT (pp. 39-44).

[7] R. G. Boboc, F. Gîrbacia, and E. V. Butilă, "The application of augmented reality in the automotive industry: A systematic literature review," Appl. Sci. (Basel), vol. 10, no. 12, p. 4259, 2020.

[8] K. Lee, "Augmented Reality in education and training," TechTrends, vol. 56, no. 2, pp. 13–21, March/April 2012.

[9] T. Khan, K. Johnston, and J. Ophoff, "The impact of an augmented reality application on learning motivation of students," Adv. hum.-comput. interact., vol. 2019, pp. 1–14, 2019.

[10] N. Joshi, "AR and VR: The Future of Smart Education is Here." https://www.bbntimes.com/technology/ar-and-vr-the-future-of-smart-education-is-here (accessed Aug. 15, 2020).

[11] "(PDF) Mixed Reality Books: Applying Augmented and Virtual Reality in Mining Engineering Education," ResearchGate. https://www.researchgate.net/publication/341658694_Mixed_Reality _Books_Applying_Augmented_and_Virtual_Reality_in_Mining_Engineering_Education (accessed Aug. 15, 2020).

[12] Welding Productivity, "Reality Check - welding productivity," Weldingproductivity.com, 14-Nov-2017. [Online]. Available: https://weldingproductivity.com/article/reality-check/. [Accessed: 10-Aug-2020]

[13] S. Mcleod, "Kolb's learning styles and experiential learning cycle | simply psychology," Simplypsychology.org. [Online]. Available: https://www.simplypsychology.org/learning-kolb.html. [Accessed: 18-Aug-2020].

[14] M. Jantjies, T. Moodley, and R. Maart, "Experiential learning through virtual and augmented reality in higher education," in Proceedings of the 2018 International Conference on Education Technology Management - ICETM 2018, 2018.

[15] Definedstem.com. [Online]. Available: https://www.definedstem.com/wp- content/uploads/2017/05/VARK.pdf. [Accessed: 11-Aug-2020].

[16] L. Dierking, "Learning theory and learning styles: An overview," J. Mus. Educ., vol. 16, no. 1, pp. 4–6, 1991

[17] T. Inott and B. B. Kennedy, "Assessing learning styles: practical tips for patient education," Nurs. Clin. North Am., vol. 46, no. 3, pp. 313–20, vi, 2011.

[18] N. Loorbach, O. Peters, J. Karreman, and M. Steehouder, "Validation of the Instructional Materials Motivation Survey (IMMS) in a self-directed instructional setting aimed at working with technology: Validation of the IMMS," Br. J. Educ. Technol., vol. 46, no. 1, pp. 204–218, 2015.

[19] Keller, J. M. (1987). Development and use of the ARCS model of instructional design. Journal of instructional development, 10(3), 2..

[20] Swan, J. Edward, and Joseph L. Gabbard, "Survey of user-based experimentation in augmented reality," In Proceedings of 1st International Conference on Virtual Reality, vol. 22, no. pp. 1-9. 2005., 2005.

[21] I. Radu, "Augmented reality in education: a meta-review and cross-media analysis," Pers. Ubiquitous Comput., vol. 18, no. 6, pp. 1533–1543, 2014.

[22] Van Krevelen, D. W. F., & Poelman, R. (2010). A survey of augmented reality technologies, applications and limitations. International journal of virtual reality, 9(2), 1-20.

[23] ŞİMŞEK, Mehmet, Sinan TOKLU, Hamza ÖZSARAÇ, Sultan ZAVRAK, Ekrem BAŞER, Büşra TAKGİL, and Zafer KANBUR., "An Augmented Reality Application for Computer Engineering Curriculum," International Journal of Informatics Technologies, vol. 10, no. 1, pp. 47–51, 2017.

[24] K.-H. Cheng, "Surveying students' conceptions of learning science by augmented reality and their scientific epistemic beliefs," Eurasia j. math. sci. technol. educ., vol. 14, no. 4, pp. 1147–1159, 2018.

[25] N. A. A. Majid, H. Mohammed, and R. Sulaiman, "Students' perception of mobile augmented reality applications in learning computer organization," Procedia Soc. Behav. Sci., vol. 176, pp. 111– 116, 2015.

[26] [17] S. Küçük, R. Yilmaz, Ö. Baydaş, and Y. Göktaş, "Augmented reality applications attitude scale in secondary schools: Validity and reliability study," TED EĞİT. VE BİLİM, vol. 39, no. 176, 2014.

[27] W. Huang, L. Alem, and M. A. Livingston, Eds., Human factors in augmented reality environments, 2013th ed. New York, NY: Springer, 2014.

Technical Papers

Effects of coronavirus pandemic spread on science, technology, engineering and mathematics education in higher learning institutions.

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***Abstract*—The traditional pedagogical methods of delivering content for Science, Technology, Engineering and Mathematics (STEM) related subjects have been shaken to their core. Normal delivery under ideal conditions was a face to face approach with the tutor in front of the class. Practical subjects that have laboratory exercises are carried out in the designated laboratory areas with the assistance of technicians or technologists. With the advent of coronavirus pandemic, where isolation and social distancing has been implemented to stop its spread and transmission, these modes of content delivery are not feasible. To fill in the gap and ensure the much needed STEM education continues despite the fear of coronavirus pandemic spread, online delivery mode of various subjects offered has been adopted. This is done using such platforms as Learning Management System, Zoom Meeting and Google Scholar. However, solving the problem of practical laboratory exercises requires much more than online teaching. This paper proposes the use of virtual reality, simulation and modeling platforms as a substitute of face to face laboratory exercises in training STEM related subjects, especially in institutions of higher learning in developing countries. Pre- recorded versions of practical experiments will be offered to students and related assignments given for practice purposes. Short webinars with details recorded will guide recipients in carrying out experiments without the need for neither technicians nor technologists. The students will then be able to attend the laboratory session virtually and submit the required reports. Several other types of content deliver exist and a combination of them can also be used depending on the areas to be covered. The exploitation of the suggested content delivery will resolve change of the attitude in learning behavior, thereby ensuring high quality and effective understanding of the subject area.**

Keywords—STEM Education, Content Delivery, Online Teaching, Practical Exercise.

I. INTRODUCTION

What are the effects of the novel Coronavirus pandemic on STEM subjects in higher learning institutions? STEM subjects unlike other subjects have an aspect of hands on requirements through laboratory experiments. The students are graded based on the combination of the theoretical work which is learnt in class and practical work which is done through experiments designed to verify the theoretical principles [1]. This approach makes the student able to apply the knowledge gained in school in providing optimal solutions for the societal problems.

The industrial revolutions have always led to a change in how things are done. From the first one that brought steam engines to the scene to the looming fourth industrial revolution that is knowledge and skill based [2]. This revolution comprises of technologies like block chain, internet of Things, Artificial Intelligence, virtual reality/ augmented reality, additive manufacturing and more recently 5G, an enabler and catalyst for the revolution. The main aim of the fourth industrial revolution is to better lives of people in the society.

With the outbreak of coronavirus (Covid-19), social distancing has been enforced as one of the ways of curbing the spreading of the novel virus [3]. This means that having face to face classes is highly discouraged by the World Health Organization (WHO). Thus, for education to continue, nations have to find an alternative way of delivering content to the learners. One of the major ways that have been instrumental is through online platforms and e-learning. Learners need only two things to access the platform, a computer/ mobile phone and an internet connection. These, however helpful, are challenging when it comes to STEM courses. This is because of the nature of practical exercises that STEM subjects have [1].

Countries have been locked down due to Covid-19 as a measure of infection prevention. This has made their citizens to be indoors and the only access they have to the outside world is the internet. Governments have responded to this by increasing the internet bandwidths supplied to their citizen as well as reducing the cost of data. Some countries like Kenya are focusing in improving connectivity by all means possible which includes using of internet balloons [4]. All these efforts are enablers of online learning and with the looming 5G technology, internet speeds will increase by a very big factor and latency will be as low as one millisecond! This will make concepts like virtual reality a real.

With virtual reality, practical exercises in STEM can now be taken online and thus no need for face to face classes. Simulation and modeling can now be done online with very small latencies using cloud computing technology and ultra-reliable and low latency network such as 5G. This means that learners will only need a computer/mobile phone and an internet connection to attend laboratory exercises.

This will change how STEM subjects are taught and even introduce a possibility of having 100% online STEM degrees. Universities could collaborate and invest on the infrastructure thus creating a pool of resources for learners making all courses in a country accredited since all resources are available. It will be easy to collaborate in research and any other advancement too.

II. LITERATURE REVIEW

A. Virtual Reality

Virtual reality (VR) is a technology that is part of the 4th industrial revolution. It relies on the synthesis of computer graphics,

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human- machine interactions, artificial intelligence to produce real vision, listen and smell. This lets human and virtual world to interact [5]. The first virtual reality gadget was created in 1968 by Ivan Sutherland [6]. Ever since, the technology has been evolving at a very high speed. Big technology giants like Google, Intel and Nvidia have all participated greatly in shaping the landscape of virtual reality. Virtual reality involves setting the user into a virtual world usually through visual, audio and touch senses [6]. With the adoption of 5G, this technology will be cheaper and readily available since 5G will provide the necessary bandwidth and speeds for its utilization. [7] proposes an integrated environment that can be coupled with virtual reality to assist learners of STEM. [5] proposes the use of VR in training mining engineers.

B. Modelling and Simulation

Modelling is the process of representing a model which includes its construction and working. The model is usually similar to the real system. Simulation on the other hand is the operation of the model in terms of space or time, which help analyze the performance of a proposed/existing system [8]. Simulations software help learners visualize a practical scenario. Some of the common ones include SIMULINK from MATLAB and Proteus.

III. METHODOLOGY

A survey was conducted among STEM students through an online survey platform, using Google forms. Random sample was used to identify participants of the survey. Users filled the form online and submitted it back. The questions asked hid the user identity and had only one aim of finding out the user experience with the current online learning systems.

The survey was sent to STEM learners in Kenya. In the first phase, the questions aimed at finding out the users experience with the current online platforms and their experience with virtual reality and simulation and modelling software.

In the second phase, some students were exposed to a 3D online platform called PXLREALM where they attended a demonstration session. Then students were able to move, maneuver and interact in the online session. Later, a survey was taken on the sample that was exposed to the platform. The aim of the survey was to find out the reaction on that platform.

The second sample was aimed at students who had interacted with virtual reality platforms. The aim of the survey was to find out their experience and preferences in these platforms.

IV. RESULTS AND DISCUSSION

After collecting survey from the sampled groups the following results are discussed below

A. Status quo

All the participants agreed that COVID-19 has interfered with learning greatly and has made universities to resolve to online learning. Some of them find it hard to adapt to this new reality. When asked about what platforms they have access to for online training, they responded as seen in Figure 1.

Zoom was the most preferred online learning platform. This was because of its added features that makes it look and seem like a face to face class.

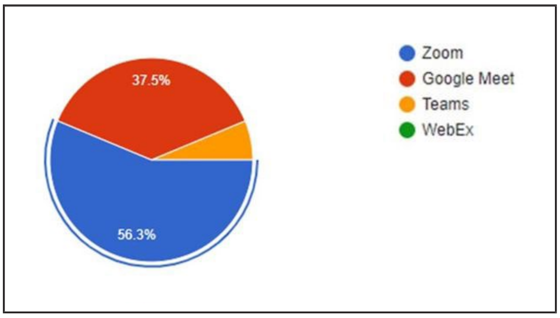


FIGURE 1 *Virtuality-reality continuum [3].*

B. User satisfaction

Users were asked if the current experience on the online platform was satisfactory. Majority of them mentioned that the main reason they attend is because the university says that they have to. Most of them feel like its not suitable in teaching STEM courses. They miss the class experience of one on one interaction with the tutor. Some of them gave concerns that solving and writing equations is somehow not easy on current platforms. Below is an analysis of the data;

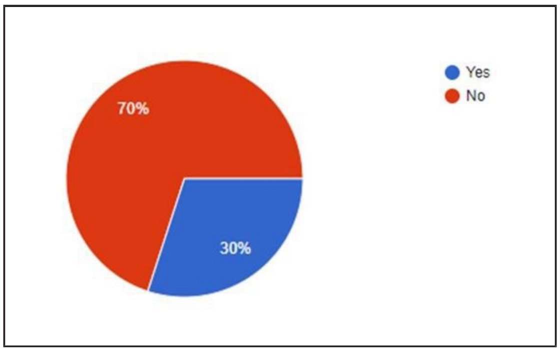


FIGURE 2 *Responses on user satisfaction*

C. Conversant with the emerging technologies

The following analysis shows how conversant the users were to emerging online technologies.

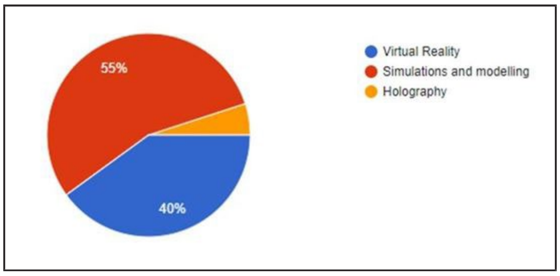
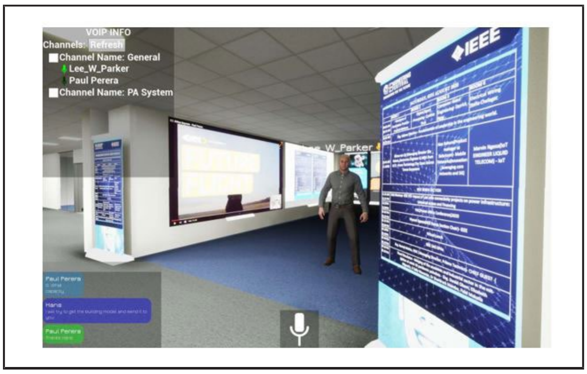


FIGURE 3 *Responses on technology conversance*

The majority of the users were conversant and had tried simulation and modelling and preferred it to virtual reality and holography. The majority felt like simulation and modelling was the best tool for STEM learning. but this might be because most of them were not exposed to virtual reality and holography. Also, simulation and modelling takes less network bandwidth than the two. This might be another reason.

The users were exposed to the PXLREALM platform and most of them felt like that was the way to go in online training of STEM programs. Below is a photo of users in the 3D learning platform.

PICTURE 1 Users making a presentation in the online platform



PICTURE 2 The PXLREALM platform

PICTURE 3 The waiting area of the 3D platform.

V. CONCLUSION

The results of the study are presented. The learners from the sampled group are exposed to two methods of online learning for STEM subjects. The first one is the classical one and the second one is the one proposed in this paper. Students in the new proposed way of learning are able to interact with the tutor and the lab experiments in a way that is very close to the real world. The learners prefer this way to the classical online meetings that current platforms provide.

COVID-19 has provided us with an opportunity to innovate around most aspects of our lives and the education sector has really been challenged. This might be the new reality and this paper proposes the integration of emerging technologies with learner training to ensure better learning experience at the lowest cost and highest convenience.

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REFERENCES

[1] C. S. D. K. A. Zendler, “Instructional Methods in STEM Education: A Cross-contextual Study,” EURASIA Journal of Mathematics, Science and Technology Education, no. 1305-8223 (online) 1305-8215 (print), 2018.

[2] V. L. G. L. M. Peña-Cabrera, “Fourth industrial revolution and its impact on Society,” in CHILECON 2019, Valpara´ıso, Chile, 2019.

[3] H. M. School, “Harvard Health Publishing,” Harvard Un iversity, 22 July 2020. [Online]. Available: https://www.health.harvard.edu/diseases- and-conditions/preventing-the-spread-of-the- coronavirus. [Accessed 24 July 2020].

[4] BBC, “BBC News,” BBC , 7 July 2020. [Online]. Available: https://www.bbc.com/news/technology-53321007. [Accessed 24 July 2020].

[5] L. M. Z.g, “The Research on Virtual Reality Applied for Digitalize Education of Mining Engineer Speciality,” in 2nd international Conforence on Education Technology and Computer (ICETC) , 2010.

[6] D. Cooke, “peeble studio,” 17 August 2017. [Online]. Available: https://www.pebblestudios.co.uk/2017/08/17/when- was-virtual-reality- invented/#:~:text=The%20first%20virtual%20realit y%20headset,and%20his%20student%2C%20Bob%20Sproull.. [Accessed 05 August 2020].

[7] J. H. K. L. B. L. R. W. F. C. J. D. D. R. R. W. a. C. C.-N. Galen Faidley, “ Developing an Integrated Wireless System for Fully Immersive Virtual Reality Environments,” in Eighth International Symposium on Wearable Computers , 2004.

[8] Tutorialspoint, “Tutorialspoint,” Tutorialspoint, [Online]. Available: https://www.tutorialspoint.com/modelling_and_sim ulation/index.htm. [Accessed 05 August 2020].

Technical Papers

Flexible learning during educational disruption: A case study of teaching integrated circuits design

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Abstract—**To date, there has been little written that explains how engineering-related tuition can be rapidly and effectively moved online. Furthermore, there is sparse literature written that focuses on how students can adapt to such technologies in a relatively short space of time. Finally, it is both necessary and prudent to increase discourse on the effective online teaching of technical design subjects. This paper evaluates the effectiveness of online tools such as interactive live lectures, slide annotation, and electronic whiteboard, for engaging students in electrical and electronic engineering education. The paper advances those debates by providing an evaluative analysis from the perspective of students taking an Integrated Circuits design module that was delivered during the 2020 COVID-19 crisis. The major research question is: to what extent do electrical engineering students perceive online learning tools to be useful in enhancing their sudden learning change? Responses were collected using an online questionnaire that was offered to 23 students who enrolled in the module, and a 70% completion rate was received. The findings showed that students engaged well with the technologies, and they found them easy to use and beneficial for their learning.**

Keywords—Flexible engineering education, online learning, interactive teaching.

I. INTRODUCTION

In this paper, a case study of an online approach used in engineering education is presented in the context of a requirement for moving rapidly from regular face-to-face teaching to online processes.

There has been little published on how the use of technology has assisted the educational community during the sudden crises [1], though some work has now been undertaken as the crisis has deepened [2]. The aim of the research presented in this paper is to add to this body of knowledge by investigating students' engagement with – and perceptions of – the online tools used in the delivery of an engineering module. The paper outlines what was done, why, and gives some indications around students' reactions to the actions taken.

It begins with an overview on the general e-learning approach at the institutional level, discusses some enhancements to that approach and then provides a case study of synchronous online teaching of the integrated circuits and systems module. The present work was undertaken in order to investigate students' preferences around various interactive pedagogic tools used in an online setting hence the paper presents findings into such questions and concludes with some thoughts looking forward.

II. UNIVERSITY GENERAL APPROACH IN RESPONSE TO COVID-19

The Coronavirus outbreak, later known as COVID-19, became a serious issue in China around the Chinese Spring Festival in 2020 [3]. Strict measures were immediately implemented by the Chinese government, leading to major challenges for teaching institutions worldwide. International institutions in China struggled to educate students both in China and overseas; particularly, after international students were restricted from returning to the mainland. Such restrictions were also applied to international academic members of staff. [4]. This meant that from January 2020, e- learning became a mandatory requirement in many institutions [5-7].

As a result, significant achievements were made in e- learning, despite the implementation challenges that have endured since 1990 [8-9]. In an attempt to overcome the challenges posed by COVID-19, the university's general approach was to request that, as a minimum, educators should upload some form of lecture slides with audio commentary, either using Panopto or by adding voice notes to existing materials such as *PowerPoint* (PPT) slides. Thus, recorded lectures became the fundamental element of an e-learning approach [10-14]. The recorded videos together with the lecture notes were uploaded to the official Learning Management System (Moodle).

Within the Faculty of Science and Engineering (FoSE) at UNNC, there were two additional challenges for programmes: 1) the requirement for accreditation and 2) the nuanced nature of engineering education, which typically requires interactive learning [15-16]. This approach facilitated legitimate concerns regarding student-faculty interaction (crucial for learning design methods) and around student engagement; specifically, would students refuse to engage with the materials in spite of the of the advantages brought by a higher degree of flexibility and autonomy?

The faculty response was to use additional learning facilities for electronic teaching delivery at UNNC, as listed below:

- Moodle, a *learning management system* (LMS), that enables the distribution of lecture notes, online videos, fora, online example sheets, amongst others.
- MS-Teams together with Moodle for providing instant interaction with students and allowing the integration of additional *MS-Office* tools such as (*SharePoint, Outlook and Forms*) as well as multiple applications including *Zoom* and *Panopto*.

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- The online video meeting application, Zoom, to provide live tutorials but not lectures. Features including screen sharing, public and private chat, polls and breakout rooms, provide opportunities for possibly increasing student interaction and attention.
- Panopto and MS-PowerPoint can be used together with Zoom for the purposes of delivering and capturing lectures. Lecture videos can be split into several MP4 files, each of a reasonable size, to overcome variations in network speed and network quality.

III. ONLINE TEACHING ADJUSTMENTS IN AN ENGINEERING MODULE

A. Module Details

The effectiveness of the described flexible approach to e-learning, during Covid-19, can be examined through a final year electrical and electronic engineering module, entitled 'Integrated Circuits and Systems'. It was offered to students from two different programmes within the EEE department, BEng in Electrical Engineering and BEng in Mechatronics Engineering and was taken by 23 students. The module contributed 20 credits out of a total of 120 credits students needed to obtain in the final year.

This module was taught in the spring semester and included 3 components, one of which was '*digital very large scale integrated*' (VLSI) circuit design, and this was the major component of the module, corresponding to 50% of the module content. The module content included both theoretical and practical aspects, and involved numerous equations and drawings; many of them precise coloured layout drawings. One quarter of the module assessment comprised of coursework, which required students to analyse, design and simulate different levels of the circuits.

B. Standard Module Delivery

According to the module specifications, the VLSI module content required a weekly lecture and seminar. In teaching the subject, the instructor needed to explain the relationship between the circuits at various levels, including architectural, transistor and layout – and this requires interactive teaching illustrated by annotations. To perform the coursework, the students have previously used a freeware tool, which could be run on lab computers or the students' own PCs. Office hours would be announced to students and would normally be conducted through a face-to-face appointment. The timetable of the course is arranged and announced before the semester starts.

C. Module Delivery under Covid-19

Flexible methods of delivery were implemented within the VLSI content, which covered a digital integrated circuit analysis and design at the architectural, circuit and coloured layout levels. A synchronous e-learning approach was used in order to improve the effectiveness of the delivery [17-18]. This approach included the annotation of teaching material, live lectures, and one-to-one tutorials [19-21]. Three further items were added:

- A tablet (MS-Surface) was used to deliver live webinars on Zoom. Synchronous teaching was used when delivering both lectures and seminars. Digital ink helped to use the digital whiteboard smoothly and replaced the physical classroom whiteboard.
- In planning for an interactive online teaching approach, the module convenor decided to maintain the contact hours of teaching sessions as per the original timetable, though online rather than in a physical classroom.
- Informal opportunities for students to discuss modular issues ('Office hours') were arranged upon request, either through chatting by text, or using audio/video short sessions for further interactive discussion. Discussions between the module convenor and students took place privately on MS-Teams platform to enhance students' engagement and as a way of providing pastoral care.

D. Lecture preparation during the outbreak

Before the module teaching started, a page on Moodle was created for uploading the teaching material. For this particular semester, a Team specific to the module was created by the module convenor on MS-Teams. All students were enrolled in the team and the invitation was confirmed by email. All module announcements were published through both Moodle and MS-Teams, but there was more interaction on the MS- Teams platform where it was observed that students would share the announcements, comment on them and mention the module convenor and each other.

An interactive approach was deemed to be the best approach in teaching the VLSI subject. 26% of the students who attended the module were international students from 5 countries and time-zones other than that of Mainland China. Fortunately, these were all Asian countries and the time difference was no more than 2 hours. The remaining students who enrolled in the module were domestic students from across different provinces. In the first teaching week, a student rep was nominated by students to facilitate the communication among the students and the convenor. PowerPoint lecture capture was used for lecture video recording and it was found to be of a reasonable resolution because the generated video file size was not excessively large for online uploading and viewing when compared with other lecture capture software. Each lecture was split into smaller sub-files because the quality of the offsite network facilities might vary where students were located, both domestically and abroad. Each file was 10-15 minutes long and no larger than 30 MB.

The videos of each lecture together with the lecture notes were uploaded to Moodle at least one week in advance to help students prepare for the lecture. The students used their own devices and internet connections to access the teaching material and engage in the live classes. All students confirmed that they were able to watch the uploaded videos smoothly. The virtual classroom was booked on Zoom and the invitation was sent to all students through announcements on both Moodle and MS-Teams, and a meeting invitation was sent through the MS-Exchange calendar.

E. Online lecture delivery

The timetable that was announced before the COVID-19 outbreak was followed when conducting all of the teaching sessions of the spring semester. The weekly two hour lecture was maintained, with the lecture time adjusted to start one hour later than originally planned to accommodate students in all time zones. The live lecture was conducted through Zoom, benefitting from its various features such as, group and private chat, whiteboard, polls, raising hands and other features. To mitigate some internet speed issues experienced by students, the streaming was deactivated from the students' side while lecturing. Students were asked whether they had questions or comments after each topic. They were also encouraged to interrupt the lecturer when they had urgent questions. The lecture slides were annotated during the lecture using electronic ink, thus replacing the physical smartboard as shown in Figure 1. After the lecture, the annotated slides were shared with the students to help them remember the discussion during the class. The electronic whiteboard was used in each session to further illustrate some of the design issues.

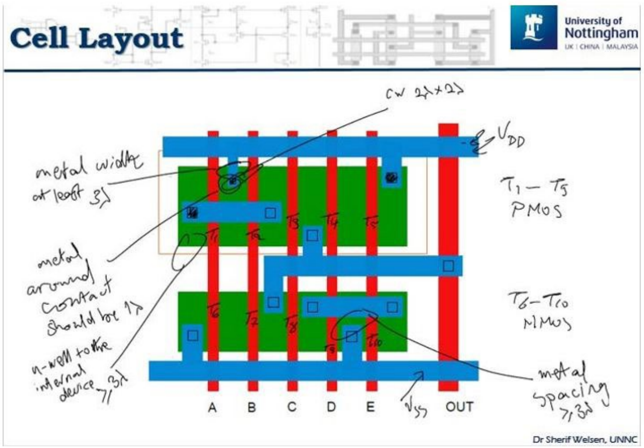

FIGURE 1 *An example of slide annotation during the online live lecture*

F. *Tutorials and problem solving*

The pre-planned timetable was also followed for delivering tutorial sessions. In addition to the official group tutorial, one-to-one tutorials were used when necessary and were deemed particularly important after the lecture sessions. Usually, few students requested the private tutorial, which was not noticeably different from face-to-face teaching. Synchronous sessions through Zoom were used for conducting tutorials in a manner similar to lectures, as opposed to using the electronic whiteboard. The tutorials were focused upon problem solving and answering questions from students. In order to increase students' engagement, problem sheets were issued as weekly quizzes that followed each lecture. Students were asked to submit the answer through MS-Teams, then during the tutorial the whole set of problems were solved in detail. After each quiz, the whiteboard view was saved and shared with students. A purposeful space was left blank on the right to give students the freedom to make their annotations, as shown in Figure 2.

FIGURE 2 *Problem solving through the electronic white board*

One-to-one tutorials were also conducted through MS-Teams and these were usually initiated by a request from students after annotating the teaching material, or even double annotating the annotated slides. Such close contact with the students seemed to be a great way of growing students' confidence because they used the tutorial not simply to ask about topics they didn't understand, but on many occasions, to emphasise what they had learnt. An example of a personal tutorial discussion topic is shown in Figure 3.

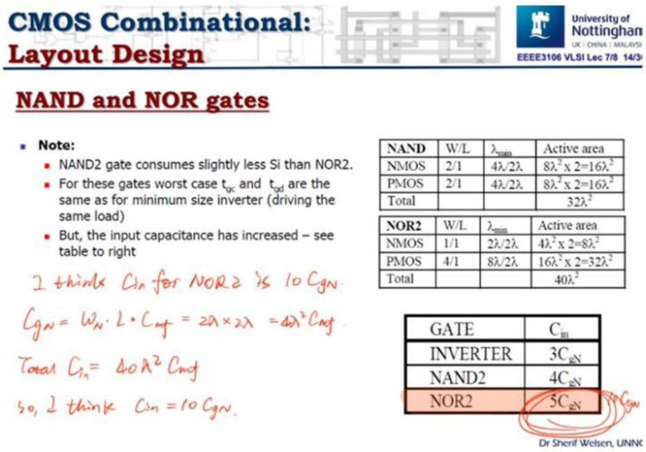

FIGURE 3 *Students' annotation of teaching material during the online one-to-one tutorial*

IV. METHODOLOGY

The current study is attempting to determine the extent to which electrical engineering students perceive various online learning tools to be useful in enhancing their sudden learning change. In this study, a questionnaire was given to all 23 students who enrolled in the module and it was completed by 16 participants. Students answered questions regarding the helpfulness of the method of teaching, the helpfulness of the teaching method and technology, student engagement and student preferences.

The invitation to participate in the survey was sent to all students as an announcement on MS-Teams, with a follow up reminder. Whilst 78% of the students who enrolled in the module responded to some of the survey questions, 69% completed the full questionnaire. The responses were analysed using simple statistics together with the responses from the open question fields to derive meaning from the results.

V. FINDINGS

The survey questionnaire responses are described in the following paragraphs.

During an intervention such as this, the investigators were interested to know if their intervention was successful. To this end students were asked:

Did you find it easy to use the online technology?

Did the online, live lectures used in this subject help you learn effectively?

The response to these questions are presented in Figure 4. Overall, students felt that they found the technology easy to use and that they perceived that the online live lectures were useful to them. When asked whether they felt this module was better or worse than other modules taken online, 8 out of the 9 gave praise for the module and students recognised the effort their lecturers used when teaching them.

This is commensurate with previous research demonstrating that students show improved engagement when they realise that their teachers have an interest in their learning [22]. Furthermore, some students offered some insight into how the method of delivery motivated them; four cited the live lectures as the reason they perceived that the current module was more effective than other online modules and gave the following comments:

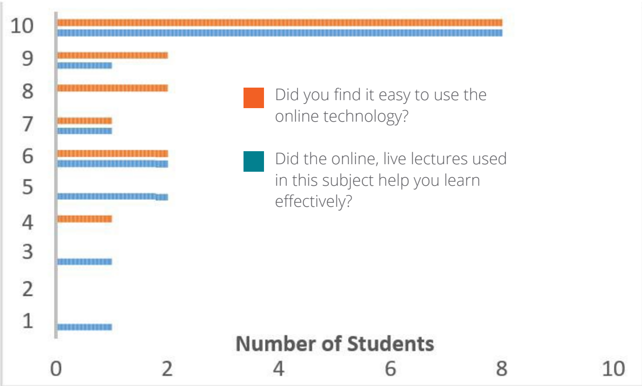

FIGURE 4 Evaluation of the Success of Online Technology and Lectures

> *I think this module is the best as it is the only module that has live online lectures.*

> *Only this module has live lectures which motives [me to] study.*

> *It has better motivation compared with other video- recorded modules.*

This useful insight perhaps offers understanding on why students become demotivated when attempting to engage with online courses and MOOCs. It is clear that the students found the real-time live lectures motivating and this is a potential avenue of investigation in future research studies on the motivation of students studying via online arrangements.

In an intervention where existing utilities were used to overcome teaching challenges, it is also interesting to investigate student perceptions of the technology that was used, so that future educators will know which resources are best to draw upon when adapting to unforeseen situations. To this end, students were asked if the annotations and whiteboard were useful, alongside asking if live lectures were better than pre-recorded lectures. The results are presented in Figure 5, which demonstrates that the teacher annotations were considered the most useful intervention in their learning. This reinforces the previous point that students felt better motivated and had improved engagement because of the live lectures. Perhaps, this behavioural trait can be explained by other work [23] which discusses the volitional nature of student learning. It is understandable that students will engage with methods that satisfy their needs and that they find useful. Furthermore, it is interesting to see that the annotations were more highly rated in this question than the comparison of live lectures with pre-recorded lectures. This suggests that simply delivering webinars will not yield the best motivational gains. It would appear that the ability for educators to annotate their slides whilst delivering online teaching is essential.

It can also be seen that students were appreciative of the adjustments that they considered useful and they applauded the online videos and the flexibility that those afforded them. This is evidenced by the answers to the question 'I recorded at least 1 live lecture on my device' which was indicated by 12 out of 16 students and had been reviewed by 10 out of those 12. This is unusually high, but not commensurate with previous research indicating that pre-recorded lectures typically have low viewing rates [24].

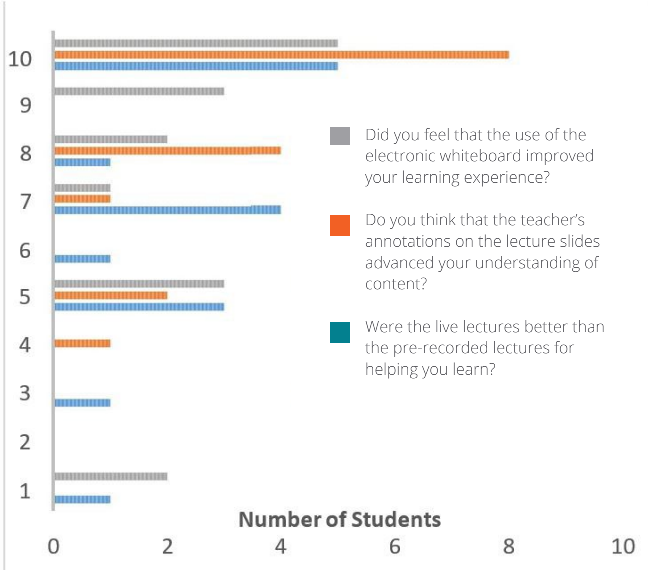

FIGURE 5 The Percieved Effectiveness of Technological Adjustments

Finally, students were asked if they would prefer to continue with online lectures as opposed to classroom lectures and if they were distracted when learning online. The responses to this question are presented in Figure 6. It can be seen that whilst students were divided on the issue of distraction, they were happy to replace face-to-face lectures with online lectures.

In conclusion, it has been seen that students are capable of making their own choices whilst learning and won't spend mental resources on activities that they perceive as wasteful. They are receptive of personalised efforts to teach them, but equally critical of one to one sessions that they perceived as low efficacy. They are receptive of efforts to increase the flexibility of their learning such as placing webinars online, but equally critical if those webinars are used as a replacement for real-time teaching. It is apparent that student perception of their needs is a critical factor in teaching and this might answer many questions concerning engagement in online education.

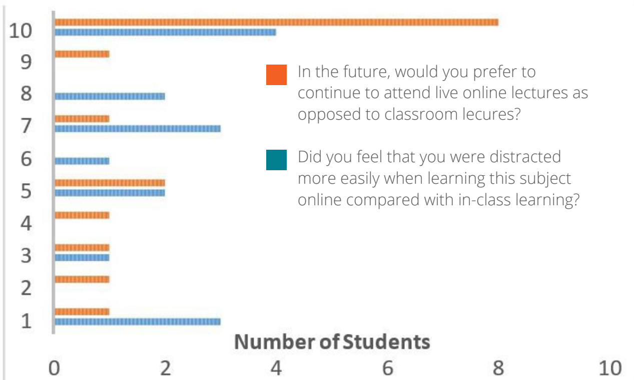

FIGURE 6 Student Preferences and Distractions

VI. CONCLUSION

The paper has outlined the learning that has come about from a series of sudden changes brought about by unpredicted circumstances. A number of tools were implemented and then evaluated in order to investigate how students have engaged with different learning situations, and the findings have suggested that students engaged well with the technologies, finding them easy to use and beneficial for their learning. In particular, slide annotations and recorded lectures appeared to be powerful tools. It certainly seems that the approach taken by the lecturers on this module has been effective and received well by the students. The findings have suggested that some technologies were more useful than others across the sample, but also that there were some differences between students regarding their preferences for the use of particular tools.

For the authors of this current work, the task of investigating why some tools and pedagogies appear to work better than others is a task that will continue: some may believe that there is some novelty value in such tools and that students' appreciation of those tools will decrease over time. Others may believe that students were sympathetic and gave inaccurately high evaluations because of the suddenness of the change and that perceptions may change over the longer term.

REFERENCES

[1] Carmel McNaught , "Using Narrative to Understand the Convergence of Distance and Campus-Based Learning During the Time of SARS in Hong Kong," Educational Media International, vol. 41:3, pp. 183-193, 2004.

[2] Huang, R.H., Liu, D.J., Tlili, A., Yang, J.F., Wang, H.H., et al., "Handbook on Facilitating Flexible Learning During Educational Disruption: The Chinese Experience in Maintaining Undisrupted Learning in COVID-19 Outbreak, Smart Learning Institute of Beijing Normal University. March 2020.

[3] World Health Organization, Novel Coronavirus(2019-nCoV), Situation Report – 11. Available at https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200131-sitrep-11- ncov.pdf?sfvrsn=de7c0f7_4 (Last accessed June 2020).

[4] WHO declares COVID-19 outbreak a pandemic. Available at https://www.who.int/dg/speeches/detail/who-director-general-s- opening-remarks-at-the-media-briefing-on-covid-19 11-march-2020 (Last accessed June 2020).

[5] Karen Smith, and John Hill, "Defining the nature of blended learning through its depiction in current research", Higher Education Research & Development, vol. 38:2, pp. 383-397. 2019.

[6] F. Rennie, and T. Morrison, E-learning and social networking handbook: Resources for higher education, Taylor & Francis, 2013.

[7] Robert A. Ellis, Paul Ginns & Leanne Piggott, "E-learning in higher education: some key aspects and their relationship to approaches to study," Higher Education Research & Development, vol. 28:3, pp. 303- 318, 2009.

[8] Yan Wang, Xuan Liu, and Zhenhong Zhang, "An overview of e-learning in China: History, challenges and opportunities," Research in Comparative and International Education, vol. 13:1, pp 195-210. March 2018.

[9] James Kariuki Njenga Louis Cyril Henry Fourie, "The myth about e- learning in higher education," British Journal of Educational Technology, vol. 41:2, pp. 199-212, February 2010.

[10] Ippakayala, Vinay Kumar, and El-Ocla, Hosam, "OLMS: Online Learning Management System for E-Learning," World Journal on Educational Technology, vol. 9, pp. 130-138. 2017.

[11] Kamal Bijlani, Jayahari, K R, and Ancy Mathew, "A-view: real-time collaborative multimedia e-learning," Proceedings of the third international ACM workshop on Multimedia technologies for distance learning, pp.13-18. December 2011.

[12] Alexander Toni Mohr, Dirk Holtbrügge, and Nicola Berg, "Learning style preferences and the perceived usefulness of e-learning," Teaching in Higher Education, vol. 17:3, pp. 309-322. 2012.

[13] Balfour, J.A.D. (2006, September 12–16). "Audio recordings of lectures as an e-learning resource," Built Environment Education Annual Conference (BEECON 2006), London 2006.

[14] Secker Jane, Bond Steve and Grussendorf Sonja "Lecture capture: rich and strange, or a dark art?," LSE Research Online (2010). Available at http://eprints.lse.ac.uk/id/eprint/29184.

[15] Taraban, R., Anderson, E.E., DeFinis, A., Brown, A.G., Weigold, A. and Sharma, M. (2007), "First Steps in Understanding Engineering Students' Growth of Conceptual and Procedural Knowledge in an Interactive Learning Context," Journal of Engineering Education, vol. 96:1, pp. 57-68. January 2013.

[16] Kebritchi, M., Lipschuetz, A., and Santiague, L. (2017), "Issues and Challenges for Teaching Successful Online Courses in Higher Education: A Literature Review," Journal of Educational Technology Systems, vol. 46:1, pp. 4–29. August 2017.

[17] Fita A., Monserrat J.F., Moltó G., Mestre E.M., and Rodriguez-Burruezo A., "Use of synchronous e-learning at university degrees, " Comput Appl Eng Educ, vol. 24:6, pp. 982-993. November 2016.

[18] Goodridge Wade H., Lawant Oenardi, Santoso Harry B., "A Learning Style Comparison between Synchronous Online and Face-to-Face Engineering Graphics Instruction," International Education Studies, vol. 10:2, pp.1-14. 2017.

[19] M. Malchow, M. Bauer and C. Meinel, "Enhance learning in a video lecture archive with annotations," 2018 IEEE Global Engineering Education Conference (EDUCON), Tenerife, pp. 849-856, 2018.

[20] Said Asnah, Syarif, Edy, "The Development of Online Tutorial Program Design Using Problem-Based Learning in Open Distance Learning System," Journal of Education and Practice, vol. 7:18, pp.222-229. 2016.

[21] S. B.R., K. M. Babu and A. Vijaykumar, "Enhanced e-Learning with Quality Enhancement in Engineering Education (QEEE) Program," 2017 5th IEEE International Conference on MOOCs, Innovation and Technology in Education (MITE), Bangalore, 2017, pp. 67-71.

[22] Skinner, E. A., & Belmont, M. J. (1993), "Motivation in the classroom: Reciprocal effects of teacher behavior and student engagement across the school year," Journal of Educational Psychology, vol. 85:4, pp. 571–58, 1993.

[23] J.J Arnett, Emerging adulthood: The winding road from the late teens through the twenties, Oxford University Press, 2004.

[24] O'Callaghan, F.V., Neumann, D.L., Jones, L. et al., "The use of lecture recordings in higher education: A review of institutional, student, and lecturer issues," Educ Inf Technol, vol. 22, pp. 399–415, 2017.

Technical Papers

Students' preferred mode of teaching: Blended vs. traditional face to face instruction

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***Abstract*—Using technology in the classroom has in most cases proven to enhance students' learning experience. There are several teaching methods a teacher may implement in the classroom, namely (a) traditional face to face teaching, (b) blended learning (face to face and incorporation of technology), (c) technology. This study was conducted to investigate if there is any link between students' pass rate/ throughput and the use of technology and to determine the mode of teaching preferred by the students. A survey, through a questionnaire was distributed to the students who have had experience with both face to face and blended mode of teaching. One module was evaluated to compare the pass rate and throughput between online and face-to-face model of teaching. A total of 33 students participated in the survey. From the responses received, it is evident that student did not have positive response on the module that relies heavily on online teaching and learning. Most of the students who participated in the study still prefer the face to face method of teaching and learning. The responses provided also shows that a majority of students believe that through the face to face method of teaching they believe their understanding of the content, pass rate, communication with peers is enhanced. The ANOVA analysis on the results also showed a significant difference between the students' responses for the two methods of teaching. In relation to the use of technology and the pass rate/throughput, there was no link deducted.**

Keywords—blended learning, face-to-face instruction, online learning, technology in the classroom

I. INTRODUCTION

The implementation of online mode of teaching and learning has increased significantly over the recent years. In the era of Fourth Industrial Revolution, many institutions have adapted to online instruction to enhance students' learning experience. The current global pandemic has forced many Higher Learning Institutions to implement online learning for teaching and learning to continue and to avoid losing the academic year. With institutions forced to go online, the greatest and most critical stakeholders in these processes are the students. Their own perception on the mode of teaching and learning and their adaption has a great impact on their own learning experiences. To improve students learning experiences and meet the diverse needs of students' satisfaction numerous technologies have emerged over the years [1]. Using a computer network to conduct teaching and learning is referred to an online instruction [2]. Blended learning is the incorporation of both online and face-to-face instruction in the classroom. It is also defined as "a thoughtful integration of classroom face-to-face learning experiences with online experiences" [3]. According to Rasheed et al. (2020), it has been proven that blending instructional materials with online interventions is considered an upgrade to both fully online mode and face-to-face traditional mode of instructions [4]. It has been reported that through blended learning, interaction between students and teachers is increased and there is a reduction on online transactional distance [5]. Ensuring value interaction and enhancement of students' engagement and the value to cater for different students are some elements associated with blending learning [6, 7]. Ref. [4], argue that with blended learning "students and teachers are automatically relocated to the online (out of face- to face sessions) component, and are therefore expected to proper self-regulate and manage their tasks using technology, and at their own pace". Four key challenges to designing a blend for blended environment have been reported and; thus, facilitation of interaction, incorporation of flexibility, fostering of learning environment that is effective and facilitation of students' learning experience and processes [8- 13].

There are several advantages associated with online instructions, such as the opportunity to reach a wider community who may not be able to attain education through the traditional based environment. Through online instruction, constraints such as time, place, and space for delivering on students learning are eliminated. There are also disadvantages such as the inability to access the online platforms due to connectivity challenges in some areas, technological illiteracy, data cost, lack of knowledge to use online tools and navigate through online learning platforms. With the advantages of online instruction, several researchers are advocating for online instruction to enriching institutions programs and instructional effectiveness [14].

This study was conducted prior the current global pandemic, to investigate the students' preferred mode of teaching. It is also important to note that the student who participated in this study are the students who were mostly taught through the traditional classroom-based mode of teaching. Adaption and transformation are some of the critical aspects that may also impact on platforms and methods of teaching and learning that students prefer.

II. METHOD

A. Survey

Third year students who were enrolled for BEng Tech participated in the study. These were students who had experienced both methods of teaching, namely blended learning and face-to-face instruction. Most of the modules were conducted through face-to-face instruction. Questionnaires with 18 questions were distributed to the participants.

B. Sampling

The targeted population was the third year students, in their final year and who have had experience with both blended and face-to-

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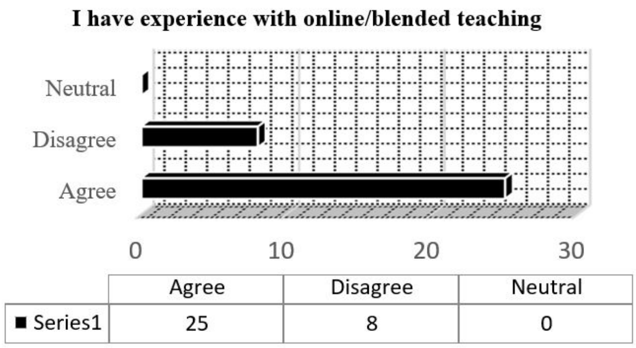
face mode of teaching. All students enrolled for the programme in their last year, were invited to participate in the study.

C. Data collection, quality control, reliability and analysis

Questionnaires were used to collect data through distribution on Blackboard. Two months was allocated to collect data. All the participants participated voluntarily. To ensure data reliability, only reliable sources were consulted in the study and only a targeted population was sent the questionnaires. Two perspectives were employed to analyze respondent's data, inferential data analysis and descriptive data analysis. After data was aggregated, categorical data was transformed to numerical representation using. Descriptive statistics, correlation tables, Excel and frequency tables, graphics were developed to describe the data gathered. To evaluate emerged 'theme' answers, the data gathered was then analyzed.

III. RESULTS AND DISCUSSION

The results obtained from the study with the theme answers are presented in Figure 1 to Figure 18.



	Agree	Disagree	Neutral
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FIGURE 1 Online/blended teaching experience

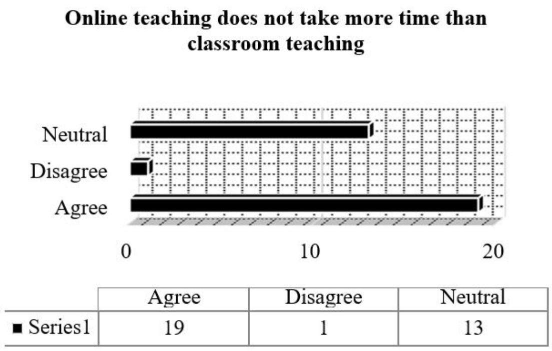

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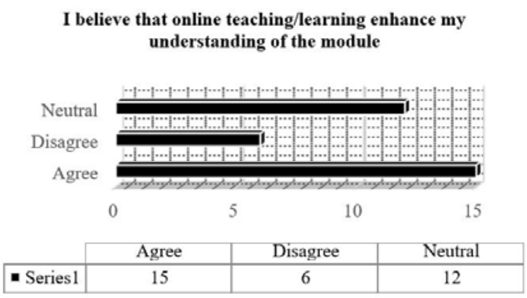
FIGURE 2 Time consumption: online vs. face-to-face instruction



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■ Series1	15	6	12

FIGURE 3 Student understanding using online instruction

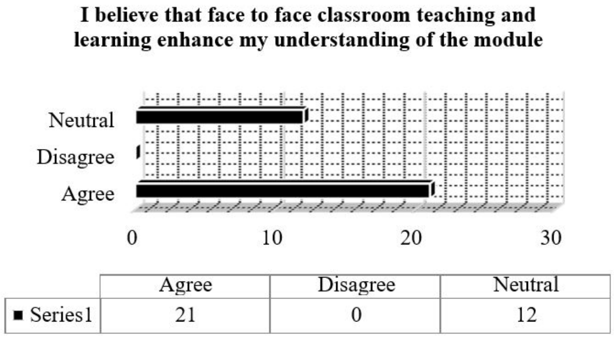

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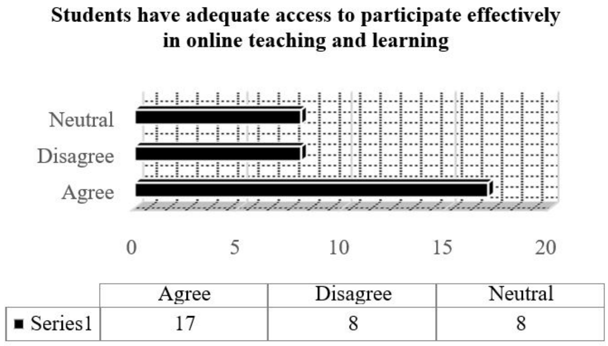
FIGURE 4 Students understanding using face-to-face instruction



	Agree	Disagree	Neutral
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FIGURE 5 Participation on online platforms

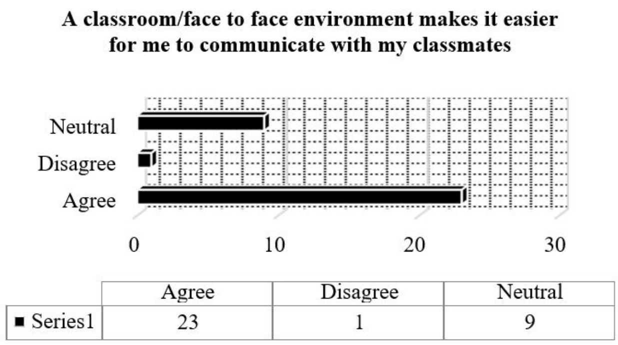

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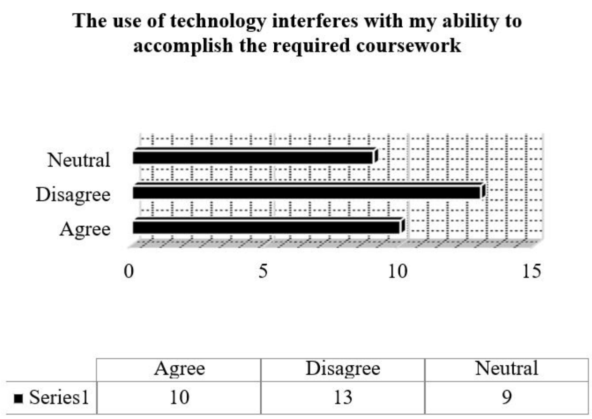
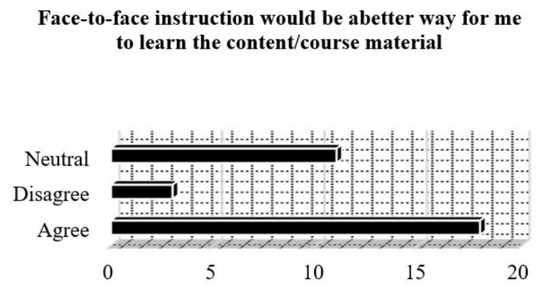
FIGURE 6 Communication with peers in classroom based setup



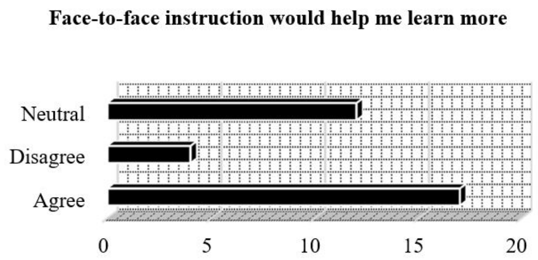
	Agree	Disagree	Neutral
■ Series1	10	13	9

FIGURE 7 Utilization of technology and accomplishing classroom activities



	Agree	Disagree	Neutral
■ Series1	18	3	11

FIGURE 8 Learning of content through face-to face instruction



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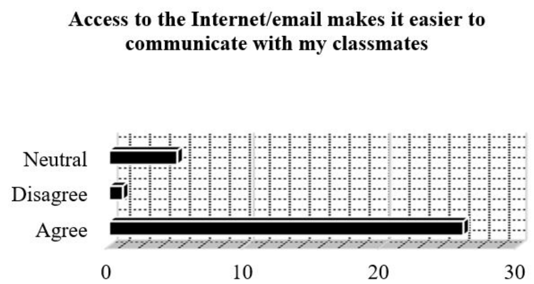
■ Series1	17	4	12

FIGURE 9 Students learning experience using face-to-face instruction



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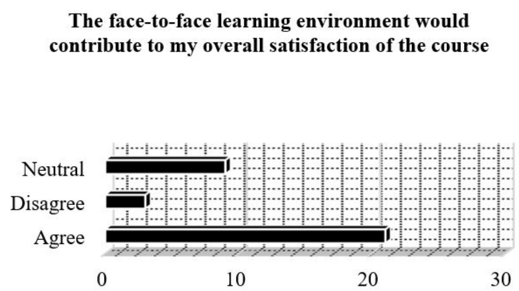
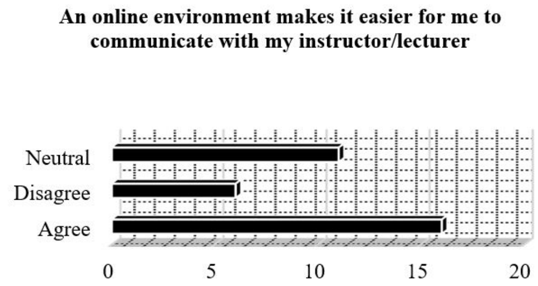
■ Series1	26	1	5

FIGURE 10 Online tools for communication between students



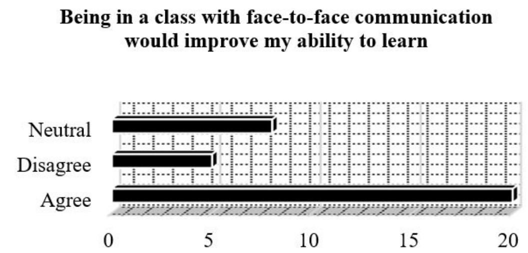
	Agree	Disagree	Neutral
■ Series1	21	3	9

FIGURE 11 Satisfaction about face-to-face instruction



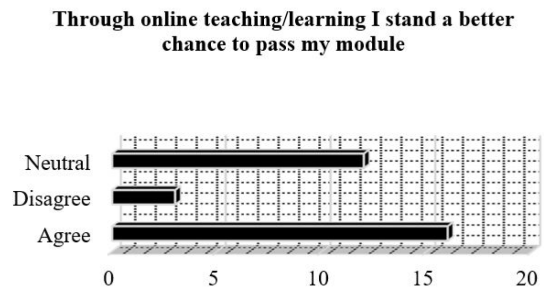
	Agree	Disagree	Neutral
■ Series1	16	6	11

FIGURE 12 Communication in the online teaching environment



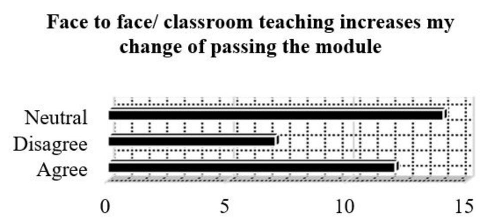
	Agree	Disagree	Neutral
■ Series1	20	5	8

FIGURE 13 Communication in the classroom based teaching environment



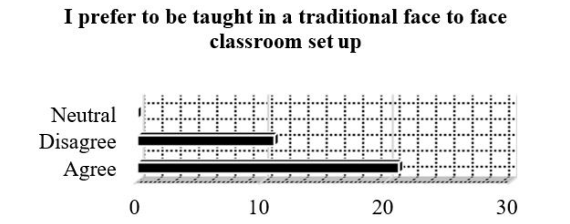
	Agree	Disagree	Neutral
■ Series1	16	3	12

FIGURE 14 Pass rate and online instruction



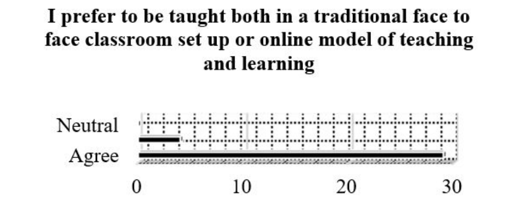
	Agree	Disagree	Neutral
■ Series1	12	7	14

FIGURE 15 Pass rate and face-to-face instruction



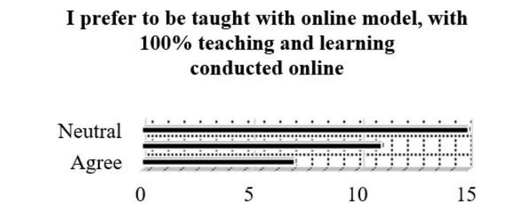
	Agree	Disagree	Neutral
■ Series1	21	11	0

FIGURE 16 *Classroom based/face-to-face instruction*



	Agree	Disagree	Neutral
■ Series1	29	4	0

FIGURE 17 *Blended mode instruction*



	Agree	Disagree	Neutral
■ Series1	7	11	15

FIGURE 18 *Online instruction*

Q.1. I have experience with online/blended teaching: There were 33 individuals who participated in the study. The results obtained showed that a majority of students had experience with online or blended teaching. 76% of the participants were exposed to blended learning.

Q2. Online teaching does not take more time than classroom teaching: Figure 2, in terms of the time taken between the two methods of teaching 56%, agreed that online teaching does not necessarily take more time.

Q3. I believe that online teaching/learning enhances my understanding of the module and Q4. I believe that online face to face classroom teaching and learning enhance my understanding of the module: From Figures 3 and 4, 45% of the participants indicated that they believed online/ blended learning instruction of teaching and learning enhanced their understanding of the module vs 64% who said the same for face to face method. For both methods, there was however a significant number of participants who were neutral 36%. 18% disagreed with the online method. Comparing Figures 3 and 4, it is clear that according to the participants, face to face method of teaching enhances students' understanding of the concept taught in the classroom.

Q5. Students have adequate access to participate effectively in online teaching and learning: In terms of the resources required for the students to participate effectively in the environment where online/blended learning is incorporated, 52% of the participants indicated that they have adequate resources required to participate online, Figure 5. 24% disagreed and 24% were neutral. 24% is a significant number and factor to be taken into consideration in the blended learning environment. This shows that 24% of the students who participated feel that they might not be prepared enough to participate in the online classroom setup.

Q6. A classroom/face to face environment makes it easier for me to communicate with my classmates: There was a significant number of participants who agreed that face to face method of teaching enhanced collaboration between their peers. 70% of the participants agreed that through the face to face method of teaching, it is easier for them to communicate with their fellow peers, Figure 6.

Q7. The use of technology interferes with my ability to accomplish the required coursework: Whether online/ blended mode of teaching interferes with students to accomplish the required course work, a majority of 39% disagreed, with 30 % agreeing, Figure 7.

Q.8. Face-to-face instruction would be a better way for me to learn the content/course materials: 55% of the participants agreed that face to face would be a better way for learning the course content, Figure 8. With 52% agreeing that the face to face method would help them learn more.

Q.9. Face-to-face instruction would help me learn more: 52% of the participants agreed that face to face learning will help them learn more, while a significant 36% were neutral and 12% disagree.

Q. 10. Access to the Internet/email makes it easier to communicate with my classmates: A majority of the participants, 81%, agreed that access to the internet makes communication easier amongst classmates.

Q. 11. An online environment makes it easier for me to communicate with my instructor/lecturer: In terms of communicating with a Lecturer or module facilitator, a majority (48%) of the participants indicated that they preferred an online environment for communication, Figure 11.

Q.12. The face-to-face learning environment would contribute to my overall satisfaction with the course: From Figure 12, 64 % of the participants agreed that face to face method of teaching contributes to the overall satisfaction of the course.

Q.13. Being in a class with face-to-face communication would improve my ability to learn: A significant 66% preference for the mode of teaching and learning is face to face, with 34% disagreeing and believe that face to face method of teaching would improve their ability to learn.

Q14. Through online teaching/learning, I stand a better chance to pass my module: 48% of the participants agreed that they stand a better chance of passing a module with online teaching. 9% disagreed and 36% were neutral..

Q.15. Face to face/ classroom teaching increases my chance of passing the module: 33% of the participants disagreed that they preferred to be taught with the online method of teaching. 21% agreed and a majority and a significant number of 45% were neutral Figure 15.

Q.16. I prefer to be taught in a traditional face to face classroom set up: 61% of the participants indicated that through face to face methods they are provided with the ability to learn in the classroom. 15% disagreed and 24% were neutral Figure 16.

Q.17. I prefer to be taught both in a traditional face to face classroom set up or online model of teaching and learning: 88% of the participants agreed that they prefer both face to face and online methods of teaching. Only 12 % disagreed, Figure 17.

Q.18. I prefer to be taught with the online model, with 100% teaching and learning conducted online: From Figure 18, only 21% agreed that they preferred 100% online method of teaching. 34% disagreed and a significant majority 47% were neutral.

Applying statistical analysis of variance (ANOVA), the significant difference on respondents' answers based on students' preference mode of teaching was studied. F value and critical F value in were evaluated. The F value can be defined as a ratio of two variances measuring the dispersion, or how far the data are scattered from the mean [15]. It is calculated by: F value = variance of the group means (Mean Square Between)/mean of the within group variances (Mean Squared Error). This is conducted from computer generated data comparing the value of variables investigated [15]. The F value and critical F value obtained was 1.6079 and 7.7086, respectively. The critical value greater than F value indicated that there was a significant difference between respondents' answers for the preferred method of teaching.

IV. CONCLUSIONS

Even though the participants in the study had experience with both face to face instruction and blended learning, most of the modules were delivered using face to face instruction. It is also worth mentioning that the study was conducted before the global pandemic and intensive online mode of instruction. The participants who were enrolled were mainly familiar to the classroom-based environment and the online learning tools were mostly used as a form of distributing the study materials and announcements but not for teaching and learning purposes. It is therefore evident that most of the participants still prefer the face to face method of teaching and learning. Many institutions have introduced blended learning as a model of instruction, the lectures should adapt to. Most of the students in the system are familiar with blended learning instruction and often apply it. With the current global pandemic, where in South Africa, 100 % online teaching was implemented in some of higher learning institutions, since March 2020, it would be of great interest to conduct a similar study to determine the students perception on the current mode of teaching. Taking into consideration the status in the higher learning sector, a similar study is underway, seeking to answer the same questions under the corvid-19 pandemic. This will also answer a question if adaption to new ways was one of the barriers for the participants to indicate face to face instruction as their preferred mode of teaching. The study underway will provide the insight to higher learning institutions to know the systems that will work to benefit students and enhance students learning experience post corivid-19.

ACKNOWLEDGMENT

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REFERENCES

[1] D.H. Lim, M.L. Morris, and V.W. Kupritz, "Online vs. blended learning: Differences in instructional outcomes and learner satisfaction," J Async Learn Network., 2007, pp.27-42.

[2] G.A. Kearsley, "Guide to Online Education," 1997. Online: http://home.sprynet.com/~gkearsley/online.htm.

[3] D.R. Garrison, and H. Kanuka, "Blended learning: Uncovering its transformative potential in higher education," Internet High Educ., 2004, pp.95–105.

[4] R.A. Rasheed, A. Kamsin, "Nor Aniza Abdullah, Challenges in the online component of blended learning: A systematic review," Comput. Educ., 2020, 103701.

[5] R. Graham, "Definition, current trends and future directions. local designs: The handbook of blended learning: Global perspectives, local design," 2006, pp.3-21.

[6] C. Dziuban, P. Moskal, and J. Hartman, "Higher education, blended learning, and the generations: Knowledge is power: No more. Elements of quality online education: Engaging communities,". Needham, MA: Sloan Center for Online Education," 2005.

[7] A. Heinze, and C. Procter, "Reflections on the use of blended learning," 2004.

[8] L.R. Halverson, C.R. Graham, K.J. Spring, J.S. Drysdale, and C.R. Henrie, "A thematic analysis of the most highly cited scholarship in the first decade of blended learning research," Internet. Higher. Educ., 2014, pp.20–34..

[9] C.R. Graham, W. Woodfield, and J.B. Harrison, "A framework for institutional adoption and implementation of blended learning in higher education," Internet. Higher. Educ., 2013, pp.4–14.

[10] W.W. Porter, and C.R. Graham, "Institutional drivers and barriers to faculty adoption of blended learning in higher education," British. J. Educ. Technol., 2016, pp.748–762.

[11] W.W. Porter, C.R. Graham, R.G. Bodily, and D.S. Sandberg, "A qualitative analysis of institutional drivers and barriers to blended learning adoption in higher education," Internet. Higher. Educ., 2016, pp.17–27.

[12] W.W. Porter, C.R. Graham, K.A. Spring and K.R. Welch, "Blended learning in higher education: Institutional adoption and implementation," Comput. Educ, 2014, pp.185–195.

[13] J. Morabito, I. Sack and A. Bhate, "Organization Modeling: Innovative Architectures for the 21st Century". Upper Saddle River, NJ: Prentice Hall, 1999.

[14] L. Bielawski, and D. Metcalf, "Blended Elearning: Integrating Knowledge, Performance Support, and Online Learning", Amherst, MA: HRD Press, 2005.

[15] T. Mashifana, F. Ntuli, and F. Okonta, "Leaching kinetics on the removal of phosphorus from waste phosphogypsum by application of shrinking core model," S. African. J. Chem. Eng., 27,2019, pp.1-6.

Technical Papers

An assessment of the students' attitudes toward engineering design and build projects

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***Abstract*—Engineering design and build projects aims at improving student ability to think and solve problem while enhancing soft skills like communication skills and teamwork. Assessing this outcome could be relatively complicated because in some instances students are being exposed to advanced engineering courses that will allow them to perform complex calculations while completing their project. It is therefore necessary to instill into students the motivation to study independently and integrate engineering concepts into practice. Solving the design problem becomes the main motivation behind self-learning that frame the context for advanced engineering courses. This happens as a result of the Problem-Based Learning approach which pushes students to acquire engineering knowledge they don't possess. This approach could raise several problem when assessing quantitatively student outcome achievement and the overall effectiveness of the course. This paper focuses on students' attitudes rather than skills. Design thinking affinities such as team work, problem solving and communication are assessed as part on an ongoing improvement plan. A survey has been developed to measure the course effectiveness. The paper aims at measuring student attitude toward engineering design. Though such instrument has been used in existing engineering education literature, the diversity of students' attitudes justify this study. The study reveals that problem-solving perception constitute the dimension that require interventions. External motivation are proposed in order to create good attitude.**

Keywords—Design and build, student attitude, problem-solving, project.

I. INTRODUCTION

Many studies suggest that the development of wide spectrum of pedagogical models have not been integrated in design courses in many engineering schools [1], [2], [3]. Various inductive teaching methods were proposed by Prince and Felder [4]. This approach consist of coaching students while they are exposed to challenging or complex real world problems until the students achieve self-learning. This is in contrast with traditional deductive technique where exposure to theoretical knowledge precede problems. The main limitation of this approach is the passivity of learners resulting in low retention rate and possible disconnect between theoretical knowledge and practical experiences.

To develop the necessary analytical and problem solving skills, Litzinger et al. [5] propose the use of Problem-Based Learning (PBL). In this approach, problem is used as starting point to build new knowledge. Students are empowered to take responsibility of their learning while the teacher facilitates the learning process. The effectiveness of PBL is demonstrated by Khalaf et al. [6] study. This study shows that students' attitudes toward problem solving improves substantially by adopting PBL irrespective of the mode of delivery categorised in three groups:

- Synchronous problem based learning: Coaching (formal teaching) is synchronised with the laboratory work;
- Asynchronous problem based learning: Coaching component is not synchronised with laboratory work;
- Pure problem based learning: there are no formal teaching taking place. The teacher facilitates learning and students are responsible of their learning.

The third year design and build course offered in the department of mechanical engineering at the University of Johannesburg adopts the latter approach. The team project lasts six months and students meet with each other. There are no didactic lectures for students registered for the course. Formal meeting are organised to facilitate experiential learning. The course is evaluated based on prototype development and written/oral presentations. Students are allowed to select team members and arrange their own meeting. Project briefs are issued to students in order to provide a short background about the problem from clients. These problems are formulated as open-ended and realistic problem that require designed solutions. Meetings with supervisors/mentors have no predetermined frequency. They are generally more frequent at the early stage of the design and gradually become less frequent.

II. MOTIVATION

Students have different attitudes toward design and build projects. As instructors, it is crucial to understand the differences to meet the diversity. Attitude is a result of beliefs and it is closely linked to student performance. Kierkegaard states that instructions truly starts when instructors become aware of the different attitudes of students toward learning and are capable to identify different approaches to influence it [7]. On the other side, making students aware of the strengths and weaknesses associated with their attitudes would improve their learning experiences. In the context of design and build project, the major outcome is to develop soft skills such as teamwork and communication while enhancing their problem solving skills. Therefore, the objective of this paper is to measure student attitude toward engineering design. Though such instrument has been used in existing engineering education literature, the diversity of students' attitudes justify this study.

III. METHODOLOGY

In this study, three core dimension describing student attitudes toward engineering design namely (1) problem-solving perception,

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(2) opinion about teamwork and (3) general views about the importance of communication were considered. This is achieved by subjecting students to 20 questions, with student registering their agreement or disagreement based on a 5-point Likert scale strongly agree, agree, neutral, disagree and strongly disagree. The survey was inspired by existing studies closely related to this study [8], [9]. The selection of Items for the survey was based on literature review, discussion with design experts and evidence of survey's test validity and reliability in studies consulted. Eight statements were used to measure problem solving perception. Student opinion about teamwork was also measured with eight question while four questions serves to assess student's views about communication. The questions were worded carefully in order to be understandable even without any exposure to engineering design concepts.

Survey questions related to problem-solving perception consist of statement such as "Only very few specially qualified people are capable of really understanding mechanical engineering design" or "Mechanical engineering design is difficult to learn". By agreeing with such statement, the students imply that the subject consider the subject as highly challenging and somewhat inaccessible. Other statements are: "I cannot learn design if the lecturer/ supervisor does not explain things well in class/during meeting" or "Achievement depends more on personal effort than on the influence of lecturer/supervisor or textbook". Such statement was meant to assess students' level of inquisitiveness and self-learning. Design projects are meant to instill into students the ability to learn by themselves and to learn by doing. Agreeing with the first statement imply that students are approaching the subject with a high level of dependency while agreement with the second statement means that students are embracing life-long learning. The rest of the questions seek to assess students' perception about personal skills, careers goals and perception about design achievements.

Opinion about teamwork was assessed with questions such as "As teammates, we are able to work through differences of opinion without damaging relationships" or "Team members seek and give each other constructive feedback". These two statements were meant to gage how students approach teammates within a group set up. A favourable response indicate that students understand the importance of teaming up in order to achieve a common goals irrespective of differences. Other statement are: "I prefer studying/ working alone" or "To understand design projects, I discuss it with friends and other students". Using these statements, this study intended to determine students' initial attitude toward fellow members. It should be noted that students are allowed to select teammates for group project. Stating that it is preferable to work alone would imply that the management of group dynamic and project was going to be challenging. The rest of the questions seek to find out students perception about group leader, views on responsibility and management within a group.
Students' views on communication was assessed with questions such as "I am confident in my writing and speaking skills" or "In order to be a good design engineer, I must have good communication skills". Assessing the students' views about this soft-skill was necessary since most of them are more inclined to problems that involves mathematics, science of engineering knowledge. It is important to establish the relevance of communication in design. Hence, a favourable response was an indication of students' consciousness about the relevance of communication.

In order to test the survey's validity with regards to the problem solving attitudes, the degree to which the authors selection of "favourable" or "unfavourable" responses were confronted with professional responses reported by Khalaf et al. [9]. A strong correlation between the responses was observed which indicate that the aptitudes and attitudes behind the success of the professionals in their respective workplace could be considered as benchmark for students considered in this survey. Two different groups of mechanical engineering students were considered. The first group consist of second year students who have been exposed to a mini group project. The second group consist of third year students who have just completed their design and build task. The responses of students were categorised in six different groups:

- Second year Problem Solving (PS);
- Second year Teamwork (T);
- Second year Communication (C);
- Third year Problem solving (PS);
- Third year Teamwork (T);
- Third year Communication (C);

IV. RESULTS AND DISCUSSIONS

The responses to the twenty survey statements in the problem solving, teamwork and communication dimension was presented on the same graph. The concept of "favourable/unfavourable) plot was based on the Maryland Physics Expectations (MPEX) survey [10]. Favourable score or percentage (%) corresponds to statements where respondents have responded as the survey creators would and vice versa. For instance, agreeing with a statement such as "Only very few specially qualified people are capable of really understanding mechanical engineering design" was "unfavourable" because the survey creators believe that all respondents are capable of understanding engineering design. No score was allocated to instances where respondents have selected neutral or have chosen not to respond. This explains why the percentage doesn't add up to 100%. The responses were distributed as illustrated in Figure 1 "Strongly agree" responses were aggregated with "agree" responses while disagreeing responses were combined for each statement.

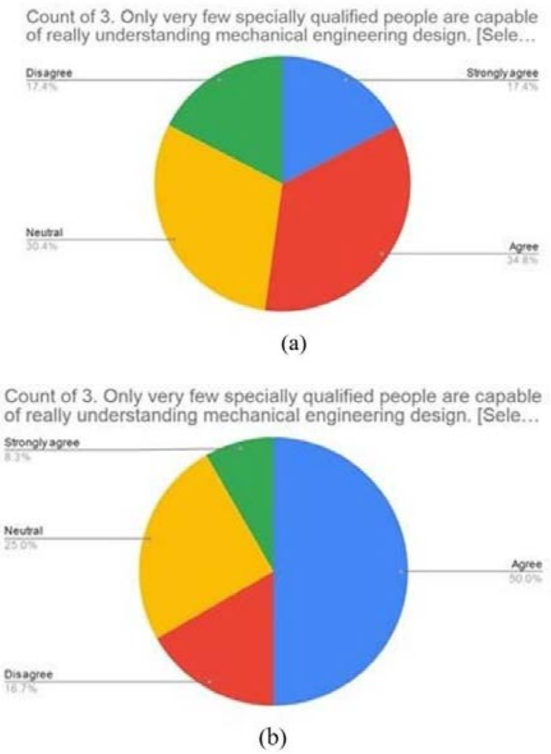

FIGURE 1 *First illustration of responses distribution (a) second year (b) third year*

Figure 2 shows the Favourable vs. unfavourable plot of the 20-statement of the survey. The average of the three section of the survey namely problem-solving, teamwork and communication was calculated. The problem solving perception is represented by a blue square (second year) and a yellow square (third year). Teamwork opinion was captured with an orange triangle (second year) and a star (third year). Communication responses is summarised with a grey diamond (second year) and a green circle (third year). Considering the 5-point Likert scale response, this paper have considered that a "favourable" response is made of two out of five possible responses for any statement. Hence, a binomial distribution of responses with probability p = 2/5 = 0.4 has been assumed. The standard deviation can be approximated as follows:

$$\sigma \approx (p(1-p)/n)^{1/2} \qquad (1)$$

Where n represents the number of statement.

The standard errors in the mean were calculated as shown in Table 1.

TABLE 1 *Standard errors in the mean*

Number of questions (n)	Standard deviation (σ)	Errors (⍰)	
		Second year class (N = 23)	Third year class (N = 24)
8	0.173	0.036	0.035
4	0.245	0.051	0.05

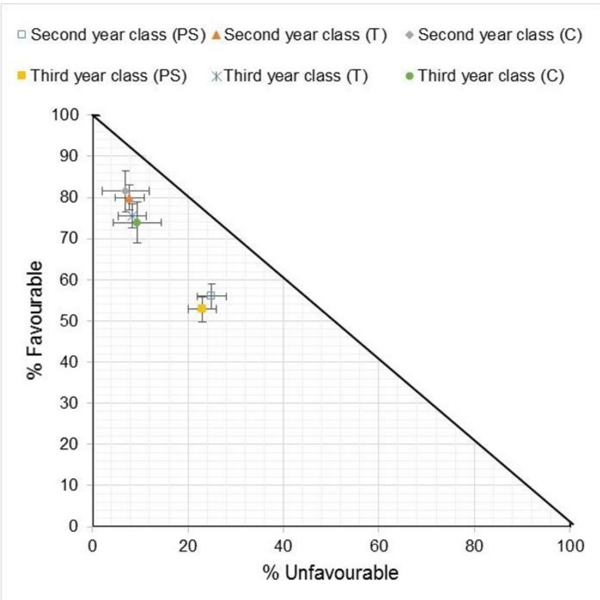

FIGURE 2 *Favorable vs. unfavorable plot for (8) problem solving (PS), (8) teamwork (T), and (4) communication (C) questions of the survey(T), and (4) communication (C) questions of the survey*

V. GENERAL OBSERVATION ON THE RESPONSES

First, the scores of the two separate groups of students were very close, practically within the error range as shown in Figure 2 Respondents who have answered all survey questions as the creator of the survey would are scored 100% favourable and 0% unfavourable which correspond to data located in the upper left-hand corner of Figure 2 Overall, considering the three dimensions namely problem solving, teamwork and communication, both group of respondents scored the most favourably for teamwork and communication (70% - 85%) as compared to problem solving (50% to 60%). The results reported in Figure 2 doesn't provide any ground to conclude the positive impact of the design and build course on students in term of shaping up their beliefs about problem solving practices as they progress from the second to the third year. The results shows consistency between the two separate groups of students.

In order to further analyze the findings, they have been two statements that could be highlighted and further analyzed from the responses obtained from the survey. The first statement is shown in Figure 1 (Only very few specially qualified people are capable of really understanding mechanical engineering design). The responses distribution shows that 52.2% and 58.3% of students in the second year and third year respectively agree with statement while 17.4% and 16.7% disagree. With this response, students imply that mechanical engineering design requires to be highly "qualified". It is necessary to understand how this specific students' attitude was formed and if it could be changed. Oroujlou and Vahedi [11] point out that because attitude is learned, it can be unlearned to raise proficiency of efficiency of students. They suggest that instructors must find ways to connect to the learners' passion because successful learning is linked to it. The second statement is illustrated in Figure 3 (I cannot learn design if the lecturer/supervisor does not explain things well in class/during meeting). The responses show that 52.1% and 33.4% of students in the second year and third year respectively agree with the statement while 39.1% and 29.2% disagree. It was interesting to note that as students are progressing from the second to the third year, they believe more in their ability to learn by themselves. This attitude is should be expected as suggested the study conducted by Khalaf et al. [9] which stipulated that design problems should become the motivator for self-learning. However, the wording or the vocabulary used in the statement might not have been clear enough. In addition, the current mode of delivery of mechanical engineering design in the second year rely heavily on lecture-based instructions. This might explain the stance of the students' responses. The transition from this mode of delivery to a pure problem-based-learning (PBL) improves students' attitudes toward design problem solving as suggested by the responses of third year students who have completed the project.

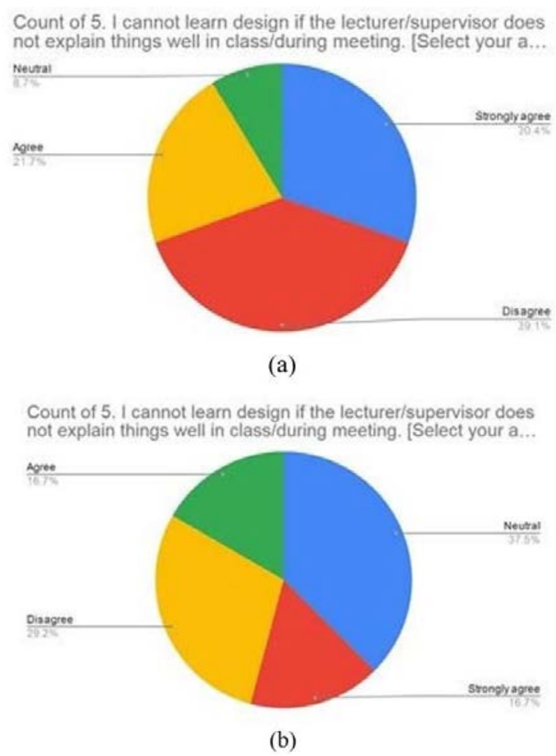

FIGURE 3 *Second illustration of responses distribution (a) second year (b) third year*

A sensitivity analysis was performed to measure the influence of the two questions mentioned in the previous section. Figure 4 shows the Favorable vs. Unfavorable plot for the problem solving (PS) questions. The designations second year class (PS) 2 and third year class (PS) 2 refer to the responses corresponding to the analysis with the survey questions made of six questions. This result shows an improvement toward expert-like attitudes by overlooking the two questions described in the previous section. The wording of questions in future surveys would be refined accordingly.

Because students' poor attitude toward learning is not new, a number of interventions could be implemented to change the perception. A study conducted by Oroujlou and Vahedi [11] (2011) proposes effective strategies that requires external motivation in order to create good attitude which can be customized using two short statement:

- Build situations that promote students' sense of accomplishment: reinforcing sense of accomplishment through positive feedback would improve students' attitude toward learning outcomes, enhance students' competence, self- esteem and self-confidence. This doesn't discard necessary corrections that are meant to provide clear explanations that appreciate good work and encourages;
- Setting short term goals: design project are meant for students to learn by doing. Irrespective of the goals students set up for themselves, it is necessary to encourage them to pursue them. These short term goals would increase motivations and lead to higher level of competence;

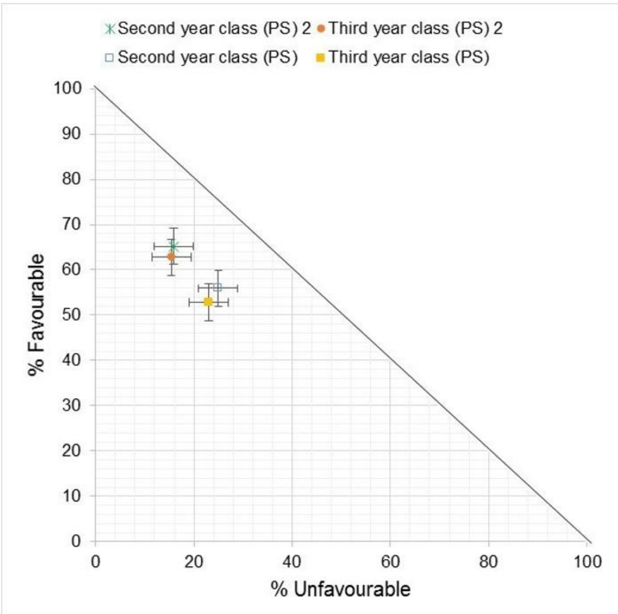

FIGURE 4 *Favorable vs. unfavorable plot for the problem solving (PS) questions*

VI. CONCLUSION

In this paper, three core dimension describing student attitudes toward engineering design namely (1) problem- solving perception, (2) opinion about teamwork and (3) general views about the importance of communication have been analysed. Two different groups of mechanical engineering students were considered. The first group had not been exposed to design and build project while the second group had. Overall, considering the three dimensions, both groups of respondents scored the most favourably for teamwork and communication (70% - 85%). Problem solving scores were the poorest with 50% to 60% favourable responses. Based on the finding resulting from the survey conducted in this study, students' attitude constitute one of the factors that is affecting their performance with design and build project. The study reveals that problem-solving perception constitute the dimension that require interventions. As was forward, it is necessary implement effective strategies that will enhance learners' external motivation and create good attitudes toward engineering design. These interventions consist of building situations that promote students' sense of accomplishment and setting short term goals that enhance competence.

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REFERENCES

[1] R. M. Marra, B. Palmer and T. A. Litzinger, "The effects of a first year engineering design course on student intellectual development as measured by the Perry scheme.," Journal of Engineering Education,, vol. 89, no. 1, pp. 39-45, 2000.

[2] C. Romero-Piedrahita, L. Vanegas-Useche and M. Díaz-Rodríguez, "Pedagogical strategies for enhancing machine design teaching in a mechanical technology programme.," Revista UIS Ingenierías, vol. 18, no. 3, pp. 15-26, 2019.

[3] D. Scaravetti and D. Doroszewski, "Augmented Reality experiment in higher education, for complex system appropriation in mechanical design.," Procedia CIRP,, vol. 84, pp. 197-202, 2019.

[4] M. J. Prince and R. M. Felder, "Inductive teaching and learning methods: Definitions, comparisons, and research bases.," Journal of engineering education,, vol. 95, no. 2, pp. 123-138, 2006.

[5] T. Litzinger, L. R. Lattuca, R. Hadgraft and W. Newstetter, "Engineering education and the development of expertise.," Journal of Engineering Education, vol. 100, no. 1, pp. 123-150, 2011.

[6] K. Khalaf, S. Balawi, G. W. Hitt and M. A. Siddiqi, "Engineering design education: Effect of mode of delivery.," International Journal of Engineering Pedagogy (iJEP), vol. 3, no. S2, pp. 46-53, 2013b.

[7] R. M. Felder and R. Brent, "Understanding student differences.,"Journal ofengineering education,, vol. 94, no. 1, pp. 57-72, 2005.

[8] K. Khalaf, S. Balawi, G. W. Hitt and A. Radaideh, "Freshman engineering design: A new model content and pedagogy.," in Proceedings of the 2012 IEEE Global Engineering Education Conference (EDUCON) IEEE, Marrakesh, Morocco, 2012, April.

[9] K. Khalaf, S. Balawi, G. W. Hitt and A. Radaideh, "Engineering design education: When, what, how.," Advances in Engineering Education,, vol. 3, no. 5, pp. 1-31, 2013a.

[10] E. F. Redish, J. M. Saul and R. N. Steinberg, "Student expectations in introductory physics," American Journal of Physics, vol. 66, no. 3, pp. 212-224, 1998.

[11] N. Oroujlou and M. Vahedi, "Motivation, attitude, and language learning." Procedia-Social and Behavioral Sciences, vol. 29, pp.994-1000, 2011.

Technical Papers

An exploratory study of student and industry professional's knowledge of sustainability in curriculum development

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Abstract—**Despite the increasing awareness that sustainability is an issue needing ongoing attention, and many a times financial investments into it. Previous research has found that university students primarily have a unidimensional understanding of what sustainability comprises in the clothing and textile sector. The current paper sought to understand the depth of students' as well as industry professional's knowledge of sustainability and the implications for inclusion within the university curriculum. A sample of 93 participants from two different universities in South Africa participated in the survey. The survey assessed participant's depth of knowledge and understanding of sustainable practices. The findings highlight that both students and professionals had a basic understanding of sustainable practices and their responses will provide the foundation for incorporating sustainability into the curriculum. This study is a first attempt to investigate the inclusion of sustainable clothing and textile practices into the curriculum for implementation into South African universities from NQF level 5 to NQF level 7.**

Keywords—Sustainability, curriculum, clothing and textile, South Africa, cleaner production practices

I. INTRODUCTION

University students today were born in the fast fashion era, which produces cheap, often poorly made, and trendy apparel. As a result, many students may not readily understand components of high-quality clothing or the type of textile it is made from (e.g. silk lining, better cotton initiative, durable stitching, etc.).The availability of clothing at different quality levels with similar appearances has had interesting implications for the industry [1]. Understanding the implications of fast fashion is vital for current and future professionals who work in the clothing and textile sectors. Therefore, the topic of sustainability is gaining global attention where it has become a ubiquitous term in teaching and learning institutions. Sustainability-focused curriculum concentrates on increasing students' knowledge of sustainable practices and engagement in sustainable consumer behaviour. However, despite the growing knowledge of sustainable initiatives on university campuses over the last decade, a review of the research on this topic reveals that student awareness has become somewhat stagnant [2]. What the student perceives and learns in an institution of learning is what they bring into the work environment as their learning hence, it was also important to investigate what industry professionals feel and know about sustainability. Therefore, the purpose of this research is to understand how the current students at two different universities in South Africa conceptualize sustainability and how future educational initiatives need to be reframed to incorporate this into the curriculum design. This also alludes to the United Nations Sustainable Development Goals of Quality Education [3] and [12] Responsible consumption and production on the African continent

II. LITERATURE

A. *Sustainability defined*

A more specific definition of sustainability is a list of behaviour, that encompass what it means to be sustainable, such as the use of renewable energy sources, conservation, recycling, environmentally friendly land development, efficient water management, a proper waste disposal [4]. A widely applied definition perceives sustainability as the intersection or overlap of the triad of economic, social, and environmental considerations [5, 6, 7, 8, 9].

B. *Student's sustainability knowledge*

Despite the focus on and around sustainability amongst, students' the core knowledge of sustainability appears to have evolved little over time. Faculty researchers report "that even after having coursework that covered the topic sustainability, responses from students were not even close to the ideal understanding of sustainability". Hiller and Kozae [10] mention that students' knowledge of social and environmental issues did improve after taking a course on globalization and understanding the clothing and textile industry. Furthermore, Emanuel and Adams [4] found that one-third indicated that they do not know much about sustainability. In addition, Savageau [11] reports that the majority of students, when confronted with issues of sustainability, find them distant, impersonal or overwhelming and therefore, gave very little thought to it. These findings from various universities, mentioned above, highlight that students need to be aware of what sustainability means or how to lead sustainable lives.

C. *Sustainability in the engineering education research*

Studies focusing on the sustainability content of the engineering programmes that have emerged in the literature. Beringer [12] assessed the status of sustainability efforts in Higher Education Institutions. The research examined the level of sustainability integration covering curriculum amongst others that found few deficiencies. Watson [13] carried similar research in an engineering curriculum and found a disproportionate spread of sustainability in the curriculum [14, 15, 16, 17, and 18]. Seeking answers to the questions around competencies, pedagogy and curriculum in relation to sustainability in engineering education, Coral [19] conducted research in some of the European higher education institutions. Coral study analysed educational processes to attain

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sustainability learning amongst engineering graduates [19]. Nonetheless, the study found strong evidence of sustainability in the European engineering curriculum.

In the African context, research and studies on sustainability content within the engineering curriculum is very scant [20, 21,17]. Manteaw argues that notwithstanding the UN-backed Mainstreaming Environmental Sustainability in African Universities, there is not much visible sustainability education programmes. The studies that have considered sustainability have generally reported a low sustainability presence in the curriculum [22, 23, 24]. In contrast, initiatives on sustainability, in South Africa, has permeated the teaching and learning, curriculum and in academic research. However, the concept and application of sustainability is multifaceted and that sustainability issues has to be incorporated into the curriculum in academia in South Africa [25, 26]. On identifying the gaps and the limited reported research conducted in the clothing and textile discipline, the authors of this paper, further validated and confirmed the need for sustainability within the curriculum, focusing on both the students and the industry professional's perspective, as the industry is the future employer of students entering the workplace.

III. METHODOLOGY

The sampling for this study included a combination of engineering students and professionals from the industry. The age group of the students ranged from 18 to 23 years and the industry 30 to 65 years old. The sample of students were from two universities based in Cape Town and Johannesburg respectively. The professionals were predominantly based in Cape Town. There were a total of 93 participants that completed the questionnaire. The questionnaire consisted of 11 questions, including a combination of qualitative and quantitative paradigms. It consisted of closed, open-ended and descriptive type questions which included five point rating scales from 1 (strongly disagree) to 5 (strongly disagree), standard demographic measures, sustainable apparel purchasing behaviour, etc. Student responses were collected in a time-span of three to four weeks across both the universities and industry personnel. To facilitate the documentation of individual student responses and behaviour, the students were asked to mention the level of the qualification they were registered in. However, the anonymity of the student responses were maintained at all times, where they were not expected to share their names or any other personal details.

IV. FINDINGS

The sample cohort consisted of 12 male and 81 female South Africans of which 45 were African, 17 Coloured, 7 Indian and 26 White. 23.5% were married, 74.2% single and 2.3% did not indicate their marital status. The sample was further sorted into the two categories of students enrolled into the undergraduate qualification from 1st to 3rd year (60.3%) and participants from the industry sector (39.7%). The study asked participants various aspects of their understanding of sustainability in the clothing and textile sector within the engineering curriculum. This to obtain feedback from students and the industry participants on how they view sustainability and the need to include it into the development of a teaching module on sustainably within the clothing and textile disciplines in engineering.

The responses were analysed using descriptive statistics and presented into four broad categories of (A) Understanding of Sustainability, (B) Purchasing Behaviour, (C) Roles and Responsibilities (D) Sustainability Post COVID-19 and (E) Concepts to consider in the coursework development.

A. Understanding of sustainability

The participants responses to the "Understanding of "sustainability" when applied to clothing or fabric or material" show that there were no two responses that were worded alike however the general words such as, 16 responded with the words "environment", whilst 2 responded with the word "re- use", 13 responded with words "sustainable production", 4 responded with word "recycle", 3 responded with "eco- friendly" 1 responded with "pollution", 2 responded with "human", 2 responded with "waste" life-long", "benefits the society" and the balance of the responses support the general themes of sustainability. The responses show that the participants are aware of and understand the key words/ concepts in the narrative that define "sustainability" both within the student cohort and by the industry.

B. Purchasing Behaviour

The respondent were asked two questions under the theme. 30 students answered "Yes" to the questions *"When you purchase clothing in retail stores, do you look to see if either the garment has a label on it that states that it is produced using organic cotton or wool, and if it has an eco-label attached to it?"* whilst, 16 students answered "No" and 14 responded 'Maybe." For those that answered "Yes" the common response used words such as the "not environmentally harmful", and "Maybe" "if it is reasonably priced" and "eco-friendly garments are more expensive", whilst 24 of the industry participants answered "Yes" and 8 "Maybe" The responses show that the participants are not only aware but are also conscious buyers who choose sustainable products wisely.

16 students responded "No" to the question *"If the garment has an eco-label attached to it and it is more expensive than a similar garment, which garment would you buy and why* although they mentioned of being aware of the stores such as Woolworths, Timberland, and H &M, whilst 14 reported "maybe" and 30 mentioned "Yes". Those that answered "maybe" mentioned that they are aware of the stores such as Woolworths, Cotton-on, Truworths, Pep, Mr Price, Cape Union Mart and H&M and those that that answered Yes, mentioned Woolworths, Zara, H&M, Foschini and Edgars. The industry respondents chose the same retailers as the students. This then indicates that these are possibly the only stores that report sustainable initiatives or at least awareness of sustainable initiatives in the form of marketing or advertising in South Africa.

C. Roles and Responsibilities

The students and industry participants were provided with options. 58.9% chose the national governmental, whilst 19.2% chose all of the above, i.e. companies, producer associations, the customer, and non-governmental organisations when responding to the question on *"Who is responsible for ensuring that eco-friendly production methods are implemented into the clothing and textile industries?"* Therefore it means that the participants expect the government to consider sustainable initiatives within clothing and textiles and implement more awareness among people.

In response to the question on *"Choose one concept listed below that best describes what you understand by sustainable production in the product stage within the clothing and textile sector."* 20 % of the student choice either (a. Reducing environmental, health or safety impacts along the product life cycle. b. Ensuring more eco- and cost efficient design, raw material extraction, manufacturing, use and disposal. c. Not sure) or (a) and (c). The majority 45% chose (b) and 14% (a), whilst 3.3% were unsure. The industry participants (72.8%) chose (a), whilst 21.2% chose (c) and 6.1% (a). This shows the students understand along with industry professionals understand the role of sustainable manufacturing.

In this section the respondents answered four questions:

C.1 *"In the product stage, choose an option listed below of which section is responsible for this activity mentioned above.*
45% chose "ensuring more eco-friendly and cost efficient design and use of raw material. The students and the industry participants i.e. 57% and 42.4% respectively, chose "the Manufacturers", 27% of the students and 45.5% industry participants choose "the retailers", whilst 15% of the student and 12.1% chose "the designers" whilst the balance 1 % of the students "did not know". This says that the students need a better understanding of sustainability in clothing and textiles and the key role players involved.

C.2 *"In the product stage, choose an option listed below, of which section is responsible for this activity mentioned".*
6.7% of the students thought that the Designers, Manufacturers and the Retailers are all responsible for implementing sustainable production at the product stage, whilst 13.3% responded the Manufacturer. The industry responded that the Retailers (45.5%) followed by the Manufacturers (42.4%) and the Designers (12.1%) are responsible for implementing sustainable production at the product stage.

C.3 *"Choose one concept listed below that best describes what you understand about cleaner production in the services stage."*
The respondents were provided with three option to choose from. 73.3% of the student chose all the options whilst 18.3% chose "incorporating a preventive environmental strategy into the design of services" whilst 8.3% chose "incorporating a preventive environmental strategy into the delivery of services. The industry respondents thought that delivery of services ranked higher than that of the students.

C.4 *"In your own words, list some of the benefits of applying sustainable product principles in the processing, production, and services to you, i.e. the customer."*
The majority of the student and industry respondents used the word "environment" such as "Longevity of the products, a sustainable environment and a customer who will recycle rather than disposing old garments." and "Safe environment for the customer and safe to wear products", second most used word is "sustainable" such as "I think if the demand for sustainable items grow, it would definitely become more accessible and affordable for customers" and "Reduces carbon emissions, creates a market for more companies to be sustainable, reduces waste." Therefore, one can summarize that students related sustainability with safe environment, waste management, etc.

D. Sustainability Post COVID-19

Responses to the question *"In your opinion, how do you think that the corona (COVID 19) virus will affect the sustainability of clothing and textile industry in the future?"* is listed below.

"As it has forced us to work from home, it assisted the push towards virtual which would have slightly less of an impact on the environment, however wrt production it caused delays on full production, full working capacities and costs are shooting up;" "There will be more focus on staying afloat than on sustainability;" "Don't know;" "Hopefully more thought will go into producing clothing, from the farming, designing and the whole chain involved;" "Due to the lockdown, many companies have closed already as demand decreases;" "People are unsure of the future, new clothing is not a priority;" Manufacturers and retailers will suffer huge losses;" and "Consumers will be cash strapped and will look for better value over eco product, sales volumes could reduce resulting in reduced purchasing power and factory and mill closure and retrenchments."

Therefore, overall the respondents are aware and had an indication of the impact of the pandemic on the clothing and textile industry. Hence,the curriculum should also focus on eco-products, upcycling and reuse as the way forward.

E. Concepts to consider in the coursework development

The following were a set of the responses from the students and industry participants in response to the question *"Any other information or comments that you would like the researchers to consider during the development of the coursework for sustainability in the clothing/textile sector."*

> "Ways in which they can make people understand about sustainability because where I stay I can say 90% of people especially the youth they are not aware about it."
>
> "They need to come up with ways of prohibiting companies from dumping their waste in landfills that is contaminating under-ground water, ways to purify water tarnished by dyes from dye houses."
>
> "Nothing."
>
> "Laws that force suppliers to adhere to ethical sourcing and pipeline traceability."
>
> "South Africa should learn to have their own textile companies so that they don't have to worry about future pandemics."

Therefore, in conclusion, the students and industry felt there needs for sustainability education and in waste management not just to bring it into daily use but also to be at par in the global market both in terms of knowledge and product development.

V. CONCLUSION

This study forms the foundation of providing key skills to the sustainability module development for the Clothing and Textile industry. The responses show that the participants are aware of and understand the fundamentals and the key words/concepts in the narrative that define "sustainability" both within the student cohort and by the industry participants. From the responses to the questions, it is apparent that the knowledge gaps and understanding of sustainability between the students and the industry participants are analogous. Even though there are a number of definitions to sustainability in the literature it however, is industry-specific. The curriculum development should reflect this as the industry participants are the current "drivers" of sustainable initiatives in the industry. The sustainable lifestyle choices of the current generation are not limited to environmental protection but also towards a social, environmental and economic aspect.

This analysis may not be at the level of a longitudinal study. The authors believe that the results of this study when placed in the context of prior research findings, indicates a larger issue surrounding students' understanding and adoption of sustainability. The multidimensional approach of sustainability practices requires an approach that raises the student's awareness of the pertinent issues that they need to know and apply. Issues such as the manufacturing processes, conserving raw material, water and energy, eliminating toxic raw materials, reducing the quantity of all emissions and waste at the source. In textile and clothing products to reduce the environmental impact throughout the entire life-cycle of the product that will involve both product and process engineering and in the upcycling and reuse of apparel items. Unless communication is initiated amongst students, and between students and educators and the industry sector on a regular basis, it will be difficult to educate the future citizens of the world who will be the caretakers of society, the goal of a sustainable planet will never be achieved, more especially in the clothing and textile sector if it is not driven collaboratively by academia and the industry.

VI. RECOMMENDATIONS FOR FUTURE RESEARCH

Studying a broader sample across different universities in South Africa could further assess the changes in students' knowledge and purchasing behaviors. Additional research should continue to examine these variables, utilizing samples representing males and females, as well as diverse disciplines and institutions. Future research should explore assessment of environmental knowledge. and additional research on the methods for encouraging greater sustainable apparel- purchasing behavior such as peer pressure may motivate the students to act more sustainably.

REFERENCES

[1] Saiki, D., and Adomaitis, A, D., 2017, Stimulating learning about textiles with fast fashion in urban and rural settings, International Journal of Fashion Design, Technology and Education, 10 (3), 363- 371.

[2] Perrault, E. K., and Clark, S, K., 2017, Sustainability in the university students' mind: are university endorsements, financial support, and programs making a difference? Journal of Geoscience Education, 65, 194-202.

[3] Anon., 2015, Sustainable Development Goals/UNDP in South Africa. Available at: http://www.za.undp.org/content/south_africa/en/home/sustainable. [Accessed 20/8/2020]

[4] Emanuel, R, and Adams, J, N., 2011, College students perceptions of campus sustainability. International Journal of Sustainability in Higher Education, 12, 79-92.

[5] Barbier, E, B., 1987, The concept of sustainable economic development. Environmental conservation, 14 (2), 101-110.

[6] Lozano, R., 2008, Envisioning sustainability three-dimensionally. Journal of Cleaner Production, 16(17), 1838-1846.

[7] Sheth, J, N., Sethia, N, K., and Srinivas, S., 2011, Mindful consumption: A consumer-centric approach to sustainability. Journal of the academy of marketing science, 39, 21-39.

[8] Goworek, H., Oxborrow, L., Claxton, S., McLaren, S., Copper, T., and Hill, H. 2018, Managing sustainability in the fashion business: challenges in product development for clothing longevity in the UK. Journal of Business Research, 117, 629-641.

[9] Wang, C., Ghadimi, P., Lim, M, K., Tseng, M., 2019, A literature review of sustainable consumption and production: A comparative analysis in developed and developing economies, Journal of Cleaner Production, 206, 741-754.

[10] Hiller Connell, K, Y., and Kozae, J, M., 2012, Sustainability knowledge and behaviours of apparel and textile undergraduates. International Journal of Sustainability in Higher Education, 12, 79-92.

[11] Savageau, A, E., 2013, Let's get personal: Making sustainability tangible to students, International Journal of Sustainability in Higher Education, 14(1), 15-24.

[12] Beringer, A., Wright, T., and Malone, L., 2008, Sustainability in higher education in Atlantic Canada, International Journal of Sustainability in Higher Education, 9(1), 48-67.

[13] Watson, M, K., 2013, Assessment and improvement of sustainability education in civil and environmental engineering, PhD Thesis, Georgia Institute of Technology.

[14] Byrne, E., Desha, C., Fitzpatrick, J., and Hargroves, K., 2010, Engineering education for sustainable development: a review of international progress, 3rd International Symposium for Engineering Education, Cork, p.42.

[15] Shields, D., Verga, F., and Blengini, G, A., 2014, Incorporating sustainability in engineering education: adapting current practices to mining and petroleum engineering education, International Journal of Sustainability in Higher Education, 15(4), 390-403.

[16] Sivapalan, S., 2015, Engineering education for sustainable development for undergraduate engineering programmes in Malaysia: A stakeholder defined framework, The university of Nottingham, Nottingham.

[17] Akeel, U, U., Bell, S., and Mitchell, J., 2019, Assessing the sustainability content of the Nigerian engineering curriculum, International Journal of Sustainability in Higher Education, 20(4), 590- 613.

[18] Qu, Z., Huang, H., and Zhou, Z., 2020, Applying sustainability into engineering curriculum under the background of "new engineering education" (NEE), International Journal of Sustainability in Higher Education, Vol. ahead-of-print No. ahead-of- print. https://doi.org/10.1108/IJSHE-11-2019-0342

[19] Coral, J, S., 2009, Engineering education for a sustainable future, Technical university of Catalonia, Catalonia.

[20] Manteaw, O, O., 2012, Education for sustainable development in Africa: the search for pedagogical logic, International Journal of Educational Development, 32(3), 376-383.

[21] Akeel, U., Bell, S., and Mitchell, J., 2017, Engineering and sustainability education in Nigeria, in Quadrado, J., Bernardino, J., and Rocha, J., (Eds), Proceedings of the 45th SEFI Annual conference 2017 Education excellence for sustainability, SEFI 2017, ISEP SEFI, Azores.

[22] UNEP-MESA, 2009, Supporting universities to respond to environmental sustainable development and climate change challenges, Publishing services section UNON Nairobi, Nairobi, p.74.

[23] Buckler, C., and Creech, H., 2014, Shaping the future we want, UNESCO, Paris, doi: 10.5363/tits.11.4_46.

[24] Etse, D., and Ingley, C., 2016, Higher education curriculum for sustainability: course contents analyses of purchasing and management programme of polytechnics in Ghana, International Journal of Sustainability in Higher Education, 17(2), 269-280.

[25] Meda, L., and Swart, A., 2017, Analysing learning outcomes in an electrical engineering curriculum using illustrative verbs derived from Bloom's Taxonomy, European Journal of Engineering Education, 43(3), 399-412.

[26] Nyemba, W., Carter, K., Mbohwa, C., and Chinguwa, S., 2019, A systems thinking approach to collaborations for capacity building and sustainability in engineering education, Procedia Manufacturing, 33, 732 – 739.

Technical Papers

Understanding the role that non-academic factors play on students' experience during the COVID-19 pandemic

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***Abstract*—The outbreak of COVID-19 has forced universities across the USA to close their campuses and quickly transition their classes to an online format. The pandemic caused many students to lose income, health care access and connection to their friends. This paper analyses the role that non-academic factors played on students experience in an aerospace engineering department at a public, Hispanic serving institution during the initial outbreak of the COVID-19 pandemic. The results show that the pandemic is impacting vulnerable groups of students the most, therefore worsening an already existing equity gap.**

Keywords—COVID-19, pandemic, engineering, non-academic factors, aerospace, equity gaps

I. INTRODUCTION

The fast spread of the COVID-19 pandemic has created a national emergency in the U.S., with most higher education institutions canceling in-person classes and moving to online- only instruction in March 2020 for the remainder of the Spring 2020 semester [1]. In the author's university, the transition to online-only instruction was very rapid, and students and faculties were given a week notice about the change. This requirement meant that faculty changed their teaching practices from in person to online very quickly, and students had to rapidly adapt to the situation mid-semester. Many students were required to leave in-campus housing, and moved back with their family.

Before the coronavirus pandemic of 2020, research has shown that non-academic factors play a substantial role in post-secondary students' retention and performance [7]. The major factors that affect students' retention and performance are: level of commitment to obtaining a degree, level of academic self- confidence, academic skills such as time management skills, study skills, study habits, level of academic and social integration into the institution, socioeconomic status and social involvement. Lotkowski et al. [7] indicate that different factors affect retention and performance differently; students' retention is mostly affected by academic-related skills, academic self-confidence, and academic goals; institutional commitment, social support, the contextual influences of institutional selectivity and financial support, and social involvement had a moderate effect. Students' performance is mostly affected by academic self-confidence and achievement motivation, and moderately affected by contextual influence of financial support, academic goals, academic-related skills, social involvement, institutional commitment, and social support.

This paper represents an effort to participate to the discussion on the role that non-academic factors that students' experienced during the COVID-19 outbreak. Current literature on the effect of COVID-19 on higher education mostly focuses on teaching strategies and effective delivery of instructional material in an online environment to improve learning [5], [6], but few studies focus on the role of non-academic factors during the pandemic. The outbreak of coronavirus resulted in significant changes to college life with students losing access to in-campus resources related to housing, food and educational material. This lack of resources has impacted vulnerable students the most, and has exacerbated existing equity gaps between wealthier students and students from less privileged backgrounds, and may have had a lifelong impact on students' success, as well as their emotional well-being [2], [3].

This time provides a unique, one-time opportunity for ground-breaking research to study how non-academic factors affected higher education students during the COVID-19 pandemic. Specifically, the research questions that the author would like to answer is how students responded to the rapid transition to online instructions, and how non-academic factors affected students' experience and well-being at the beginning of the COVID-19 pandemic. In addition, the author would like to investigate whether the pandemic has deepened the equity gaps in engineering education, by comparing the survey results with Daniels et al. [8], which analyzed the early results of a survey sent to students at multiple elite-institutions about the impact of COVID on their experiences. Many respondents reported feeling "worse" or "much worse" than before COVID 19, and that they felt that their ability to pursue their academic goals was "worse" or "much worse" than before the coronavirus outbreak [8]. The authors also discuss how worse mental health could arise from general feelings of anxiety due to the uncertainty and stress of the pandemic, as well as from specific changes to the students' own situation [8]. The data presented in this paper is collected at a public Hispanic Serving Institution, with the intention of showing how a vulnerable student population has been affected.

II. DESCRIPTION OF SURVEY

The survey has been distributed to all students in the department of aerospace engineering, which offers a 4-year BS degree and a MS degree. In order to capture how the switch to online modality affected students' learning in aerospace engineering classes in Spring 2020, an in-depth survey was distributed to all aerospace engineering students in June 2020 after the end of the spring semester. The author feels that this analysis is crucial in understanding how students are coping to this unprecedented crisis, and to define support strategies for the student body. The author's university will offer classes primarily online for Fall 2020 and Spring 2021, and this data has proven to be helpful in planning for the new semester.

The questions contained in the survey explore the following aspects: (1) changes in living condition, (2) psychological well- being, (3) access

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to technology. These aspects are directly related to non-academic factors linked to students' retention and performance during regular times. In addition to the quantitative data collected through the questions in the survey, the author allows for free-form comments to provide more in-depth representation of the students' experiences. The questions contained in the survey are listed in Table 1 .

TABLE 1 List of questions in survey

Question
What is your work environment? - I work fulltime in a job outside of campus - I worked fulltime in a job outside of campus but I lost my position or my hours were cut - I work part-time in a job outside of campus - I worked part-time in a job outside of campus but I lost my position or my hours were cut - I worked on campus before the COVID 19 pandemic and still work at a distance - I worked on campus before the COVID 19 pandemic but lost my position - I did not work during Spring 2020 - Other
Are you currently living or staying with anyone over the age of 65, or with anyone over the age of 60 who also has one of the following risk factors? (heart conditions, diabetes, hypertension and/or obesity)
Are you or anyone living or staying in your household currently in a medically imposed quarantine?
Do you currently have to care for children or elderly while under quarantine?
After the shelter-in-place order in March 2020, what was your living situation? - Selected Choice
Relative to your life before and after COVID 19, how would you rank your current (Much worse than before/ Worse than before/ Same as before/ Better than before/ Much better than before): - Health care access - Time management - Ability to socialize with my fellow students - Ability to socialize with my friends - Overall psychological wellbeing, including feelings of anxiety and/or depression
Overall, how much stress are you feeling about the consequences of COVID 19? - A little or no stress - A moderate amount of stress - A great deal of stress
Relative to your life before and after COVID 19, is there any change in the following for you this semester in (Decreased/ About the same/ Increased): - Expenses - Income - Financial Aid - Debt - Having a safe place to sleep each night - Having enough to eat each day
Do you have access to the following resources to support your remote learning? - Computer, laptop or tablet - Enough Internet Access for doing your classwork online - Physical space for studying and doing assignments - Library resources (including books, articles, etc) - Scanner - Webcam - Printer
Please reflect on the following aspects regarding your learning experience during the online transition (Strongly disagree/ Disagree/ Somewhat disagree/ Neither agree nor disagree/Somewhat agree/ Agree/ Strongly agree) - I need to share the computer I use to attend classes - I have an online learning community - I have witnessed an increase in academic dishonesty due to exams offered online
Given the unexpected changes in course instruction after the spread of COVID 19, how often do you worry about the following (Never/ Sometimes/ About half the time/ Most of the time/ Always) - Doing well in your classes now that all of them have moved online - Accessing and using the technology required for your online classes - Your ability to do internships, field studies or projects as an undergraduate - Your progress to obtaining an undergraduate degree

III. ANALYSIS OF RESULTS

A total of 35 aerospace engineering students agreed to respond to the survey, distributed as 86% male, 11% female, 3% other, which is in line with the major composition. Responses represented all levels in the major, with 17% freshman, 6% sophomore, 34% junior, 26% senior and 17% graduate student respondents. The majority of the students (63%) took 4 or more classes in Spring 2020; 74% of the respondents have a GPA higher than 3.0/4.0.

The ethnicity of the respondents is divided as 26% Asian-American, 14% Hispanic or Latinx, 37% White, 6% international students, 17% other ethnicity, thus representing a good mix of ethnical background. In addition, 31% of the respondents are first generation students.

A. Changes in living conditions

Students have been affected by changes in their living condition, and 21% of the students reported difficulties due to these changes. Many of the respondents worked part-time and full-time outside the university or in campus before the pandemic (69%). Among the students that were working before the pandemic, 52% either lost their position or had their hours cut due to COVID-19 closures. This job loss affects mostly upper division students, with 33% of junior, 44% of seniors and 66% of graduate students that experienced cut of hours or loss of position. It also affects students from different backgrounds unequally: of the students that were working before the pandemic, all of the Hispanic or Latinx respondents lost their job/had their hours cut, 80% of the Asian-American students, while only 44% White students found themselves facing the same challenges. No international students experienced job loss.

About 12% of the students "always" need to care for children or elderly during shelter in place, and 15% "sometimes". This need fell mostly on the shoulders of Hispanic-Latinx students (40% - "always" and "sometimes" responses combined) and International Students (50% - "always"), while 22% of Asian- American students ("always" and "sometimes" responses combined) and 8% of White students ("sometimes"). Female students also reported to have responsibilities in the family, with 33% of the female students that need to "always" care for family members, versus 10% of male students that "always" have to care for dependents, and 17% "sometimes".

Health care access has also changed due to COVID-19: 42% of the students report their ability to access health care "worse than before", and the remainder 58% reported as "same as before". This decrease in health access affected male students only, and affected 25% of students identifying themselves as Asian-American, 60% of Hispanic, 30% of White students, 67% of students from two or more ethnicities, 50% of International students.

Many students (42%) reported a decrease in their expenses due to the coronavirus outbreak, but 55% of the students experienced a decrease in their income as well. The loss of income especially affected Hispanic-Latinx students, with 80% reporting a loss of income, see Figure 1. Some students reported a decrease in financial aid (8%), with Hispanic-Latinx and International students mostly affected by the change, as well as an increase in debt (27%). Selected free-form responses highlight stories behind the financial challenges exacerbated by the COVID-19 outbreak:

Student 1: "Family income is from a family owned small business, zero-very little business due to shelter in place closure and COVID-19. Personally lost my position at my place of work for the foreseeable future. Currently threatened by landlord with eviction with no understanding on their part about not being able to pay rent properly, but others have it the same or much worse."

Student 2: "My father is a high risk to covid so I decided not to go home after the spring semester ended. I am paying rent, car insurance, phone bills, groceries, you name it, all while trying to save up money for higher living expenses in the fall."

Student 3: "Before the government stimulus check and unemployment checks, it was very hard in mid-March to Early April to have enough to eat or travel due to financial constraints."

B. Socialization and psychological wellbeing

Students report a deterioration in their overall mental health. To the question: "Relative to your life before and after COVID 19, how would you rank your current overall psychological wellbeing, including feelings of anxiety and/or depression", 19% of the students responded that they feel "Much worse than before" and 50% "Worse than before". Hispanic-Latinx students' mental health was hit the hardest, with 100% reporting "Much worse than before" or "Worse than before", 91% of White students, 50% International Students, 37% Asian- American, 33% Two or more ethnicities. As a consequence, 28% of the students reported to have experienced a little or no stress 28%, a moderate amount of stress 47%, a great deal 25%.

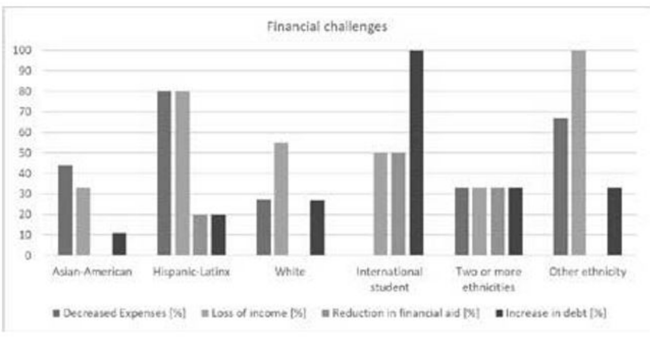

***FIGURE 1** Percentage of students affected by financial challenges in percentage for different ethnicities*

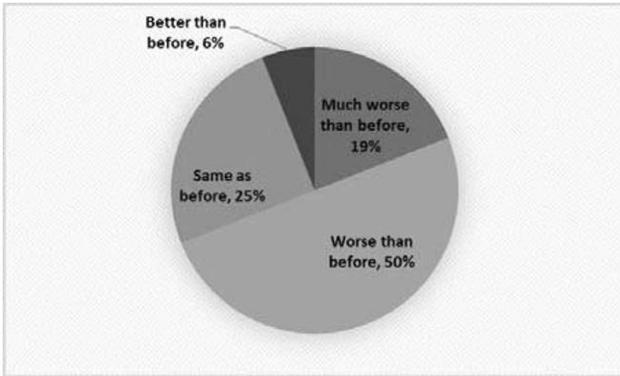

***FIGURE 2** Overall psychological wellbeing as a result of COVID-19*

Only upper division students (junior, senior, graduate) reported a "great deal" of stress.

Students' well-being has been greatly affected by the lack of socialization during shelter in place restrictions: 85% of the students report a "much worse" or "worse than before" ability to socialize with fellow students, and 78% with their friends. Most of the students feel less connected to their peers (85%).

As the survey asked students to reflect on the statement "I have an online learning community", 50% express a negative response, with 12% "strongly disagree", 25% "disagree" and 13% "somewhat disagree", and 9% "neither agree nor disagree". Please reflect on the following aspects regarding your learning experience during the online transition

Selected free-form responses highlight stories behind the worsening of students' well-being as well as loss of social life due to COVID-19:

Student 1: "One of my parents might lose their jobs in the future. This has caused a lot of stress as it would cause me to lose access to health care."

Student 2: "Lack of regularly available gyms has put a lot of stress on me"

Student 3: "I have anxiety which flares when I am at the store getting groceries or other essentials and I hear someone cough, or when people are standing close to me. This had effected my interaction with people which resulted in me going out less and less."

Student 4: "Mental health and physical health is definitely the issue. There is no motivation to do anything especially school work. [..] Humans are social animals and not being able to see your friends for an extended period of time really messes with your mental state. To top it all off, since you're home all day, you're not really moving much unless you make an effort to do so."

Student 5: "I got depressed living at home and it greatly impacted my grades"

Student 6: "The stress of remaining isolated at home is wearing my mental health to a very unhealthy state."

C. Access to technology

Access to technology represented a challenge for many students. Most of the students (97%) had access to a computer, laptop or tablet, and 84% had always access to internet for doing online classwork. The remaining 16% of the students defined their ability to access the internet as "sometimes". Hispanic-Latinx students are mostly affected by this occasional internet access, with 60% of them having access "sometimes". More students reported a lack of physical space for studying and doing assignments: 9% of the students did not have an available space, and 25% only "sometimes". Hispanic-Latinx students are more affected by the lack of physical space, with only 20% of them reporting consistent availability of a space to study. It also affected upper division students more than freshman and sophomore students.

Students also reported a lack of library resources (19% reported a consistent lack, and 25% an occasional lack of library resources), of scanners (25% reported a consistent lack, and 12% an occasional lack of scanners), of webcams (16% reported a consistent lack, and 16% an occasional lack of webcams) and printers (22% reported a consistent lack, and 17% an occasional lack of printers). As a consequence, only 26% of the students reported that they "never" worry about accessing and using the technology required for their online classes.

Selected free-form responses highlight the technological needs of the students during COVID-19:

Student 1: "Scanner and Printer would help immensely when submitting assignments."

Student 2: "I needed a printer."

D. Overall perception

Given the unexpected changes in course instruction after the spread of COVID 19, many students often you worry about their ability to do well in their classes (73% worry at least "about half the time to do internships and field studies (73% worry at least "about half the time").

Students worry about their ability to do well in their classes in Spring 2020: overall, 77% of the students in aerospace engineering worry at least "half of the times: 100% of Hispanic-Latinx and International students worry at least "half of the times", 67% of Asian-American and 60% of White students.

As a consequence, more than half of the students (52%) worry about their ability to progress to obtaining an undergraduate degree at least "about half the time": 66% Hispanic-Latinx students worry "about half the time", 43% of the Asian-American students, and 40% of the White students. Only 8% of the students report that they never worry about their degree as a result of COVID-19.

IV. DISCUSSION

Students well-being has deteriorated due to COVID-19, due to changes in their financial situation, ability to work and access health care and in their social connections. The overall results of this survey are in line with the initial results presented in Daniels et al. [8], as can be seen in Table 1. However, students in the author's department experienced a more widespread loss of income. However, these results differ largely when Hispanic-Latinx students are considered: 100% of these students experienced a deterioration in psychological well-being, a loss of income and a negative feeling about being able to pursue their long-term goals.

TABLE 2 Comparison of results between current survey and Reference [8]

Factor	Source		
	Overall student respondents	Hispanic-Latinx students	Reference [8]
Psychological well-being: "worse" or "much worse"	85%	100%	79%
Loss of income	55%	100%	30%
Access to healthcare: "worse" or "much worse"	42%	60%	40%
Ability to pursue long term/ academic goals: "worse" or "much worse"	45%	100%	78%
Worry about ability to obtain degree at least half of the times	52%	66%	N/A

It is also important to compare how the analyzed non- academic factors related to students' retention and performance before the pandemic. Half of the respondents to the survey declare that they are worried about their ability to obtain their degree at least half of the times, and they worry about their ability to pursue their academic goals. Both these statements can be summarized as lack of academic self-confidence and academic goals, which have been shown to be strongly correlated to students' retention and performance by Lotkowski et al. [7]. Many students in their answers describe a lack of social involvement and financial support, which has also shown to have an effect on students' retention and performance [7].

V. CONCLUSION

Students have been strongly affected by the pandemic, and non-academic factors such as challenges in their living conditions and financial status, and access to technology. In particular, students belonging to vulnerable groups such as Hispanic-Latinx have been deeply affected by the COVID-19 outbreak, resulting in an increase of existing equity gaps in their education.

It is yet to see how these students will progress in their academic career, and whether the anxiety of this new reality will have long term effects. As the coronavirus pandemic progresses, and online instruction and social limitations become the new norm in most of the United States, universities are defining new strategies to support their students during these difficult times. It will be possible to understand whether the difficulties of Spring 2020 will progress into the following semesters and affect the academic progress of our students indefinitely only in the months and years to come.

ACKNOWLEDGMENT

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REFERENCES

[1] "Higher Education Responses to Coronavirus (COVID-19)." [Online]. Available:https://www.ncsl.org/research/education/higher-education-responses-to-coronavirus-covid-19.aspx. [Accessed: 15-Aug-2020].

[2] "The pandemic has worsened equity gaps in higher education and work." [Online]. Available: https://www.insidehighered.com/news/2020/06/17/pandemic-has-worsened-equity-gaps-higher-education-and-work. [Accessed: 14- Aug-2020].

[3] "The Challenge of Equity in Higher Education Under COVID-19 | Learning Innovation." [Online]. Available: https://www.insidehighered.com/blogs/learning- innovation/challenge-equity-higher-education-under-covid-19. [Accessed: 14-Aug-2020].

[4] J. L. Malisch et al., "Opinion: In the wake of COVID-19, academia needs new solutions to ensure gender equity," Proceedings of the National Academy of Sciences of the United States of America, vol. 117, no. 27. National Academy of Sciences, pp. 15378–15381, 07- Jul-2020.

[5] "Supporting student wellbeing during COVID-19: Tips from regional and remote Australia - NCSEHE." [Online]. Available: https://www.ncsehe.edu.au/student-wellbeing-covid-19-regional- remote-australia/. [Accessed: 14-Aug-2020].

[6] G. K. Saw, C.-N. Chang, U. Lomelí, and M. Zhi, "Gender disparities in remote learning during the COVID-19 pandemic: A national survey of STEM faculty and students," 2020.

[7] V. A. Lotkowski, S. B. Robbins, and R. J. Noeth, "The Role of Academic and Non-Academic Factors in Improving College Retention ACT POLICY REPORT," 2004.

[8] B. Daniels, J. Das, A. Hamza, and B. Leydier, "Covid-19 Diaries: Early Impressions from an Online Questionnaire.," Covid-19 and Student Focused Concerns: Threats and Possibilities, Veena Das and Naveeda Khan, eds., American Ethnologist website, 2020. .

Technical Papers

Automated generation of test questions and solutions

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Abstract—While the automatic generation of test problems has been considered in the past, the importance of also generating solutions is largely unconsidered. Additionally, current approaches to automatically generating test problems are normally limited to multiple-choice questions (MCQs) and often only consider language-based problems. The generation of problems and solutions that are based on graphical processes is explored in an attempt to address these limitations. Rapidly generating questions and their solutions helps educators set better questions by allowing more iterations than manual processes, and allows students to be provided with worked examples. These and other considerations are illustrated by considering a number of examples, and suitable software tools are suggested.

Keywords—Automatic question generation, automatic solution generation, engineering education, education technology.

I. INTRODUCTION

Setting test papers is a notoriously difficult, time-consuming task, with chapters on assessment in books on teaching having titles like "The Challenge of Assessment" [1] and "Walking the Assessment Tightrope" [2]. This challenge arises from the many conflicting requirements placed on tests, including time limits, adequate coverage of course material, relevant difficulty level, testing a range of skills, etc.

As a result of the tremendous burden that setting tests places on educators, systems capable of automatically generating test and examination question papers have been developed since at least 1990 [3]. Generating suitable test papers from a database of existing problem is a complex problem [4] and such systems are tremendously useful. However, they suffer from the fact that questions will inevitably be reused over time.

As noted by a number of researchers, the way students study is strongly influenced by the way they are examined [2], [5]. It is thus likely that students will focus their efforts on studying the solutions to questions that were posed in previous database-derived tests rather than on understanding the underlying concepts. Given that research has found that tests set by faculty tend to emphasise recall too strongly [5], the additional reliance on databases is likely to exacerbate this over-emphasis of recall in tests.

As a result, there is currently interest in the automatic generation of test questions with a recent review paper having over 160 references and noting a significant increase in the number of such papers in the last decade [6]. However, the vast majority of the approaches considered deal with lan- guage questions, possibly as a result of the tremendous recent strides in natural language processing (NLP). Additionally, most work on automatic question generation has focused on multiple-choice questions (MCQs) and fill-in-the-blank questions, though with some notable exceptions (e.g. [7], [8]).

While systems that automatically generate test questions normally also produce answers as well, the intention of these answers is to enable automatic marking. However, feedback to students is so important that it has been referred to as the "lifeblood of learning" [1], [2]. So as important as setting test papers and questions is, providing solutions that explain how the answers are obtained is arguably more important. However, this aspect of setting tests does not appear to have been adequately investigated.

The automatic generation of test questions and their solutions for engineering courses is considered below. Unlike the majority of similar work, the questions considered are not based on MCQs and language, but rather on algorithms that require diagrams both for the problem description and solution. Such problems tend to be unusually time-consuming to set because the full solution is required to determine the suitability of a problem. As a result there is a strong temptation to reuse problems from previous tests with the associated negative effects noted above, or to be satisfied with a problem that is not ideal. The ability to rapidly generate and evaluate a large number of problems overcomes both of these difficulties. The exposition will start by considering some software tools that can be used to generate questions, and more importantly, their solutions, along with the types of question most suitable for this approach. The discussion will then move to a consid- eration of a number of examples to show how the automatic generation of problems and their solutions can assist educators and students, followed by a brief conclusion.

II. TOOLS

The issue of tools suitable for developing test questions and answers is considered below in two parts, the tools to generate the question and solution, and the tools to create the required text and graphics in documents.

A. Question and Solution Generation

The selection of software tools depends strongly on the type of problem being considered. Additionally, it is necessary that the tool used be capable of generating high-quality documents, which may require suitable libraries.

Examples of tools that could be considered for generating test questions and solutions are R, which has been specifically developed for statistics, GNU Octave or Maxima for mathematical problems, and C/C++ or Java for programming problems. While specialised tools are normally preferable, the use of a general-purpose tool may be preferred if a single standard is to be adopted throughout an organisation, for example. Python [9] is a good choice under these circumstances as it is a general-purpose programming language that has libraries supporting a wide range of specialised requirements.

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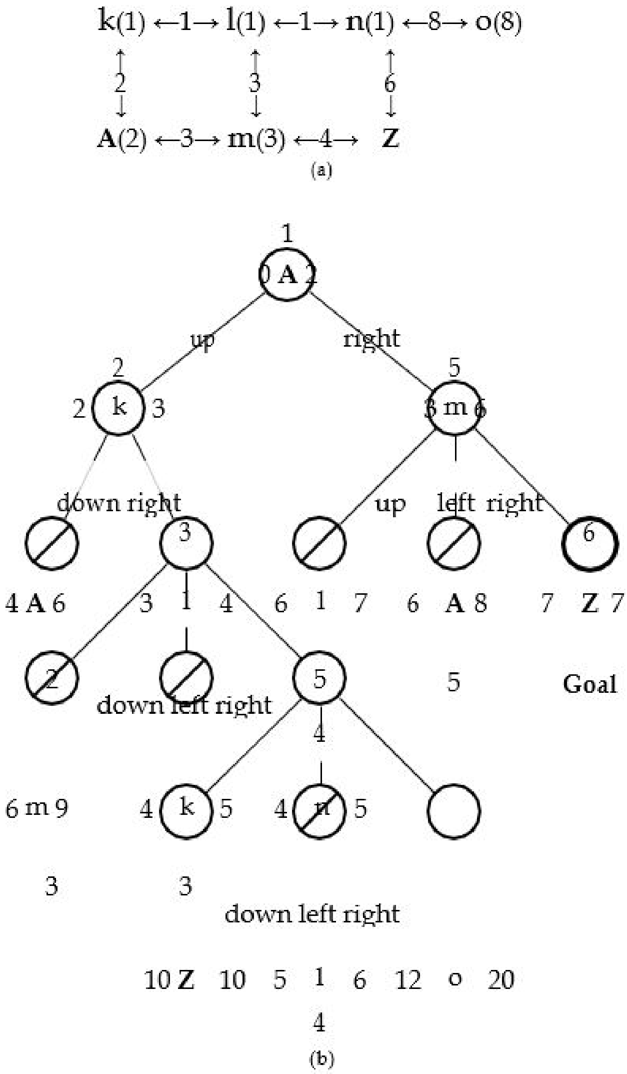

FIGURE 1 An A search example with (a) the map and (b) the resulting search tree. The nodes are denoted by letters with the search starting at node A and seeking to reach node Z. The distances between nodes are provided between the relevant nodes in (a), with estimated distances to the goal node being provided in brackets after the node labels. The numbers above each node in (b) indicate the order in which nodes are expanded, the numbers on the left and right provide the distance to the node and the estimated total distance to the goal, respectively. The number below a crossed-out node indicates the step (number above a node) when that node was pruned.*

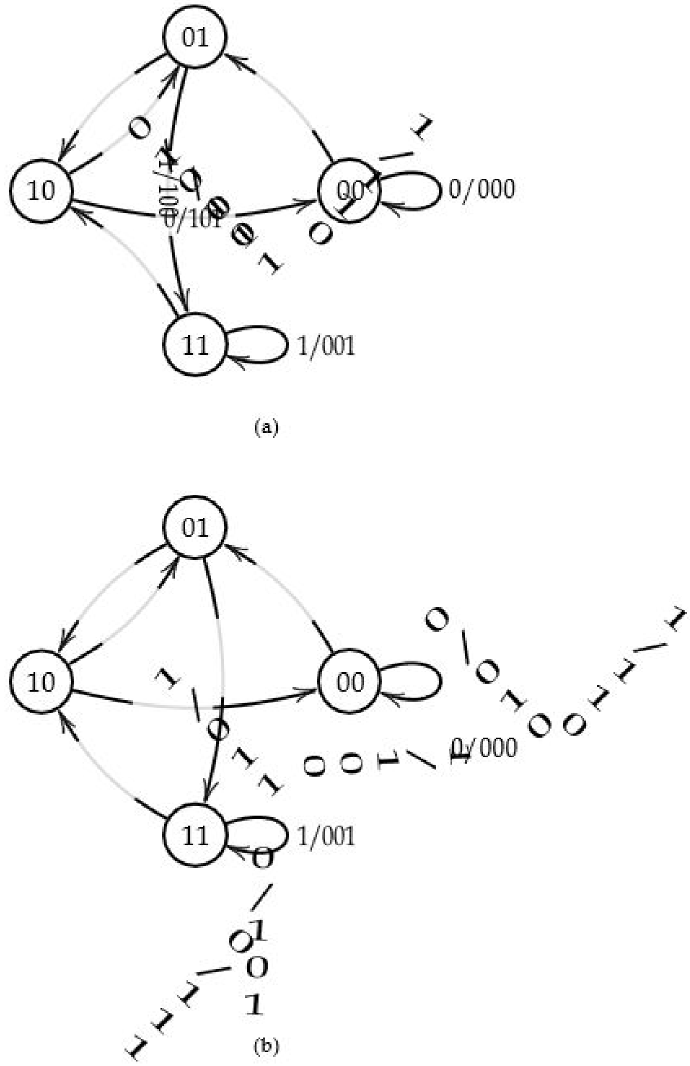

FIGURE 2 The (a) generated and (b) edited state-transition diagram for the trellis

The tool used will significantly influence the type of prob- lem that can be considered. For example, some mathematical tools can process symbolic equations (e.g. Maxima), while others perform numerical computations (e.g. GNU Octave). More importantly, the tools noted above are most suitable for implementing algorithms. This constrains the types of problem that can be considered to those where algorithms are applied. However, this limitation is primarily a result of the tools considered here, so it is likely that other tools will be capable of addressing more complex problems. Despite this limitation, the application of an algorithm to a problem requires a higher level of cognition than merely recalling the algorithm steps.

Another important consideration is that it is necessary to generate high-quality documents. This can be achieved by using libraries to interface with specific tools, but at the very least, the tool should be capable of processing text files. Fortunately, most tools that are relevant here can process text files, so this is unlikely to be a significant issue.

B. Text, Mathematics, and Graphics Generation

As noted above, libraries exist to generate documents in a range of software systems ranging from word processors diagrams in Figure 3. The bits corresponding to each state are shown inside the circles, and the data bit and the bits that are transmitted are shown on the arrows indicating transitions between states.

to learning-management systems (LMSs). However, such li- braries may only be available for certain tools, and the inability to use certain tools can restrict the types of problem that can be considered. The approach proposed here is thus based on tools that use text files as input because of the ubiquity text-file support in software tools.

The LATEX document-preparation tool takes text files as input and produces high-quality documents in a range of formats including PDF [10]. For example, this entire document was generated using LATEX to produce a PDF file. The fact that LATEX was developed with technical documents in mind means that it has excellent support for mathematics and technical diagrams. Useful LATEX libraries include TikZ for drawings [11], and fforest for trees [12]. However, it is worth noting that a variety of other software tools are also based on text files, including the widely-used SVG image format.

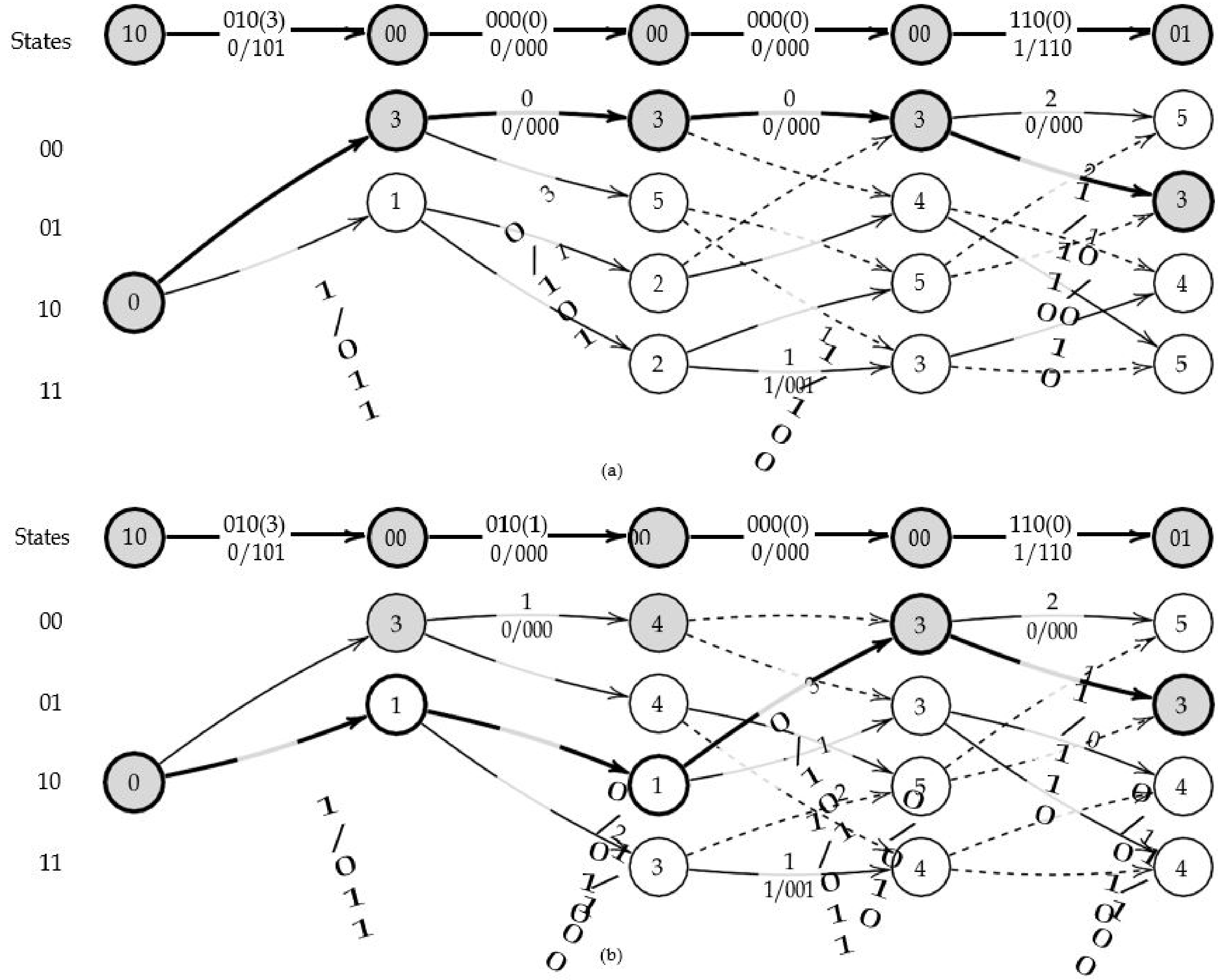

FIGURE 3 The Viterbi decoder trellis obtaining using the state-transition diagram in Figure 2 for received bit streams (a) 010 000 000 100 and (b) 010 010 000 100 that differ by one bit. The retained and pruned paths are indicated by solid and dashed lines, respectively. The correct path through the trellis is indicated by nodes with grey backgrounds, and the path selected by the Viterbi algorithm is highlighted by thicker lines. The number in each node is the total errors of the best path to that node, and each transition is labelled by the number of errors above the data and transmitted bits corresponding to that transmission. The states are indicated on the far left of the diagram, and the top line indicates the actual states in the circles, the bits that were received and the errors for that transition on the top line of a transition, above the data and transmitted bits on the line below.

III. EXAMPLES

Examples that are similar to questions the author has used in third-year engineering courses are provided to illustrate the concepts outlined above. The examples will inevitably reflect the courses the author teaches in artificial intelligence (AI) and telecommunications, but it is believed that the principles illustrated are generally relevant.

The examples that will be considered are briefly summarised below along with a brief indication of their significance.

- Figure 1 shows a question that requires use of the A* search algorithm. This is an important algorithm that is able to efficiently solve mapping problems where an estimate of the distance to the goal exists.
- Figure 3 shows the application of a Viterbi decoder to the received data bits 010 000 000 100 when using the convolutional encoder described by the state-transition diagram in Figure 2. This type of question deals with how error-correction using convolutional codes works.
- Figure 4 shows a game tree where the score of a number of potential game states has been evaluated, and Figure 5 shows how an alpha-beta search reduces the number of game states that need to be considered to determine the best move. Figure 6 provides an extract from the text description of how Figure 5 was obtained. The alpha-beta search is significant in game-playing algorithms.

The most important aspect of the examples is that the generation of solutions that clearly outline how the problems are solved is automated along with question generation. Apart from allowing the rapid evaluation of questions noted above, this also means that students can be provided with solutions that enable them to gain insight into how the problem is solved. Additionally, the fact that the full solutions are available at the same time as the question itself means that solutions can be provided to students immediately on completion of the test. This immediacy can increase the value of feedback [2] because the problem and the way it was solved during a test are still fresh in the students' memories.

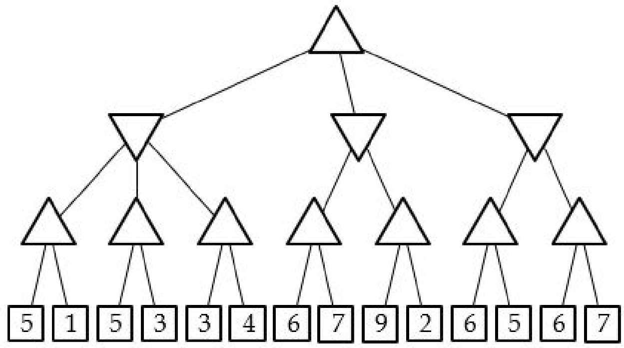

FIGURE 4 *The tree for an alpha-beta search problem.*

A significant observation about the examples provided is that the solutions are far more complicated and extensive than the problems themselves, and this characteristic is true of many problems. One of the consequences of this solution complexity is that the number of sample problems, and especially, worked examples provided by textbooks and other sources is quite limited due to the time required to generate them. Using an automated tool allows a far larger number of carefully-crafted worked examples to be provided to students. Additionally, the questions from previous tests and their solutions can also be provided as worked examples leading to an ever-expanding library of sample problems.

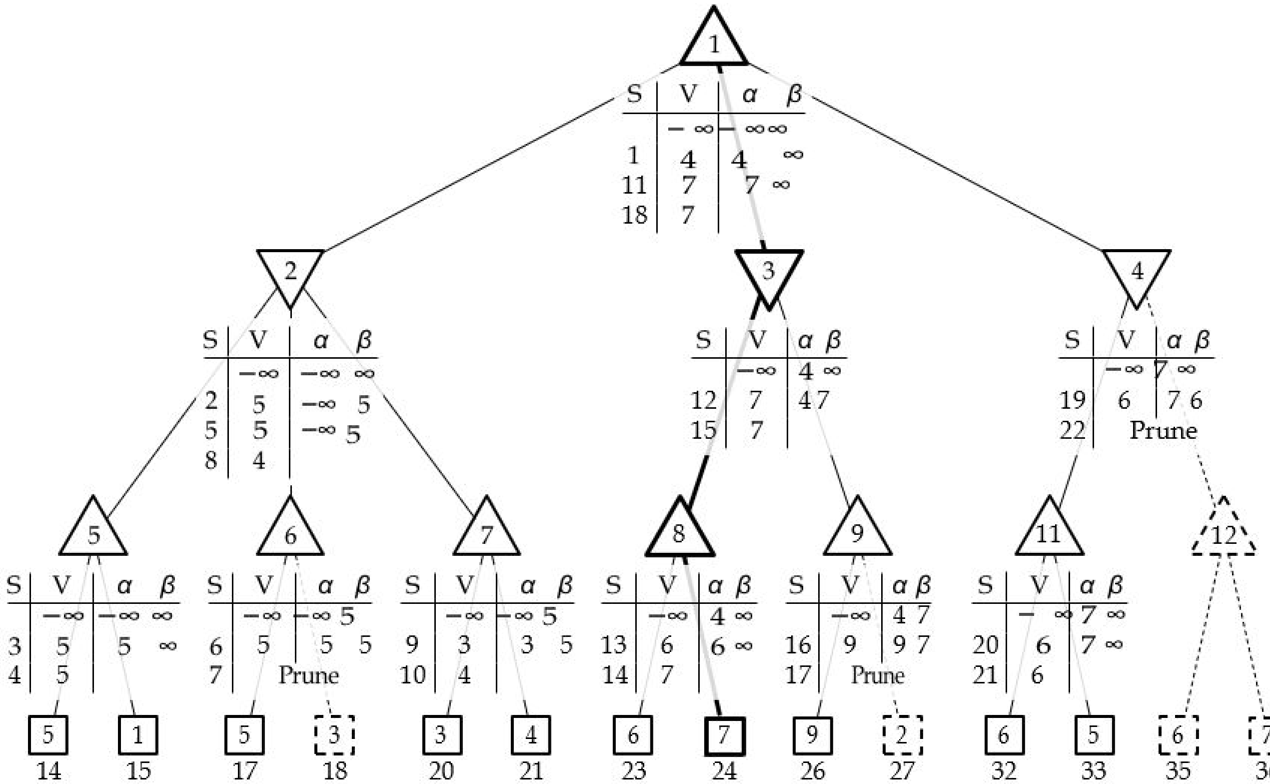

FIGURE 5 *The resulting alpha-beta search tree for the game tree shown in Figure 4. Considered and pruned nodes have solid and dashed lines, respectively, with the selected move behind highlighted with thicker lines. The node labels are the numbers inside the triangles and below the squares. The letters "S," "V," "α," and "β" in the tables show the step numbers, values, and the alpha and beta values for each node as the search progresses.*

An extract from the text description of how the alpha-beta search tree in Figure 5 was obtained is provided in Figure 6. As can be seen, the description is repetitive and extremely long, but it does contain information that is not provided in Figure 5. That said, the question of whether text descriptions are required in addition to diagrams would benefit from further study as students have not requested such descriptions for any of the algorithms for which the author has not provided them.

Another important consideration is that all the examples have clear diagrams, which is an important consideration as any lack of clarity or ambiguity can lead to unnecessary difficulty for students taking a test [13]. This was achieved by using relatively thick lines to ensure that they are correctly reproduced when copied and on low-resolution screens. Fur- thermore, the diagrams are made large to allow bigger fonts to be used and clear separation between the various elements to be achieved. Finally, labels are positioned so that there is no ambiguity about which part of a diagram they are associated with. Automatically generating these diagrams means that there is consistency in aspects such as these, thereby avoiding the inevitable changes that will occur when such diagrams are manually generated over an extended period.

As noted previously, the solutions to the problems consid- ered here change dramatically with even small changes to the questions. For example, Figure 3(b) shows the effect of changing a single bit of the received data to be 010 010 000 100 instead of 010 000 000 100 as in Figure 3(a). The majority of error values (the values in the circles) and which paths between nodes are retained (the solid lines) change, to the point that the selected solution (the thick lines) differs from the transmitted data (the filled circles). The ability to generate new solutions without having to manually determine solutions such as those in Figure 3 thus allows the evaluation of a number of different questions until the appropriate balance between difficulty, coverage, time required, and other factors is achieved.

The following examples of issues that were specifically considered when developing the examples are provided:

- The A* search in Figure 1(b) has the goal node Z twice with it only being selected the second time it appears. Additionally, node o appears in the search tree in Figure 1(b) even though it is clear from the map in Figure 1(a) that node o will not be part of the solution.
- The best path in the Viterbi trellis diagram in Figure 3(a) only has the lowest total errors on the final step to test whether students understand that only the final total error should be considered.
- The alpha-beta search tree in Figure 5 prunes both at the lowest level in steps 7 and 17, and the level above this in step 22. While nodes 18 and 27 at the lowest level of the alpha-beta search tree in Figure 5 are pruned, node 24 is not pruned to show that not all lower-level nodes are pruned.

Expand node 1 (Max)
. . .
1. Consider child 1 of node 1 (node 2)
. . .
11. Consider child 2 of node 1 (node 3)
. . .
18. Consider child 3 of node 1 (node 4)
Expand node 4 (Min)
Initial value: ∞
Initial α: 7
Initial β: ∞
19. Consider child 1 of node 4 (node 11)
Expand node 11 (Max)
Initial value: $-\infty$
Initial α: 7
Initial β: ∞
20. Consider child 1 of node 11 (node 32)
Child value is 6
Update node value to 6 $(6 > -\infty)$
α is unchanged at 7 $(6 \leq 7)$
21. Consider child 2 of node 11 (node 33)
Child value is 5
Node is unchanged at 6 $(5 \leq 6)$
Child value is 6
Update node value to 6 $(6 < \infty)$
Update β to 6 $(6 < \infty)$
22. $\alpha \geq \beta$ $(7 \geq 6)$, so prune
Child value is 6
Node is unchanged at 7 $(6 \leq 7)$
The best move has a value of 7, which is found from the final value of the root node. The best move is found by traversing down the tree and selecting the first node which has a final value equal to that of its parent at each step.

FIGURE 6 *An extract from the text description of how the alpha-beta search tree in Figure 5 is obtained from the game tree in Figure 4. The node numbers correspond to those in Figure 5, and the step numbers correspond to the values labelled "S" in the tables in Figure 5.*

Finally, pruning is performed when alpha and beta are equal in step 7 in Figure 5 to illustrate that pruning should take place in such cases.

In each case, these characteristics of the question are necessary to determine whether students have correctly understood the relevant material. In fact, many of these considerations are motivated by the author's experience of issues students struggle with, thereby ensuring that these issues are both evaluated in tests and illustrated in examples provided.

The discussion above is solely from the perspective of an educator, so the question naturally arises of what the students' perspective on automatically-generated questions and solutions is. This question has not yet been investigated, so no conclusions can be provided at this time. However, the author has noted an ever-increasing number of students using the same notation as that in the automatically-generated solutions when completing tests. This notation differs from that used in other sources (as more information is provided here), so students would not have learnt this notation somewhere else. This use of this unique notation is thus believed to suggest that students are making use of the automatically-generated questions and solutions provided to them.

As a final observation, it is noted that the tools the author developed and used to generate these examples still have room for improvement. For example, the tool could be adapted to ensure that the desired problem characteristics are present in all solutions generated, as the process presently entails a significant manual component. Additionally, the formatting sometimes requires some fine-tuning before suitably clear diagrams are obtained, with Figure 2(a) showing the initially- generated form of Figure 2(b). Similarly, a number of the arrow labels in Figure 3 needed to be moved to avoid overlap. Fortu- nately, the nature of LATEX and its libraries means that these changes were normally as simple as changing the instruction "bend right" to "bend left" or "pos=0.5" to "pos=0.3," for example.

IV. CONCLUSION

The automatic generation of test questions is by no means a new concept, but the emphasis of previous work has been on reducing educator workload. However, the feedback provided on tests can play a vital role in education, and the quality of many questions can only be fully evaluated on the basis of the full solution. This suggests that the solutions to automatically- generated questions are at least as important as the questions themselves.

The use of software tools to generate both questions and their solutions, and to render these as high-quality documents was considered. This approach ensures that the formatting of questions and solutions is of a consistently high quality, allowing these to be provided to students. The ability to rapidly produce and modify questions allows an educator to ensure that the question adequately addresses the many conflicting requirements of tests. Finally, the ability to automatically generate questions and solutions is beneficial in providing students with worked examples for problem types where such examples are rare due to the effort required to set them and their solutions up.

REFERENCES

[1] V. E. Cree, "The challenge of assessment," in Transfer of Learning in Professional and Vocational Education : Handbook for Social Work Trainers, V. E. Cree and C. Macaulay, Eds. London, UK: Routledge, 2000, ch. 2.

[2] B. R. Crisp and P. G. Lister, "Walking the assessment tightrope," in Effective learning and teaching in social policy and social work, H. Burgess and I. Taylor, Eds. Abingdon, UK: RoutledgeFalmer, 2005, ch. 7.

[3] P. Lira, M. Bronfman, and J. Eyzaguirre, "Multitest ii: a program for the generation, correction, and analysis of multiple choice tests," IEEE Trans. Educ., vol. 33, no. 4, pp. 320–325, Nov. 1990.

[4] G.-J. Hwang, "A test-sheet-generating algorithm for multiple assessment requirements," IEEE Trans. Educ., vol. 46, no. 3, pp. 329–337, Aug. 2003.

[5] B. G. Davis, Tools for Teaching. San Francisco, CA, USA: Jossey-Bass, 1993.

[6] G. Kurdi, J. Leo, B. Parsia, U. Sattler, and S. Al-Emari, "A systematic review of automatic question generation for educational purposes," Int. J. Artif. Intell. Educ., vol. 30, pp. 121–204, 2020.

[7] B. Gru¨n and A. Zeileis, "Automatic generation of simple (statistical) exams," Wirtschaftsuniversita¨t Wien, Res. Rep. 77, Nov. 2008.

[8] A. Papasalouros, "Automatic exercise generation in Euclidean geome- try," in Artif. Intell. Applic. Innov. (AIAI), Paphos, Cyprus, 30 Sep.-2 Oct. 2013, pp. 141–150.

[9] (2020, Aug.) Welcome to Python.org. https://www.python.org/

[10] (2020, Aug.) LaTeX – A document preparation system. https://www.latex-project.org/

[11] T. Tantau, The TikZ and PGF Packages, 8 Jan. 2020, v3.1.5b.

[12] S. Zˇ ivanovic´, Forest: a PGF/TikZ-based package for drawing linguistic trees, 14 Jul. 2017, v2.1.5.

[13] V. Crisp, M. Johnson, and F. Constantinou, "A question of quality: con- ceptualisations of quality in the context of educational test questions," Res. Educ., vol. 105, no. 1, pp. 18–41, 2019.

Technical Papers

Exploring student perspectives on assessment practices in an engineering context

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***Abstract*—This study explores the influence of assessment on student approaches to learning through the voice of the student. Focus groups were conducted with four groups of students with varying academic performance in their second, third and fourth year of their engineering studies. The study reveals the importance of constructive alignment in assessment design. Specific findings relate to tutorials, assignments and group work.**

Keywords— learning-oriented assessment, constructive alignment, student learning, focus groups, student voice.

I. INTRODUCTION

Constraints in higher education like increasing student numbers and decreasing teaching capacity can result in compromises in pedagogical alignment that can negatively affect student learning and drive assessment practices away from a learning-oriented paradigm [1].

As more students fail, the impact of capacity constraints becomes more significant, and assessment practices can move in a direction that does not enhance learning and leads to a deterioration of student performance over time [1]. A thorough understanding of the role of assessment in learning is required to break this vicious cycle and improve assessment practices and the quality of students' approaches to learning. This study is motivated by this need and is therefore an exploratory study that aims to gain broad insights, through the voice of the student, into an engineering school's assessment practices and how these shape student learning. As a result, the research question for this study is: What are students' current learning practices and how are these shaped by assessment practices in the School?

II. LITERATURE

This section introduces literature that informed the theoretical framing of this study. The study adopts a theoretical lens based on assessment for learning [2] and learning-oriented assessment [3] paradigms. Traditional thinking claims that formative and summative assessment are quite distinct, implying that formative assessment supports student learning (assessment *for* or *as* learning) and summative assessment does not (assessment *of* learning). However, it has been argued that in some cases formative and summative assessment can be indistinguishable [2] and that informal tasks (traditionally seen as formative) can be summated to provide input into final (summative) results and that results from a summative assessment task can be formative by providing feedback on learning [4]. This perspective shakes up the traditional view implying that both summative and formative assessments can be used *of* and *for* learning. Assessment thinking has therefore evolved and considers perspectives that view assessment more holistically, focusing on the influence that assessment can have on student learning. As a result, assessment literature is becoming more learning-oriented [3], focusing on assessment tasks that encourage high levels of cognitive engagement over an extended period, stimulating deeper approaches to learning [3]. There is also an emphasis on the need for strong constructive alignment [5] between learning outcomes, teaching and learning activities and assessment tasks. Learning-oriented assessment also shifts agency towards the student, moving from a lecture-driven learning environment to one where the students themselves play an active role and take responsibility for their own learning [6]. Often, students are more focused on the time they need to allocate to assessment tasks [7] and are preoccupied with marks and passing an assessment over learning [8]. It is these types of challenges that student or learning-oriented assessment needs to address so that assessment practices not only encourage student engagement and learning but more importantly that they do not drive approaches that do not lead to learning.

III. RESEARCH METHODOLOGY

A. *Study Context*

This study takes place at an engineering school (The School) in a South African university. Most courses in the degree use a traditional, lecture-centred format and in-class activities are limited due to the large class sizes which can exceed 250 students. Some courses also use formal, scheduled tutorial sessions where students work through problems, individually or in smaller groups with assistance provided by tutors. Attendance at lectures and tutorial sessions is not compulsory although students are sometimes 'encouraged' to attend tutorials through the use of spot tests. Practical laboratories take place in dedicated courses. Assignments (or projects), tests and exams are the primary means of assessing student performance. Exams typically contribute 50-70% towards a course mark, tests 20-30% and assignments up to 20% except in design and lab courses where these can contribute significantly to the course mark.

B. *Research approach*

The study presented in this paper forms part of a larger triangulated case study that also made use of student surveys [9] and lecturer interviews [10]. This study focuses and reports on student focus groups that were conducted to gain a richer picture of student experiences and their response to the assessment environment in the School.

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C. Method

A question guide, consisting of 13 questions, centred the discussion around the issues that emerged from literature, the student surveys and the lecturer interviews conducted previously [9,10]. Questions encouraged students to reflect on both their own feelings and, where necessary, comment on what other students might experience or do [11]. The questions probed a number of issues including: students' overall approach to their studies in respect to different assessment tasks; how they know what is expected from them in assessments; an example of a situation where they were disappointed by an assessment and how they reflected on this experience; forms of received feedback and their response to feedback. The focus group ended with questions that aimed to elicit a degree of self-reflection in students, questioning whether they believed that assessments supported their learning and requiring them to make recommendations of how they, and the School, could change practices to facilitate and support improved learning. For selected questions, students were asked to reflect individually by writing their thoughts down before the group discussion. This eased students into a reflective mood using "writing as thinking" [12] and allowed students to formulate their thoughts before being influenced by others. The focus groups were facilitated by a researcher and observed by a research assistant. Notes were taken by both and the sessions were recorded and later transcribed. After each focus group, a reflective essay was written by the researcher, to capture observations, the mood, social interaction and initial thoughts [11].

D. Data Collection and Sampling

The focus groups sampled all students in the School from the second, third and final years of study where failure rates are still high even though students have already passed their first year of study. This suggests that the transition from school to university is not the core reason for the lack of student success and that interventions and support in the first year are not necessarily long-term or create sustainable changes in students which extend into their higher years. The study is also not focused on any particular course or module as it is believed that student experiences and associated responses to assessment manifest at a holistic level. Four separate groups of students were chosen for the focus groups using maximum variation sampling [13] – a high-performing group, a low-performing group, a mid-performing group and a group of students categorised as turnaround students. The turnaround students were students who performed exceptionally poorly in one year followed by a year when they performed particularly well. The reason for choosing the groups in this way was twofold. Firstly, due to the wide performance range in the original data set, it was anticipated that some students might not be comfortable speaking out in a group where their performance was significantly different to others in the group. Secondly, it was hoped that further insight could be gathered on how students experience assessment differently. This could prove useful in understanding the relationship between different approaches, experiences and assessment performance. To categorise students, academic records were obtained, and all students were ranked based on the total number of subjects that they had failed in their second year of study (results were extracted as of July 2018). The population of students, therefore, included second, third and fourth-year students although the number of subjects failed by these students corresponded to every student's second year of study. Emails were then sent to students from all groups inviting them to be part of the focus group on a specified day. The number of emails sent out was increased until 5-10 students [11,14] consented to be part of each focus group.

A total of 22 students participated in the focus groups. Details of the focus group participants are included in Table I. The performance characteristics for the group (aggregate and number of subjects failed) corresponds to their second year of study. The current year of study is also shown for each group. The high-performing group does not include any second-year students since no current (2018) second-year student had completed their second year when the data was collected. For this group, high-performing students currently in their second year of study were identified (based on the mid-year results) and invited, but no students agreed to participate. The turnaround students were chosen by analysing their marks for two subsequent years of study. The characteristics of the emailed students, the number of students emailed and responses received are included in Table II.

***TABLE I** Participant details for the mid, high and low – performing groups*

- PERFORMING STUDENTS	HIGH	MID	LOW
No. of students invited via email:	50	66	34
No. of students who participated:	5	7	7
% of invited students who agreed to participate	10%	11%	26%
No. of subject fails in second year:	0	2-3	8-12
Aggregate percentage in second year - Range:	80 - 90 %	42 - 63 %	37 - 54 %
Aggregate percentage in second year - Average:	82.3%	53.5%	44.5 %
Distribution of students per current year of study:			
2nd year	0	2	4
3rd year	4	4	1
4th year	1	1	2

***TABLE II** Participant details for the turnaround group*

TURNAROUND STUDENTS	
No. of students invited via email:	4
No. of students who participated:	3
Average No. of fails in second year - First attempt	7.7
Average aggregate in second year - First attempt	56%
Average No. of fails in second year - Second attempt	0.7
Average aggregate in second year - Second attempt	66.9%
Average number of distinctions (over 75%) - Second attempt	2
Average rank in class - Second attempt	Top 15 %

E. Data Analysis

The analysis incorporated both the individual voice and the collective voice [15]. The voice of the individual within this research enables the researcher to explore differences between students as well as determine to what extent individuals can be summarised as a collective voice [16]. The analysis, therefore, considered three core aspects: the individual, the group and group interactions [17].

Each focus group was initially analysed individually by reading through the transcript in conjunction with the notes and reflective essay identifying emerging codes, key supporting quotes (or evidence) and making personal notes where appropriate. This provided a rich overview of the focus group, considering the process, individual ideas and the group interactions. This process was repeated for each focus group, comparing and adding codes when required. The identified codes and evidence were then captured into a case study database [18]. To organise the data for analysis purposes, it was clustered into topical categories [11]. Once data from all four focus groups had been captured a comparative analysis was carried out across the four focus groups for each category capturing similarities and differences. The identified codes under each category were then summarised, compared and, where possible, reduced until a final set of preliminary themes into which all codes could be grouped was obtained. These themes were arranged in a mind map to sequence the data and create relationships to facilitate the process of discussing the data logically. To address the credibility of findings, rich descriptions and evidence were used to support claims and efforts were made to avoid being selective or distorting data when presenting findings. Surprising or 'outlying' evidence was investigated, and rival explanations were considered when interpreting data by constantly referring to literature [13]. Peer review was used at several key points to challenge interpretations and raise further alternative views [11].

F. Introduction to the Findings

Reflecting on the process observations made during the focus groups, it was noted that all participants contributed to the discussions. While participants often agreed or reinforced the ideas of others, there were situations where participants openly disagreed with each other suggesting that participants felt free to participate and did not feel pressured to have a particular opinion by either the facilitators or fellow participants. It was easy to tell when there was consensus around any participant's response, with laughter being the most common way for students to indicate that they could relate to and agree with what someone was saying. Other ways of telling how the group was responding to any participant were through the nodding of or shaking of heads. Many students were particularly honest during the focus groups often sharing very personal and emotional experiences.

Selected, emergent themes are presented in the following section. Quotations are used to provide evidence referenced back to the corresponding focus group as follows: FG1- mid- performing students, FG2- high- performing students, FG3- low-performing students and FG4- turnaround students.

IV. FINDINGS

A. Planning, prioritisation and studying for passing

Participants described how they approached their studies on a week-by-week basis during the term. The dominant discussion for all groups centred around the planning and prioritising of work. The degree to which planning takes place and the time horizon seems to be a significant difference between the groups, reinforced by the turnaround students who indicated that one of the critical shifts in their weekly studying routines was towards a more planned approach. Participants elaborated that work was typically prioritised based on the marks or course weighting for the assessment task. Another factor that plays a role in the prioritisation of work is the perceived "value" that tasks have for students. It emerged from the interviews that students sometimes struggle to connect the purpose of assignments with the purpose of the tests and exams and due to prioritisation, they are hesitant to spend time on work for an assignment if they do not feel that they will "need" it in the exam. The following quotation reveals several interesting ideas:

> *"Some courses are structured such that the assignments that they give you are stuff that they can't test in a written test, and usually in those particular situations the stuff that you do for the assignments you won't need for the exam. ...those types of assignments usually get sent to the back of my list because they're not part of the core material of the course and they won't help me with the test and the exam. Whereas with some assignments, ...the assignment is linked to what you're given in the test and linked to what you'll get in the exams, so doing the assignment is actually helping you prepare for the test and the exam as well. So I tend to like to focus on those." (FG3)*

Students therefore appear to dedicate more time and effort to assignments that are seen to support the learning process of preparing for exams. Despite valuing assessment geared for exams, participants also described how these assessments tend to compromise understanding, resulting in a series of behaviours that revolve around trying to replicate answers to problems without an in-depth understanding. Students said that they dedicated many hours to practising problems, rote learning approaches to solve standard problem types that are likely to come up in tests or exams rather than trying to gain a deeper understanding of core material. These "practising" behaviours resonate with procedural approaches to learning [19] where students have a clear intention to merely reproduce knowledge and procedures [20].

> *"...and if you get hold of the answers, you just look at the common thread throughout the answers, and then you try and formulate your answers based on that." (FG1)*

> *"If I don't understand something... I normally divert to just doing problems then at least even if I don't understand it but if I'm given an equation then I might be able to solve it." (FG3)*

These procedural approaches, across focus groups, spill over to other facets of the teaching and learning process with participants adopting more strategic approaches to learning, lectures and the purpose of worked examples. Attention becomes more about the method that needs to be replicated than the concept that is illustrated in a particular application. This participant describes the value of worked examples used in class:

> *"...because that's where they actually show us like what method we're supposed to use." (FG2)*

A theme that emerged was the notion that students were *studying for passing* rather than *studying for learning*. This was prevalent in all groups, with the act of studying for passing approach selected as a conscious tactic for the high and mid-performing students and being used more as a survival tactic for the low-performing students.

Participants start to shift their entire perspective of a deeper approach to studying and learning. The focus becomes what needs to be known to pass a particular assessment rather than a holistic view that incorporates and synthesizes the skills and knowledge needed to address problem-solving tasks in the profession.

Participants struggle with this shift as they compromise their desire for meaningful engagement in order to 'get through' all the material that they need to.

> *"In second year, I wanted to know, but I ended up knowing more than I had to know. But I ended up being like confused as to what I had to know." (FG1)*

> *"I remember talking to people who had been here, I remember this guy. So he once told me that, whatever you need to know, just know. But some of the things that you know you don't have to understand. Just do it because you have to.... Okay, you don't*

know how this thing, why you solved it this way, don't go into knowing why, just do it that way and get the answers." (FG1)

Despite this shift in perspective towards a studying for passing mindset, many participants acknowledged discomfort with this approach suggesting that they would prefer to grasp the material and build their understanding but feel constrained by the environment in which they find themselves.

"I wouldn't spend time on a subject that doesn't have an exam or an assignment over one where I need to pass. Ja, it's not who I am but because of time and pressure, I sort of gravitate towards and end up doing that just because I have to pass." (FG1)

Furthermore, the general performance of students in assessments School suggests that these approaches to studying do not enable students to master concepts and do well in tests and exams. A participant described this process as follows:

preparing for a test, *"...we did all the question papers they gave us, we did all the question papers and then we were so confident only to go to the test and it was so hectic. So it was really a dramatic end..." (FG1)*

B. Assignments, the real world and group work

Participants generally indicated a preference for extended assignments as they are perceived to be less stressful as the time available to work on them is longer. Participants explained that as a result, they gained a better understanding of concepts.

"I think assignments are valuable because there's usually like a lot of time, or enough time allocated so...you have...well, I've found that I have...it's easier for me to learn concepts and put them into practice in an assignment as opposed to...in another setting...because, I don't know, I feel like I learn better when I'm not under pressure. So with assignments I feel like they just work better for me because I have had enough time to read up on stuff and, you know, and discuss things with my classmates." (FG3)

Participants also really value the practical work-based nature of assignments that give them a better sense of relevance to the real world and the engineering profession.

"I think they expose you and then like encourage you to also be able to try to find out some things even those you are not studying what they are... so I think it's exposure." (FG3)

"I think assignments are better because they help you apply and you get to see, okay, how does what we're learning apply to the everyday world." (FG2)

"You're getting more like practical approaches to whatever you're being taught." (FG4)

An aspect of assignments that students struggle with is group work. Many assignments are group projects, and this has an impact on how students view and are able to learn from these assignments. Group assignments involve several individuals, and as a result, this affects the control that students have over time management and scheduling. This was raised by participants as one of the features of group assignments that they found most difficult to manage.

"We had a lot of group assignments this year and time management has been an issue always." (FG3)

"I think assignments are a bit tough because if it's a group project then you can try and schedule it, but sometimes you don't stick to it because there's other people's schedules." (FG4)

More importantly, however, many participants expressed the view that they struggle to work productively in groups. This was more prevalent in the lower-performing groups who articulated that although they see the development of these skills as essential, that they battle with the learning process. There appears to be a insufficient scaffolding to provide students with the necessary skills and facilitate the process of working in teams.

"I think a valuable skill is learning how to work with people, learning how to get information from people and I think that in the university setting, you know, the best way to learn that is through group work. And I think that is, in that sense, assignments are really good in forcing...in giving the students that skill...for a lot of students it's overwhelming....you don't know how to deal with all these different kinds of personalities, and everything is just happening all at once. So I think that it's something that should be like introduced gradually from first year." (FG3)

Some participants described negative experiences with group work that also appears to affect their overall self- confidence and motivation.

C. Tutorials, marks and getting help

Participants' experiences of tutorials are complex with some groups indicating that tutorials are one of their most valued assessment methods while other groups revealed that these are their least favourite. Although there are students who said that they would not attend tutorials if they did not count for marks, introducing marks adds stress to the learning environment of a tutorial and hinders the learning process of those who need to and want to attend. Most participants suggested that tutorial sessions are the most useful means of assessment as tutorial sessions facilitate significant conversations between students and lecturers or tutors.

"Some tutorials are more useful, when they are not for marks and actually reinforce the material...and you can get help, it's like a consultation because there is an opportunity if there is something that you don't understand." (FG1)

For participants who find it challenging to approach lecturers, the tutorial environment seems to break down some of these barriers, making it easier for students to approach lecturers with questions.

"I haven't always been one to consult one-on-one with the lecturer but I've found that in a tutorial environment it's very relaxed. It's easier for me to ask questions from the tutors...even from the lecturers, I don't know why but it's just...I just feel like it's a lot less intense. (FG3)

There are affordances in assigning marks for tutorials as it breaks down the process for students who are not able to ask for assistance or work through problems in smaller groups. There are some participants, mainly from focus group three, the low-performing group, who seem to lack the self- regulation to keep up with work and the tutorial sessions become a form of "guided homework" that structures their studying and "forces" them to keep up with the material.

"If tutorials are weighted then like you are forced to work, like to always prepare for it. So staying up to date with the course content it's easier that way." (FG3)

Although it is important to ensure that students keep up to date, it appears as if some participants become reliant on the "forced" tutorial environments, and might struggle in higher years where students are expected to exercise more independent learning skills. There appears to be a lack of agency and the development of lifelong learning skills in some participants. As a result, the tutorials "for marks" in lower years reinforce this tendency especially since there is no scaffolding that gradually diminishes support and structure for enabling self-directed learning. independence.

V. CONCLUSIONS

The findings of this study on student perceptions of assessment practices confirm that assessment plays a critical role in determining the planning and prioritisation of study processes and student learning strategies in this engineering context. The intention of students when choosing learning strategies is strongly influenced by their perceptions of the assessment environment and can lead to the adoption of surface approaches to learning. This, in turn, can undermine the development of lifelong and sustainable learning skills [6]. Excessive workloads, increasingly large undergraduate classes and inadequate teaching resources in higher education can further amplify unproductive approaches to learning. The authenticity and relevance of assessment tasks also influence student engagement and motivation.

Participants in the study emphasised how they saw real value in written assignments and preferred them to other assessment methods because of their flexibility and potential to facilitate learning. Participants also felt that assignments were more authentic and gave them better access to developing skills needed for the real world. There appears to be insufficient scaffolding for the development of group skills needed for these assignments. It emerged from the interviews that this could lead to experiences that affects the self-confidence and motivation of many students, particularly those who are already struggling. The issues around group work hinder students' ability to develop effective teamwork and communication skills This has implications for the design of assignments, especially if the development of group skills is a valuable competence that is facilitated through learning - oriented methods of assessment [5].

Tutorials are one of the few formative assessment practices that the School has established and have the potential to create collaborative spaces that facilitate interaction between students and lecturers [4]. Tutorial sessions are being used by students to approach lecturers and obtain feedback as a result of reduced barriers in these more informal settings. Forcing attendance at tutorials by creating a testing-oriented environment destroys this possibility and closes down alternative learning possibilities. Most importantly, it removes one of the few learning spaces that assist many students in the School, particularly those who struggle with the pace and workload. Although tutorials are often seen as a very useful formative assessment process, the current purpose and structure of tutorials is not meeting diverse student needs and is therefore not supporting learning consistently.

Although participants find themselves adopting *studying-for-passing* behaviours, there is evidence that they have a strong desire to move towards practices that develop deeper levels of understanding.

This study shows that the selection and design of assessment strategies and tasks has a significant impact on student learning and that there needs to be constructive alignment [5] between assessment, the curriculum and teaching design if a shift in learning is to occur. This study provides valuable insights that can be used to transform assessment practices and address the divide between formative and summative assessments. The recognition of student experiences of assessment through such studies will provide a better structure for student access, engagement and success in engineering and higher education contexts.

REFERENCES

[1] Gibbs, G. "How assessment frames student learning." In. Bryan, C., & Clegg, K. (Eds.). Innovative assessment in higher education. Oxon: Routledge, 2006.

[2] K. Sambell, L. McDowell, L & C. Montgomery. "Assessment for learning in higher education." London: Routledge, 2013.

[3] D.Carless. "Exploring learning-oriented assessment processes". Higher Education, 69(6), pp.963-976, 2015.

[4] H. Fry, S. Ketteridge & S. Marshall. "A handbook for teaching and learning in higher education: Enhancing academic practice". Third Edition. New York: Routledge, 2009.

[5] J.B. Biggs. "Constructive alignment in university teaching". HERDSA Review of Higher Education, 1(5), pp. 5-22, 2014.

[6] G. Gibbs & C. Simpson. "Conditions under which assessment supports students' learning". Learning and Teaching in Higher Education, 1, pp. 3-31, 2004.

[7] L. Scott & C. Fortune. "Towards the improvement of the student experience of assessment and feedback in construction management education". European Journal of Engineering Education, 38(6), pp. 661-670. 2013.

[8] S. Bloxham & P. Boyd. "Developing Effective Assessment In Higher Education: A Practical Guide". London: McGraw-Hill Education, 2007.

[9] Hattingh, T., Dison, L., & Woollacott, L. "Student learning behaviours around assessments". Australasian Journal of Engineering Education, 24(1), 14-24. 2019.

[10] Hattingh, T.S., Dison, L. "Why lecturers in an engineering School assess the way they do". Research in Engineering Education Symposium, July 2019, Cape Town, South Africa, 2019. Available at: https://www.reen.co/papers-proceedings. 2019.

[11] S.B. Merriam. "Qualitative Research: A guide to design and implementation". San Francisco: Jossey-Bass, 2009.

[12] G. Gibbs. "Analyzing qualitative data". London: Sage, 2007.

[13] L.Cohen, L.Manion & K. Morrison. "Research Methods in Education", 7th Edition Oxon: Routledge, 2011.

[14] J.W.Creswell. "Educational Research: Planning, conducting and evaluating quantitative and qualitative research", 4th Edition, Boston: Pearson Education, 2012.

[15] S. Wilkinson. "Focus groups: A feminist method". In. S.N. Hesse-Biber& M.L. Yaiser (Eds.). Feminist perspectives on social research. Oxford: Oxford University Press, 2004.

[16] R. Barbour. "Doing focus groups". Thousand Oaks: Sage, 2008.

[17] K. Willis, J. Green, J. Daly, L. Williamson & M. Bandyopadhyay. "Perils and possibilities: achieving best evidence from focus groups in public health research". Australian and New Zealand journal of public health, 33(2), pp. 131-136, 2009.

[18] R.K. Yin. "Case study research: Design and methods". 5th edition. Thousand Oaks: Sage, 2014.

[19] J. Case & D. Marshall. "Between deep and surface: procedural approaches to learning in engineering education contexts". Studies in Higher Education, 29(5), pp. 605–615, 2004.

[20] K. Crawford, S. Gordon, J. Nicholas & M. Prosser (1994). "Conceptions of mathematics and how it is learned: The perspectives of students entering university". Learning and instruction, 4(4), pp. 331-345, 1994.

Technical Papers

'Assessment as Learning' as a tool to prepare engineering students to manage ill-defined problems in industry

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***Abstract*—Under-preparedness of engineering students to solve ill-defined problems in industry is a significant shortfall in Higher Education (HE). The root cause of under-preparedness is, 'problems' that need to be resolved in workplace settings in the real world are notably different to traditional textbook problems presented in class. Thus, a transformation in pedagogical approach is needed in HE as industry problems are often more complex and are commonly poorly defined. Against this backdrop, a redesigned assessment strategy in an Applied Statistics class for final year students at a University of Technology (UoT) presented an opportunity to re-think traditional assessment methods.**

An assessment strategy was designed as an intervention which included a series of online self- and peer-assessments (formative online assessments under guidance of the lecturer) which culminated in development of a final industry style report with a potential solution to the problem. The aim of the teaching intervention was to promote metacognition and thereby improve students' problem-solving skills. Prior to the commencement of this study, ethical clearance was requested and obtained through institutional channels.

The results of this study demonstrate that the 'assessment as learning' (AaL) teaching intervention enjoyed a certain degree of success, as the findings were AaL facilitated metacognition in students which is vital to solve ill-defined problems. This research also confirmed the importance of feedback during an AaL project and foregrounded the critical role of the educator in an AaL project. It is proposed that this research serves as a pilot study since the findings of this research are capable of providing a foundation for an improved AaL teaching intervention. The paper concludes with implications and limitations of the study and recommendations for future research.

Keywords—Assessment, Metacognition, Feedback, Graduate attributes

I. INTRODUCTION

'Assessment as learning' (AaL) is defined by Jones [1] and Manitoba [2] as the use of ongoing self- and peer-assessment by students in order to monitor their own learning. This process is characterized by students reflecting on their own learning as part of an assessment and making adjustments so that they achieve deeper understanding. Aurah, Koloi- Keaikitse, Isaacs, and Finch [3] refer to this as 'metacognition' and explain that that metacognition is an important dimension of problem-solving. It entails having an awareness of one's own heuristic techniques which is, thinking, monitoring and regulation of self-cognitive processes. They assert that metacognition is a good predictor of problem solving ability. Underpinned by this, metacognition which occurs during AaL is believed to be the fundamental exercise that takes place in students, that equips and assists them during the process of finding solutions to ill-defined problems, and thereby makes them more valuable and sought after by industry.

Thus, this paper is aimed at evaluating the effectiveness of AaL from a student perspective, and describes the pedagogical context, methodological approach and the results of a teaching intervention in an engineering department at a UoT where an AaL strategy was used prepare engineering students to adequately manage and solve ill-defined problems in industry.

II. THEORETICAL FRAMEWORK

The foregoing commentary draws attention to the concepts that need to be defined in the context of this study. These concepts are 'ill-defined problems', 'metacognition during AaL', 'the impact of feedback on AaL' and 'the educator's role to facilitate AaL'. Thus, a theoretical discussion on these concepts which are regarded as influential, as well as important contextual variables to this study, follows below.

A. Ill-defined problems

It is commonly accepted that problems of the 'real world' are ill-defined [4], [5], [6],[7],[8] and the resolution of these problems require skills that go beyond discipline specific (engineering) skills, such as: identification and acquisition of contextual information, recording of relevant information, dialog with problem owners and team members in a problem- solving team, which may have to be multidisciplinary, and the analysis of the problem constraints and barriers. Moreover, Reisfield [4] argues that when comparing the procedural steps of solving a well-defined text book type engineering problem, to that of a poorly-defined problem such as one would encounter in industry, a glaring omission is the checking and verification of results in the former procedure. By implication, if the initial solution devised is not suitable, this would signify the start of additional problem-solving process. Significantly, he adds that several iterations may be required.

Reisfield [4] and Pan, Strobel and Cardella [6] claim that due to this, there is a shortfall in the training of engineering students as consequently, they are only trained to solve only textbook problems. In terms of pedagogy, it is not sufficient to rely on a 'transmission of knowledge' approach, which relies heavily on regurgitation of facts and concepts and the solution of routine problems or exercises. The authors advance that this type of approach targets only lower-order cognitive skills, however ill-defined problems have, among other things, conflicting goals, various solutions, and different types of constraints that require which require more specialized training.

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This is aligned with the view of Arifin, Zulkardi, Putri, Hartono and Susanti [9] who reported five capabilities (attributes) which newly graduated attributes must have in order for them to add value to an employer. These are communication skills, the ability to reason, organize, define and understand a problem, the ability to connect, gather analyze and interpret data, the ability to document and present results and the ability to be able to project-manage the overall problem-solving process.

With specific reference to 'teaching students how to resolve ill-defined problems', Mendonca et al. (2009) assert that educators need to employ a combination of strategies that are different to traditional teaching strategies to successfully achieve this. These authors propose that students use a framework which includes five sequential steps. These steps are 'exploratory reading', 'interpretation', 'information acquisition', 'analysis' and 'organization'.

Step one, 'exploratory reading' involves the comprehension of language and the identification of specific terms that specify the problem. During step one, information that is important and relevant must be extracted. All ambiguities and contradictions in the problems statement and background are identified and information that is lacking is noted. Mendonca, de Oliveira, Guerroro and Costa [7] explain that step two, 'interpretation' involves the contextualization of relations between relevant information of the problem. In this step the client (problem owner) must be identified and the client's needs clarified to be able to solve the problem.

According to Mendonca, de Oliveira, Guerroro and Costa [7], step three, 'information acquisition' consists primarily of observation, an information search and dialog with the client. Step four, 'analysis' explores and attempts to delineate the constraints and boundaries of the problem. This includes the investigation of possible errors that may occur and, in this step, inferences are also made. Finally, in step five, which is referred to as 'organization', information is organized and registered and the problem statement is updated to clarify the client's needs. Although more commonly used in the information technology discipline, Mendonca, de Oliveira, Guerroro and Costa [7] opine that the use of this framework can assist students in any discipline, by enabling them to systematically recognize ambiguities and thereby clarify an ill-defined problem rather than make assumptions. This approach encourages students to explicitly ask questions about ambiguous issues, critically reflect and work together as a team when used by a group.

The above-mentioned steps is consistent with an assertion by Reisfield [4] who eleven year later proposed similar steps for solving poorly-defined problems, which are 'define the problem', 'list the possible solutions', 'evaluate and rank the possible solutions', 'develop a detailed plan for the most attractive solution(s)', 're-evaluate the plan to check desirability', 'implement the plan' and importantly, 'check the results'.

Significantly, Cardella and Tolbert [10] and Aurah, Koloi- Keaikitse, Isaacs, and Finch [3] advance that 'reflection' is the key to the holistic professional development of students. They advocate the use of several reflective stages in student academic projects to teach students to solve problems. Aurah, Koloi-Keaikitse, Isaacs, and Finch [3] specifically concluded that ***"students with high metacognitive ability are good at solving problems"***. This foregrounds the importance of developing teaching strategies which facilitate metacognition to adequately prepare students to solve ill-defined problems.

B. Metacognition during 'assessment as learning'

When assessment is designed with purpose (such as the above-mentioned) in mind, learning for all students can improve [2]. Engineering educators have traditionally relied on assessment that compares students with more successful peers as a means to motivate students to learn. This traditional approach has been described by Jones [1] as 'assessment of learning'(AoL), where students are only summatively assessed after content has been covered in class. Recent studies suggest however that students will likely be motivated and confident learners when they experience progress and achievement during AaL, rather than the failure and defeat associated with being compared to more successful peers in AoL. For this reason, an AaL project (rather than AoL) may be designed to promote critical thinking and learning in engineering students during an iterative formative project process. As opposed to AoL, AaL helps students to take more responsibility for their own learning and monitoring future directions as depicted in Figure 1.

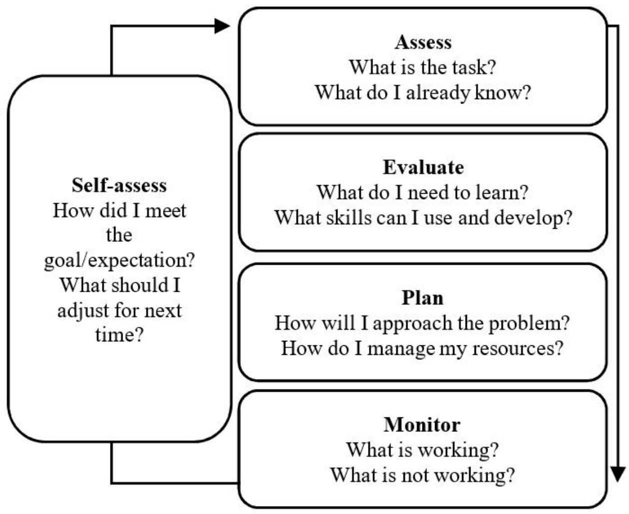

FIGURE 1 *Self-regulated learning cycle [11]*

Siegesmund [11] asserts that metacognition is an integral part of self-assessment. Self-assessment is a reflective process where students use criteria to critically evaluate their performance and determine how to improve. The author proposes a selection of assessment strategies that may be used to facilitate this in students, and while she does not mention specifically peer assessment, a review of her research indicates that both self- and peer-assessment may be used to provide a learning environment where students feel empowered and safe to explore their strengths and weaknesses.

Heick [12] argues that an educator's decision to use AaL as opposed to AoL in a classroom environment is tantamount to purpose. Her view is aligned to that of the Directorate of Learning and Assessment Programmes [13] who affirm that through the process of AaL students not only gain discipline specific knowledge, but they also learn how to take more responsibility for their own learning as they discover how to monitor their future directions. From this perspective it may be considered that AaL is not only a tool to enable learning and the transmission of knowledge, but also an effective tool for the development of graduate attributes (soft skills) that are equally important to help students solve ill-defined problems in industry.

C. The impact of feedback in 'assessment as learning'

Dann [14] advances that a key feature of AaL is feedback, wherein educators explicitly teach students to become effective self-assessors. Through this process they become empowered to take charge of their own learning, which is a necessary skill for lifelong learning.

This is consistent with the opinion of Directorate for Learning and Assessment Programmes [13] who explain that feedback from educators as well as peer feedback may be regarded as fundamental in the AaL process. For most students, it's recommended that peer assessment precedes self- assessment, though some students may be able to engage in the two processes simultaneously. As with peer assessment, self-assessment takes time and practice and educators need to explicitly teach and model how to self-assess before students are expected to use self-assessment effectively.

Further research by Dann [14] suggests that it is advisable for educators consider how students interpret and understand feedback obtained from AaL, from the students' self- regulatory and self-productive perspective, and how vocabularies for assessment can be more collaboratively shared in learning contexts. Essentially, she illuminates that student feedback requires educators to give as much attention to the interpretation by pupils, knowing that students will first have to make complex decisions about how they are to use the feedback and then only engage with the learning priorities of the classroom.

D. The educator's role in 'assessment as learning'

The preceding discussion underscores the importance of the educator's role in AaL. Careful consideration of the feedback required during AaL is however only one aspect of the role that educators fulfill during the process of AaL.

Directorate for Learning and Assessment Programmes [13] and Manitoba [2] believe that it is the duty of educators to guide students in developing monitoring mechanisms for the internal reflection practices. By doing so, educators become instrumental by assisting students with the validation of their self-reflections. This allows students to question their own thinking in a safe environment, where the implications of being unsuccessful is not as severe as in industry. This teaches them to become comfortable with ambiguity and uncertainty - something which is inevitable when learning anything new, while allowing students to build simultaneously confidence. A deduction that is made from the review of this literature is that students' being comfortable to operate in such a position is valuable training for being able to solve ill-defined problems, such as those which need resolution in industry.

III. METHODOLOGICAL APPROACH

This research took place from July 2019 until March 2020 when students in a final year applied statistics class were divided into project teams and given two different ill-defined problems. The first problem was solved in the first problem- solving stage, which took place over a period of four weeks through a scaffolded process. Each week students were given some contextual information; however, some information was deliberately withheld, prompting students to ask relevant questions and search for appropriate information which would enable them to solve the problem. All students gave each other peer-feedback after each submission, but students were also given both individual feedback and group feedback from the lecturer. Working in groups, the students needed to try to identify the root cause of the problem and thereafter identify and use appropriate statistical tools to solve the problem, before performing a risk assessment as a final step to ensure that the problem does not recur. No grades were allocated for the first problem-solving stage, as the purpose of this stage was formative assessment. Following the completion of the first problem solving stage (and resolution of the first ill-defined problem), the students were given a more complex ill-defined problem in a second problem-solving stage. The same procedure to resolve the problem was followed in the second problem-solving stage, however the second problem-solving stage lasted eight weeks.

Following this teaching intervention, a mixed method approach was used to collect data in the form of student perceptions on the impact of the intervention. Quantitative data collection commenced in November 2019 with an online survey (n=31) and consisted of 17 survey questions including six Likert scale questions and three open-ended questions to obtain a deeper richer understanding of students' perceptions on the experience. Alpha Cronbach's coefficient was used to ensure internal validity of the Likert scale questions. Thereafter, survey data was analyzed using SPSS and was examined to explore three constructs associated with AaL namely, 1) student metacognition; 2) the role of feedback in assessment 'as' learning and 3) educator role in assessment 'as' learning. Responses to the three open-ended survey questions were examined to detect recurring themes.

The findings of quantitative data analysis provided the basis for the development of the qualitative data collection instrument, thus a focus group interview (n=6) took place in February 2020. Qualitative data analysis took place in March 2020. To eliminate bias and ensure validity and reliability of results the interview and transcription was done by a colleague who was not part of this research project. Qualitative data was coded and thematically analyzed. The codes and code families for the thematic analysis were derived from the objectives of this study. The design of this cross-sectional study was geared towards gauging student perception as preliminary research for a further longitudinal study, which has been planned to evaluate industry perception of the outcome of this teaching intervention. Ethical clearance for this study was received prior to data collection, through institutional channels.

IV. RESULTS AND DISCUSSION

A. Student metacognition

The results of quantitative data analysis highlights that only 35% of the students believed that this teaching intervention was successful. When this was qualitatively probed, it became apparent that this intervention was plagued by several technological challenges which detracted from the original project objectives. This was articulated by Student A who said ***"...But a lot of the students got caught up in the technological challenges – so how to use Blackboard, or when to update stuff and how to update stuff, so they lost the focus of actually solving the problem of the practical test and spend most of their time trying to challenge the technology and get that right".***

All the students who partook in the focus group interview however agreed that that 'trial run' first problem-solving stage was very important for the success of this intervention as Student B described this as "ideal preparation". Significantly approximately half (48%) of students reported not being able to see the value of peer-assessments which were part of this intervention, however 67% of the students said that self- assessment aided their own development and promoted metacognition. Student C stated ***"The self-review helped me to reflect and also express thoroughly my line of thought, why I made certain decisions and my understanding of the task. Working in groups is challenging but it helped me with personal development goals, soft skills part of personal development".***

For the group work component of this intervention, 45% of the students said that they reflected on the solutions to the various stages of the ill-defined project and 41% reported reflecting on the procedure that was followed by the group to derive the solutions. This was notably different to individual component of the intention as 78% of students said that they reflected on their individual solutions and 56% of the students reported reflecting on the process that they followed as individuals to derive the solution to the ill-defined project.

This finding is consistent with the claim by Siegesmund [11] which is that metacognition is an integral part of self- assessment, which is the reflective process where students use criteria to critically evaluate their performance and determine how to improve. Thus, a deduction made from the results of data analysis was that student engaged in deeper metacognition when preforming a self-assessment, rather than when working in groups. This was confirmed by the focus group interview by Student C who said ***"On my side, I was more critical towards myself. According to my experience with the project that we were doing, we learnt to work in groups or teams where everyone has to come up with his or her own ideas, so this was also giving us some experience with coming up with ideas, trying not to reject other person's ideas.***

It is worth noting that 87% of the students reported that if they were not instructed to perform self-assessments as part of the teaching intervention, they would not have critically reflected on their own work. With respect to metacognition, the students in the focus group confirmed that it facilitates solving ill-defined problems as it ***"trains us to looks [at] all perspectives"*** (Student A) and ***"bring in new ideas and see the problem from a different angle... ...It allows you to think out of the box and as a consultant"*** (Student D). Ultimately, a finding of this study is that using AaL promotes student perception of metacognition. Literature suggests that metacognition is a key ingredient to be able to solve ill- defined problems such as those which are expected will be encountered by students when working in industry and therefore another finding of this study is that steps be included in the teaching and learning process that elevates student awareness of metacognition.

B. Impact of feedback on 'assessment as learning'

The results of both the quantitative and qualitative data analysis highlight the importance of feedback to the AaL process. Survey results were that 31% of the students who took part in the teaching intervention wanted more feedback (peer and lecturer feedback) than what they were given. In addition, some responses to an open-ended question in the survey which asked students about what they valued about the intervention were ***"Brainstorming with group members" and "I had an idea in my mind on how the outcome should be, but different ideas from certain group members expanded my view".*** While these were not direct references to feedback, this study deduced that these forms of indirect feedback were also regarded as valuable to the students.

In the focus group interview some students expressed frustration at getting too little feedback from their peers. For example, Student E said ***"I was not happy that students who reviewed my work gave a mark for the work, but they did not give me any comments". Student C and Student F agreed with this. Student C commented "The mark was not so important because it was not a final mark, but it doesn't help if you cannot see where you went wrong or how to fix it".***

The results of this data analysis on the impact of feedback on AaL are consistent with the view of Dann [14] which was previously discussed. Complex skills, such as monitoring and self-regulation which are required to solve ill-defined problems, become routine only when there is constant feedback and practice using the skills. Effective feedback challenges ideas, introduces additional information, offers alternative interpretations, and creates conditions for self- reflection and review of ideas.

Essentially, feedback in AaL encourages students to focus their attention on the task, rather than on getting the answer right. It provides students with ideas for adjusting, rethinking, and articulating their understanding, which will lead to another round of feedback, and another extension of learning.

C. Educator's role in 'assessment as learning'

Shifting the research lens to the role of the educator in this teaching intervention, 43% of the students indicated that they experience this teaching intervention as a complicated task. One response to an open-ended question in the survey which asked students to reflect on the educator role was ***"The project was in my opinion too tedious and one never could fully grasp what was really expected. Instructions were vague, not explicit, and did not give enough information to lead you to the critical outcomes that were expected with each task".*** While this student did not specifically mention the educator role, this study deduces that this student wanted more guidance from the lecturer. Interestingly, one student expressly articulate unhappiness at the piecemeal design of the teaching intervention, stating ***"The method of questioning to acquire solution to the problem, that is bits and pieces of information which could have been requested on one go".***

Analysis of data obtained from students confirmed that the success of this intervention heavily relies on educator engagement and support due to the complex nature of this type of AaL intervention. This corresponds with the opinions of Directorate for Learning and Assessment Programmes [13] and Manitoba [2] claim that it is duty of educators to guide students in developing monitoring mechanisms for the internal reflection practices during AaL, and equally important, also create a safe space for them in which to do that.

V. RECOMMENDATIONS FOR FUTURE RESEARCH

This research study was aimed at the examination of 'assessment' as a form of learning, and also as a mechanism to teach students to solve ill-defined problems while simultaneously developing graduate attributes such as communication skills, relational skills and global vision. While this project enjoyed a certain degree of success, as the findings were AaL facilitated metacognition in students, which literature indicates is vital to solve ill-defined problems, it is proposed that this project serve as a pilot study as the findings of this research is capable of setting the foundation for an improved AaL teaching intervention. Another finding of this research is that steps be included in the teaching and learning process that promote student awareness of metacognition. This research also confirmed the importance of feedback during an AaL project and foregrounded the role of the educator in an AaL project.

Aside from the research findings which are mentioned above, it is unknown to what extent students will be able to use the skills which they developed during the course of this project, in industry. Therefore, a proposed recommendation of this study is that that be explored. This study has also illuminated important consideration around the role of the educators who facilitate an AaL project and highlighted certain questions such as "what else can be done to more adequately prepare final year engineering students to take part in an AaL teaching intervention such as this, to ensure maximum success and the development of desired graduate attributes in them?" and "what be done to control or to simplify the e-learning technology used during the project, which hindered student progress in this intervention?" It is also important to note that this small case study was conducted at one department in a faculty at a UoT, and thus these findings cannot be generalised to all situations at different universities.

VI. CONCLUSION

The ability of industry-based engineers to demonstrate independence and initiative in problem-solving and develop practical and innovative solutions is a critical factor to the success of organizations in the fast-changing global economy [6], [9], and this research has showcased an AaL teaching intervention which is enjoyed some success in preparing final year engineering students to solve ill-defined problems in industry. The results of this study form the basis for further recommended research.

REFERENCES

[1] B. Jones. "Assessment of, for and as Learning" Curriculum Officer Workshop in Cape Town: Cape Peninsula University of Technology Bellville Campus. 2019.

[2] Manitoba Education. (2019, September 4) Rethinking Classroom Assessment with purpose in mind [Online]. Available: https://digitalcollection.gov.mb.ca/awweb/pdfopener?smd =1&did=12503&md=1

[3] C. Aurah, S. Koloi-Keaikitse, C. Isaacs and H. Finch. "The role of metacognition in everyday problem-solving among primary students in Kenya" Problems of Education in the 21st Century 30 (2011) 9 - 21. 2011.

[4] B. Reisfield. (2020, June 15). Engineering Problem Solving [Online]. Available: https://www.engr.colostate.edu/CBE101/topics/engineering_problem _solving.html

[5] M. Balbles. (2020, July 14) Dealing with poorly defined problems in an agile world. [Online]. Available: https://adtmag.com/articles/2017/05/16/poorly-defined-problems.aspx

[6] R. Pan, J. Strobel and M. Cardella. 2014. "Engineering Students' Experiences of Workplace Problem Solving." in 121st ASEE Annual Conference and Exposition Indianapolis USA 15 – 18 June 2014.

[7] A. Mendonca, C. de Oliveira, D. Guerroro and E. Costa, E. "Difficulties in solving Ill-Defined problems: A case study with introductory computer programming students" in the 39th ASEE/IEEE Conference: Frontiers in Education - San Antonio October 18-21 2009.

[8] J. Sharp. "Methodologies for problem solving: An engineering approach" The Vocational Aspect of Education, 42(114), 147-157. 2007.

[9] S. Arifin, R. Zulkardi, I. Putri, Y. Hartono and E. Susanti. "Developing ill-defined problem solving for the context South Sumetera". Journal of Physics Conference Series 943(1) 2017.

[10] M. Cardella, M. and D. Tolbert. "Problem-solving" in engineering: Research on students' design practices and mathematical modeling practices" in 2014 IEEE Frontiers in Education (FIE) Conference, Madrid, Spain. 2014.

[11] A. Siegesmund. "Using self-assessment to develop metacognition and self-regulated learners" FEMS Mictobiology Letters 364 (11) 23-31 2017.

[12] Heick, T. (2020, August 10) The difference between Assessment of Learning and Assessment as Learning [Online]. Available: https://www.teachthought.com/pedagogy/the-difference-between-assessment-of-learning-and-assessment-for-learning/

[13] Directorate for Learning and Assessment Programmes. (2019, September 4) Assessment of, for and as Learning [Online]. Available: https://curriculum.gov.mt/en/Assessment/Assessment-of- Learning/Documents/assessment_of_for_as_learning.pdf

R. Dann. "Assessment 'as' learning: Blurring the boundaries of assessment and learning for theory, policy and practice." Assessment in Education: Principles, Policy and Practice 21(2) 149-166. 2014

Technical Papers

Engineering students' virtual learning challenges during COVID-19 pandemic lockdown: A case study

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Abstract—**As a result of the pandemic lockdown, most Faculty, Staff, and students in Nigerian universities were unable to learn online because of irregular power and internet unavailability. As a major concern to the Nigerian Deans of Engineering, a study was commissioned by the Deans to identify the extent of the problem with a view to identifying the research and development areas and proffer an indigenous solution to the problems identified. This paper discusses the results of an online survey administered during the lockdown to a stratified sample size from the over 80,000 engineering students' population in Nigeria. The initial results showed that there is need to develop some form of a cost- effective but modular and mobile integrated boosted internet- ready power system suitable for teaching, learning and research which is always-on both day and night for learning.**

Keywords—Virtual learning, Internet, Power Supply, Pandemic, Lockdown, Engineering students

I. INTRODUCTION

Globally, the COVID-19 pandemic disrupted the educational system, as most countries around the world temporarily closed all their educational institutions to contain the spread of the disease. As a result, education delivery changed dramatically, with the distinctive rise of e-learning, whereby teaching is undertaken remotely and on digital platforms. However, developing countries including Nigeria are faced with the challenge of shifting from the traditional teaching method to e-learning during the pandemic. The challenges arise as a result of the varying degree of preparedness of the institutions, lack of infrastructure, paucity of funds and policies issues in the Nigeria education sector. Beyond these challenges and despite the immense benefits of the e-learning platforms available for students, including access to coursework from anywhere at any time, there are several other problems that may hinder participation of students during organised virtual learning programme. This phenomenon is not peculiar to Nigeria or Africa but worldwide. Several studies have been carried out corroborating the problems and importance of virtual learning especially during the Pandemic lockdown.

The impact of the lockdown enforcement was discussed by Favale et al. [1] on the Politecnico di Torino campus network in Italy as social distancing and lockdown measures modified people's habits, and the internet gained a major role in supporting remote working, e-teaching, online collaboration, gaming, video streaming. Profound effects on healthcare system including medical training and education in India were observed by Upadhyaya et al. [2] as a large number had problems in completing their dissertations and 96% had concerns about mental health. Similarly, Kapasia [3], using online survey assessed the impact of lockdown amidst COVID-19 on undergraduate and postgraduate learners of various colleges and universities of West Bengal. They found out that around 70% of learners were involved in e-learning. Most of the learners used android mobile phones for attending e-learning and students faced various problems related to depression, anxiety, poor internet connectivity, and unfavorable study environment at home. Also in India, Malhotra et al. [4] reported the conduct of a "zero-patient contact virtual practical exit examination" for orthopaedic residents with clinical cases prepared in a digital presentation format. The impact of the COVID-19 pandemic was observed by Caruana et al. [5] on the well-being, practice, and progression of all trainees in cardiothoracic surgery in the United Kingdom and they found that the deviation may require an extension in their planned training time. Also, Rajhans et al. [6] reported how COVID-19 pandemic lockdown impacted training in India.

It was noted by Croxton [7] that the use of virtual learning is an emerging topic in the theory of education and practice and some of the benefits of virtual learning include flexible participation and convenience [8]. Also, Obringer [9] affirmed that learning experience could be enhanced if technology is effectively used. The use of virtual learning can improve the achievement of a student, provide access to learning, increase efficiencies of learning, and reduce costs. It will also enhance ability to learn and provide opportunity to prepare them for a globally competitive workforce as observed by Weller [10].

While these studies identified some challenges and benefits, they did not address the peculiarities in Nigeria and many African countries as it affects power and internet facilities.

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The objective of this study was to identify the problems encountered by students in participating in organised virtual learning programmes using engineering students as a case study with a view to recommending a cost-effective way to solve these problems leading to effective use of sustainable virtual learning platform. The choice of engineering students as a case study was motivated by the complexity of engineering programmes. Many engineering courses require the use of laptops which requires energy to power them. For example, computer-aided design, computer-aided engineering, laboratory practical, simulation and modelling, computational fluid dynamics, artificial intelligence, and web development cannot be effectively done on smartphones. These problems need to be solved to reduce disruptions in academic calendar. This research will answer the following research questions:

1. What are the virtual learning challenges faced by students during the COVID-19 pandemic?
2. What is the indigenous engineering solution that is cost-effective to overcome the virtual learning challenges?
3. Will the indigenous engineering solution be affordable to the students?
4. How will such indigenous solution impact engineering education in Nigeria and Africa at large?

METHODOLOGY

To provide answers to the research questions, an online survey was created and grouped into relevant sections, as follows:

a. To identify the virtual learning challenges faced by students during the COVID-19 pandemic, data of the participating universities and the student profile such year of study, location of online studies and gender were collected. Also, respondents were required to enumerate the challenges as well as proffer their solution.
b. The cost-effectiveness of the indigenous engineering solution was evaluated based on responses relating to the computing device, alternative source for charging, preferred internet service provider, packaging and transportation preference.
c. To identify the affordability of the solution, the research profiled the student's financial capacity exemplified by their financial support through scholarship and sponsors as well as disposable income
d. As regards to the impact of the indigenous solution on engineering education in Nigeria and Africa at large, the questionnaire sought the opinion of the students on how power and internet connectivity challenges could be solved in the location of their study and the impact on their education.

A. *Sampling Plan*

The population data used in this study is based on the report of NUC [11] on students' enrollment and the Committee of Deans of Engineering and Technology of Nigerian Universities (CODET) statistics. There was a total of 1,727,782 students enrolled in Nigerian Universities in 2017, out of which 960,417 were males and 750,717 females. Today, there are 171 universities in Nigeria out of which 65 offer engineering programmes. CODET [12] estimates that there are about 80,000 engineering students in these 65 universities.

The sampling plan used in this study was a hybrid of clustering by geography and stratified by students' year of study. However, because of the COVID-19 lockdown some elements of convenience sampling were adopted. The participating Deans were requested to create 5 strata based on students' year of study, namely, Year 1, Year 2, Year 3, Year 4 and Year 5. An online survey was carried out to identify the virtual learning challenges faced by students during the lockdown from April to August 2020. The bulk of the responses were received when there was a total national lockdown between April and June 2020 in Nigeria.

B. *Survey Analysis*

A survey instrument consisting of 17 items was developed with a stratified sample size by level of study and administered to the students online. A total of 5,166 students responded largely during the national total lockdown. The survey data as reported by CODET [13] were analysed using Minitab®19.2020.1 and Microsoft PivotTable®

II. RESULTS AND DISCUSSIONS

A. *Profile of Respondents and Participating Universities*

A total of 44 of the 65 engineering universities participated in the survey with the largest number of respondents from the South-West Zone followed by the South-East and North-Western zones as shown in Table I. The 3rd year students topped the groups that responded followed by the 2nd year and interestingly the 5th year (final year) students in that order.. Table I shows the respondents by the year of study.

TABLE I *Participating students by year of study*

Zones	Year 1	Year 2	Year 3	Year 4	Year 5	Others	Total
North-Central	**41**	**59**	**75**	**50**	**62**	**27**	**314**
North-East	66	180	188	181	82	31	728
North-West	59	53	147	136	216	213	824
South-East	99	174	240	122	213	46	894
South-South	86	93	177	103	117	6	582
South-West	210	518	418	297	324	57	1824
TOTAL	561	1077	1245	889	1014	380	5166

Engineering programmes in Nigerian universities are dominated by the males and this is reflected in the gender ratio of the respondents with the Males to Females ratio being 4:1 as shown in Figure 1. It is noted, as depicted in Table II, that the computing devices used by engineering students include laptops since smartphones alone cannot meet the requirements for many engineering courses such as computer-aided design and computer-aided engineering. The use of smartphones is still limited to web-based virtual learning. Power requirement therefore for engineering students must include its use for charging laptops. Table II shows that laptops make up about one-quarter of the computing devices owned by engineering students.

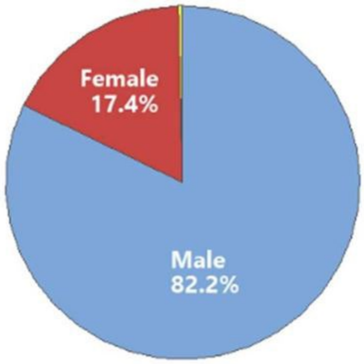

FIGURE 1 *Respondents by Gender*

TABLE II *Computing devices of respondents*

Zones	PC	Laptop	None	Smart Phone	Total	%	Total
North-Central	1	135	7	152	295	5.7	314
North-East	2	92	17	518	629	12.2	728
North-West	1	250	4	582	837	16.2	824
South-East	3	204	9	749	965	18.7	894
South-South		60	14	487	561	10.8	582
South-West	8	589	20	1262	1879	36.4	1824
Grand Total	15	1330	71	3750	5166	100	5166
Percentage	0.3	25.7	1.3	72.7	100		

B. Challenges Faced by Students

Virtual learning challenges faced by students in Nigeria were largely power supply such as: irregular power supply, poor quality power supply and poor internet connectivity. These are shown in Table III. Power related challenges dominated the challenges. A power solution for students will go a long way to address virtual learning challenges. Table IV shows that students resorted to the assistance of friends, use of generators, wait for the startup of public places such as Hotels, Schools, Churches, and Mosques to charge their computing devices.

For internet, the service providers are dominated by three providers, namely, MTN, Glo and Airtel as shown in Figure 2. The MTN tops the three followed by Airtel and Glo. Therefore, a solution that has the capability to access these three internet sources will improve the probability of getting connected to the internet by more than 90% as no service Provider can meet the national demand of students.

TABLE III *Challenges faced by respondents*

Zone	Internet	Other	Power	Total
North-Central	7	13	275	295
North-East	11	19	599	629
North-West	14	13	810	837
South-East	14	17	934	965
South-South	11	8	542	561
South-West	46	85	1748	1879
Grand Total	103	155	4908	5166

TABLE IV *Computing device recharging alternatives*

Zones	Generator	Friends	Public	School	Total
North-Central	96	103	67	29	295
North-East	79	188	278	84	629
North-West	120	243	338	136	837
South-East	169	376	351	69	965
South-South	92	288	146	35	561
South-West	568	714	421	176	1879
Grand Total	1124	1912	1601	529	5166

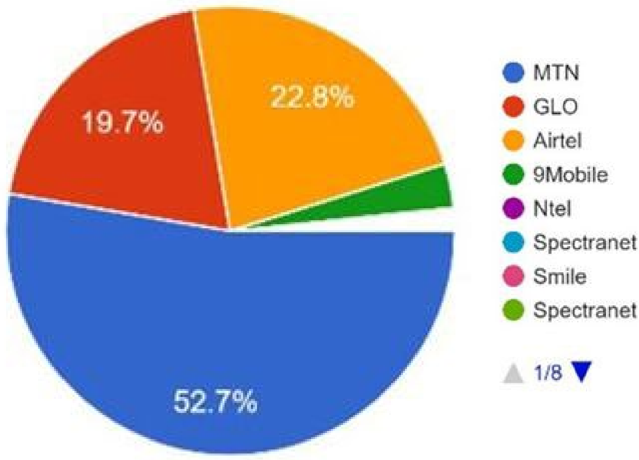

FIGURE 2. *Preferred Internet Service Provider*

C. Financial Capability of Student

The ability of students to purchase a given solution is a source of concern. Only 10% of the students receive some form of financial assistance for their study as depicted in Figure 3. The 3rd year students appear to be more financially stable and the 1st year students are worse-off as shown in Table V. The sponsors of their education are largely civil servants, traders and the middle-class professionals as shown in Table VI. The disposable income for many the students' populations is quite low; barely enough for subsistence signifying the low disposable income of the students.

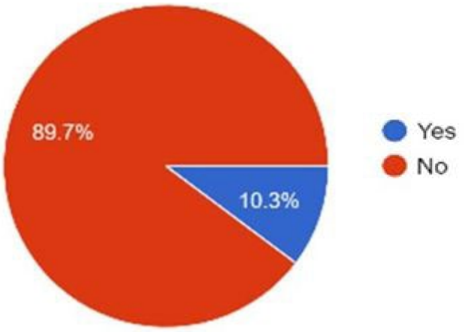

FIGURE 3 *Students on some form of fnancial assistance*

TABLE V *Scholarships by level of study*

Study Level	No	Yes
1st Year	92.69	7.31
2nd Year	88.49	11.51
3rd Year	87.39	12.61
4th Year	92.46	7.54
5th Year	90.24	9.76
Postgraduate	90.26	9.74

TABLE VI *Occupation of sponsors*

Occupation of Sponsors	Percentage
Civil Servants	22.87%
Businesspersons	13.94%
Traders	12.62%
Engineers	12.45%
Retired	8.76%
Teacher/Lecturers	7.36%
Farmers	6.75%
Public Servants	3.33%
Pastors	2.80%
Doctors	2.10%
Accountants	1.58%
Lawyers	1.05%
Bankers	0.88%
Others	3.51%
TOTAL	100.00%

Figure 4 shows the monthly data usage and Figure 5 shows the monthly upkeep allowance of students. Depending on the Service Provider data plan, more than one-third of the students use about $5 monthly translating to between 4.5GB to 9.5GB of data if they only spend their upkeep allowance on data. The data on upkeep allowance in Figure 5 seems to corroborate this projection. Given that 40-50% of the upkeep allowance is used for data, the students cannot maintain the level of data consumption.

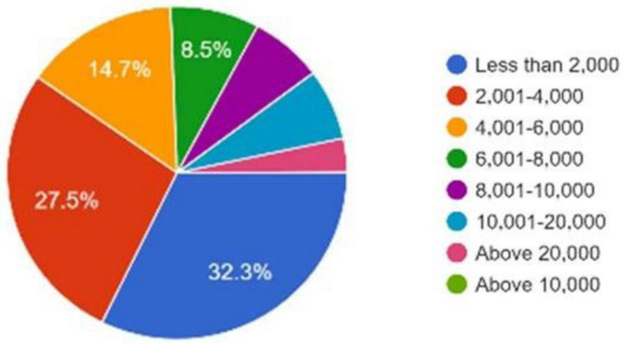

FIGURE 4 *Data usage by respondents*

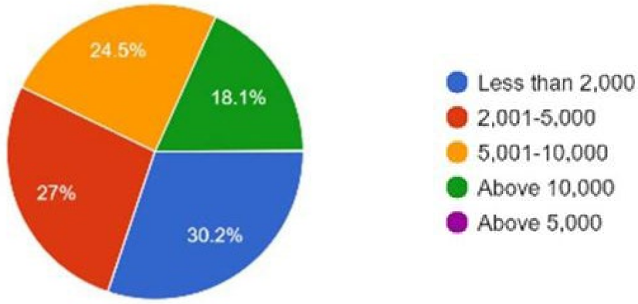

FIGURE 5 *Students upkeep allowance per month*

The research attempted to find out from the students the value they will place on a solution to the virtual learning challenges they are facing and how much they will be willing to pay for the solution. From the responses shown in Figure 6, most of the students, 87.4%, can afford to pay about $50. The rest of the students will be willing to pay between $50 and $125 for the solution. About 2% will be willing to pay beyond $125. The interesting thing about the students' answer is that they placed a great value to the solution to their challenges to as high as half of their disposable income.

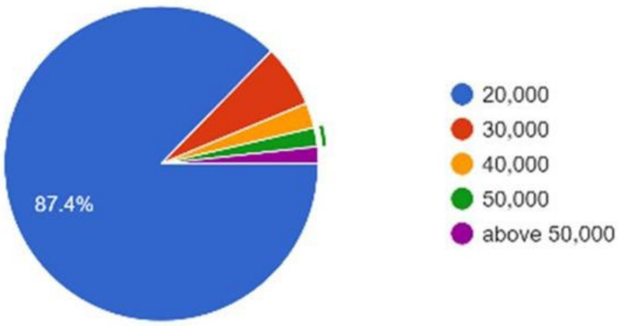

FIGURE 6 *Perceived ability to pay for a solution*

D. Student Solution and Packaging

One of the objectives of this study was to collate the views of the students on the type of solution they will require. It was clear that students would like to resolve the problem of power and internet in one solution. Students recommended a solution that will combine the power solution and the internet facility in one piece. Figure 7 shows that over 80% of the respondents will like the power and internet solution to be combined and the rest will want to have the power and internet solution separate.

With regards to packaging, it should be small enough to be carried in their school bag. Figure 8 shows the opinion of the students. Most students subscribe to a mobile solution as against fixed location solution. They were as follows:

In the School Bag	51%
Fixed in study location	38%
Create a special container	9%

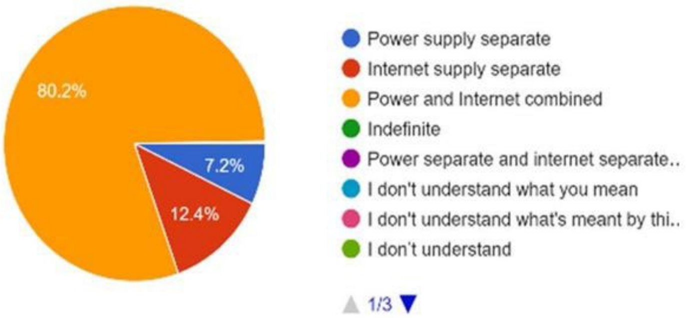

FIGURE 7 Packaging of solution

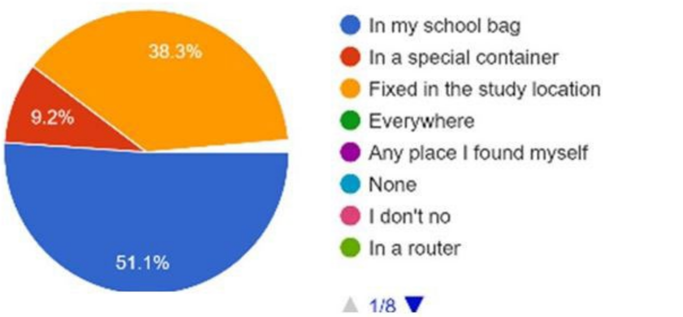

Figure 8. Transportation of solution

The solution to these virtual learning problems will have far reaching impact on engineering education in Nigeria and Africa. Some of these impacts are:

i. Capacity to teach weak students thereby reducing dropouts due to flexible participation and convenience,
ii. Laboratory exercises can be performed anytime thus increasing laboratory availability especially where laboratory facilities are scarce,
iii. Regional industry collaboration will be enhanced,
iv. Inter-university collaboration among students across universities in Nigeria and Africa will also be enhanced.
v. Enabling online examination which will reduce academic calendar disruptions,
vi. Industry experts teaching agreed topics in Faculty/College of engineering programmes to leverage their industry experience will be much easier to implement,
vii. Mentorship by industry experts to support engineering education in Faculty/College of Engineering through membership of both the Departmental and Faculty/College Academic Boards will be enhanced,
viii. Development of training videos and clips with Nigerian industry content can be used in the classrooms to illustrate science and engineering theories, principles, and practice and
ix. Opportunities for the development of software for online connection to laboratory equipment, machines etc. will increase.

CONCLUSION AND RECOMMENDATIONS

This study revealed that students' virtual learning challenges were two-fold, irregular and poor-quality power supply on one hand and on the other hand, poor quality and expensive internet data. It is also clear that despite the low disposable income of students they place a high value to the solution to these challenges. The students are also eager to be a part of the solution but must be affordable at below $100. The solution to these virtual learning problems will have far reaching impact on engineering education in Nigeria and Africa

It is therefore recommended that the engineering family in Africa should constitute themselves to solve these problems working with industry. The solution must be cost-effective, modular, mobile integrated, with boosted internet-ready uninterrupted power system suitable for teaching, learning and research.

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REFERENCES

[1] T, Favale, F. Soro, M. Trevisan, I. Drago, M. Mellia, "Campus traffic and e-Learning during COVID-19 pandemic", Computer Networks, Computer Networks, 2020, 176 107290, Elsevier

[2] G. K. Upadhyaya, V. K. Jain, K. P. Iyengar, M. K. Patralekh, A. Vaish, "Impact of COVID-19 on post-graduate orthopaedic training in Delhi- NCR", Journal of Clinical Orthopaedics and Trauma, https://doi.org/10.1016/j.jcot.2020.07.0180976-5662/, 2020

[3] N. Kapasia, P. Paul, A. Roy, J. Saha, A. Zaveri, R. Mallick, B. Barman, P. Das, P. Chouhan, "Impact of lockdown on learning status of undergraduate and postgraduate students during COVID-19 pandemic in West Bengal, India", Children and Youth Services Review 116, 2020, 105194, https://doi.org/10.1016/j.childyouth.2020.105194

[4] R. Malhotra, D. Gautam, J. George, D. Goyal, M. T. Ansari, "Conducting orthopaedic practical examination during the Covid-19 Pandemic," Journal of Clinical Orthopaedics and Trauma 11 (2020) S448eS455, https://doi.org/10.1016/j.jcot.2020.07.002, Elsevier

[5] E. J. Caruana, A. Patel, S. Kendall, S. Rathinam, "Impact of coronavirus 2019 (COVID-19) on training and well-being in subspecialty surgery: A national survey of cardiothoracic trainees in the United Kingdom", The American Association for Thoracic Surgery https://doi.org/10.1016/j.jtcvs.2020.05.052, Elsevier

[6] V. Rajhans,, U. Memon, V. Patil, A. Goyal, "Impact of COVID-19 on academic activities and wayforward in Indian Optometry", J Optom. (2020), https://doi.org/10.1016/j.optom.2020.06.002

[7] Croxton, R.A.,. "The role of interactivity in student satisfaction and persistence in online learning". MERLOT Journal of Online Learning and Teaching, 10(2), pp.314-325

[8] Feldman, P. "Higher education leaders share challenges of the sector". JISC. Available at:https://www.jisc.ac.uk/blog/higher-education-leaders- share-challenges-of-the-sector-27-jun-2016, Accessed 29 Jul. 2017

[9] Obringer Lee Ann, (2002), How E-learning Works, Available: http://www.howstuffworks.com/elearning1. htm

[10] Weller, M., Virtual learning environments: using, choosing and developing your VLE. Abingdon: Routledge, 2007

[11] National Universities Commission (NUC), "Nigerian University System Statistical Digest", April 2018, Abuja, Nigeria

[12] Committee of Deans of Engineering and Technology of Nigerian Universities (CODET), "Statistics of Graduating Engineering Students in 2017-2018, Unpublished, 2019.

Committee of Deans of Engineering and Technology of Nigerian Universities (CODET), "Engineering Students Virtual learning Challenges during COVID-19 Pandemic Lockdown", accessed at https://docs.google.com/forms/d/1IUEXCW4I6SDOeFAlU9fU3fjh0m5Ehyk-7xuoDo0k_Bo/edit on September 8, 2020.

Technical Papers

Engineering student experiences of a remotely accessed, online learning environment

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***Abstract*—This study explores engineering student experiences of the emergency, remote online teaching and learning environment initiated due to the COVID-19 pandemic. The study uses a Likert scale survey based on the Community of Inquiry model evaluating Social, Teacher, Learner, and Cognitive presence in the online environment. Insights are provided relating to the design of the teaching and learning environment, student behaviours, assessment, social learning and how students cope in this mode. The results from this study can be used to better understand how students experience this environment, informing design and integration in similar interventions in the future.**

Keywords—online learning, community of inquiry, learning presence, teacher presence, social presence

I. INTRODUCTION

New technologies provide increasing opportunities to challenge traditional teaching and learning in Higher Education [1]. Online learning environments, in particular, have the potential to broaden access to higher education [2]–[4] and to align university teaching with the lifelong learning of contemporary professionals [5]. Many would argue that the shift to online teaching and learning environments is not only inevitable but an imperative to align graduate competencies with evolving workplaces [6], to ensure that higher education is sustainable into the future and facilitates collaboration between institutions, [7]. Online learning environments, how- ever, need to be designed differently and cannot merely be a replication of traditional learning environments in an online space [1]. There is also still uncertainty regarding how easily students can adapt to these changes and whether online environments can adequately facilitate the development and attainment of the intended outcomes and graduate attributes.

For many higher education institutions in South Africa and across the world, the COVID-19 pandemic has resulted in a sudden move from traditional teaching and learning

to the online environment. For the university used in this study, teaching and learning changed from a blended learning approach incorporating face-to-face and online elements to a fully online-dependent and remote model. This study was mo- tivated by these circumstances which provided an opportunity to explore student's experiences of this process and their learning behaviours as they interact with this emergency, remote, online [8] learning environment. There is currently limited literature that specifically explores how students experience this unique circumstance and Jeffery & Bauer [9] have shown how understanding the student experience can provide insights for all teaching and learning environments. As a consequence, the research question for this study was: How do students experience teaching and learning in an emergency, remote, online learning environment?

The aim of this study is that the findings can provide insights for the design of online teaching and learning environments in general and can inform similar, future interventions. Furthermore, although the circumstances around the abrupt introduction of online learning is likely to influence results, valuable data can be gained regarding online learning more broadly. Current thinking suggests that the move to online learning as a result of the COVID-19 pandemic will forever change teaching and learning environments and that the future of higher education is likely to see a more rapid introduction of hybrid, online and remote experiences. The findings can therefore also be used to highlight challenges experienced by students and the intended and unintended consequences of online and remote learning environments.

II. LITERATURE REVIEW

Higher-order thinking is a requirement for any learning in a higher education context. Garrison et al. [10] state that a critical community of inquiry is essential to facilitate and encourage this higher-order thinking through a collaborative and reflective learning experience. This experience needs to create opportunities for students to critically analyse subject material by questioning and challenging what is presented and then using this process to re(construct) knowledge by relating the material to experiences. The Community of Inquiry (COI) model [10] recognises three essential elements for a successful online learning experience: the cognitive, social, and teaching presence. Cognitive presence relates to thinking and involves the ability of students to construct meaning through reflection and communication. Social presence involves the personal and emotional connection to the group and the ability of students to project themselves as "real people" [10]. Teaching presence represents the course facilitator, who directs the cognitive and social processes and provides feedback to students.

Shea & Bidjerano [11] have identified a fourth presence that they believe completes the Community of Inquiry model. This additional presence, the learning presence, refers to the self-direction skills that are required to identify and operate in the learning context. They propose that online learning environments rely more heavily on self-directed learning skills than face-to-face learning environments. Students often lack important self-regulating skills, particularly when exposed to online learning for

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the first time. Pool et al. [12] have found that if the self-regulation skills of students are under-developed, this affects teacher presence as additional guidance, scaffolding and support needs to be provided as students navigate the new territory.

Several studies have explored how students experience online learning environments. It has been found that many challenges and opportunities exist and that understanding these can result in improved design and use that can sustain and even enhance student learning. Many of the challenges of online learning stem from practices and expectations developed in traditional learning contexts. These include lack of pacing and direction facilitated by weekly class schedules and lecturer-centred teaching approaches [1]. Bourne et al. [7] however, argue that it is the underlying pedagogy and design of the teaching and learning environment that determine these factors and that online learning can involve high levels of communication and instructor engagement resulting in a people-oriented learning solution. Online environments do however, initiate a change in the skills required by students. Students need to be more adept at using technology [13], which can alienate students who are apprehensive or have an aversion to using it [14]. Engaging in these environments, depending on their design, can also require students to be more proficient in written communication [13].

The impact of an online environment on students should be understood by teachers so that they can provide opportunities for students to expand and develop their skills and engage more meaningfully [7]. This includes self-directed learning skills [1], which are linked to independent learning competencies (a graduate attribute required by accrediting bodies) and the creation of engineering entrepreneurs and innovators [15]. A key feature of the online learning environment is the learning community that is created. Communities are relatively informal, flexible, and collaborative spaces that form around a common objective through a series of interactions and exchanges [16]. Online communities have the potential to create more equal and accessible spaces and can increase the ability of students to personalise their learning experiences [1], enhancing independence and agency and improving students' attitudes towards their learning [13].

III. METHOD

A. Study context

This study took place in the Faculty of Engineering at the North-West University in South Africa. This Faculty consists of several engineering disciplines located in four Schools. The Engineering Council of South Africa (ECSA), the ac- crediting body, plays an influential role in degree outcomes and internal processes development to ensure that students meet these outcomes. In general, teaching and learning in the Faculty is facilitated through a combination of face-to- face and online components. Class sizes vary depending on the year of study and the chosen discipline. Some modules are also shared across disciplines resulting in larger class sizes and opportunities for multi-disciplinary interaction. The University makes uses of a customised Learning Management System (LMS) that incorporates functionality for teaching material and content, formative assessment and collaboration and interaction between students and lecturers and between students in the class. Adoption of the LMS to enhance teaching and learning varies significantly between modules with some modules making little to no use of the LMS and other modules making extensive use of a wide variety of tools in a blended learning environment. All students and staff have access to support for the LMS through several avenues. The face-to-face component of teaching and learning includes lectures from faculty staff and industry experts, tutorials, laboratory activities and experiential learning through interaction with industry and the broader community. Assessments for many modules are traditional sit-down tests and exams but can include a variety of project and portfolio work. As a result of the COVID-19 pandemic, the Faculty developed a strategy to continue the first semester of teaching and learning in an emergency, remote online learning mode. Interventions aimed to give as many students as possible access to devices and data and the LMS and other associated software portals were given zero-data ratings so that students could interact on these platforms without any additional costs. Lecturers were required to place all learning material on the LMS and were encouraged to make use of the tools in the LMS to get students to engage with the material, classmates and the lecturers. Formal, end-of-semester exams were replaced with continuous online assessment throughout the semester. A decision was made to favour the asynchronous teaching and learning mode to reduce pressure on students who had limited access. The implementation of the Faculty's strategy for the emergency, remote online mode was not entirely smooth and many issues were encountered by staff and students along the way.

B. Research instrument design and data collection

An online student survey was developed for this study, using the Community of Inquiry Model [10], [11] as the underlying framework. The survey included a total of 44 questions and statements, divided into three main sections. The first section included demographic questions related to the year and discipline of study, quality of internet access, and the physical study environment. The second section explored student experiences, addressed through the four presences of the theoretical framework. A section also considered student experiences of assessment. The statements in this second section were collated and randomised and were not categorised according to the presences or assessment and used a four- point Likert scale. including the categories of strongly agree (1), agree (2), disagree (3) and strongly disagree (4). The third section provided an opportunity for students to discuss their experiences and challenges in their own words by answering three open-ended questions. Ethics clearance was obtained for the study, and ethical principles were adhered to throughout the study. Using SurveyMonkey, online questionnaires were distributed to all undergraduate students (n= 1447 students) in the Faculty in late July 2020. This sampling period coincided with the end of the first teaching semester for the students.

C. Analysis

The data from the Likert scale section of the survey were analysed using simple descriptive statistics [17] including percentage strongly agree/agree, loading factor, the mean (μ) and standard deviation (σ) for any statement. An exploratory fac- tor analysis using principal component analysis was also per- formed on the student responses to identify emergent themes and consistency between responses [18]. Negative loading factors, identified during execution of the factor analysis, were sign-reversed to align positively and negatively phrased statements. These statistics were interpreted by comparing the results to the literature that supports the theoretical concepts for this study. Internal consistency between statements within a factor was measured using Cronbach's Alpha and mean inter-term correlations as appropriate. The qualitative data revealed rich findings that will be presented in another paper; however findings are used to support the overall argument for this paper where appropriate.

IV. RESULTS

A. Demographic considerations

1) *Respondent profile:* Responses were received from 558 students with a distribution between Schools that corresponds with the enrolled students per School. The percentage split across years of study was: 26% in first year, 25% in second year, 29% in third year and 20% in fourth year.
2) *Quality of internet access:* Of primary importance for internet teaching and learning is access through the internet and a suitable device. Respondents indicated that 91.0% had access to a computer (7.0% to a shared computer) and 85.1% had access to a mobile device (3.4% to a shared mobile device). The combined access to a computer and mobile device is important as students often had to use a mobile phone to set up a hotspot if they wanted to make use of zero- rated data. The responses regarding access to data are shown in Table I. The students could choose more than one option therefore, the total is greater than 100%. For students who did not have sufficient available data, 8.8% indicated that the zero-rating of data provided a solution while 5.4% indicated that it did not.

TABLE I *Access to data*

Statement	%
I had unlimited (uncapped) data available	45.3
I had sufficient (capped) data available	34.8
I had to purchase data but had sufficient funds	13.4

For online teaching and learning to be successful, in addition to access to the internet, it is also important to explore the stability and speed of the internet connection. Responses to selected statements regarding internet access quality are shown in Table II. The Cronbach Alpha for this group was 0.874, indicating high internal consistency between the statements. In general, respondents indicated that they did not have serious internet problems. However, almost a third of the respondents indicated that their internet connection was unreliable and unstable, and 15% of respondents felt that they were hampered by their inability to access the internet. This suggests that it is necessary to make provision for interruptions in internet access and that synchronous, online modes may present problems for a significant number of students. Students may also experience problems with submitting tests and assignments within narrow time frames, a theme that also emerged in the open-ended responses.

TABLE II *Internet access and quality*

Statement	Strongly Agree (%)	μ	σ
The internet connection was unre-liable and unstable	32.9	2.73	0.813
The internet was often unavailable when I had to submit assessments	29.4	2.86	0.789
My internet connection was sufficiently fast	74.1	2.15	0.734
My ability to study was hampered by my inability to access the internet	14.8	3.19	0.730

3) *Physical environment:* For effective learning, students should also have a conducive physical environment; selected responses are shown in Table III. The Cronbach Alpha for this group was 0.84, indicating high internal consistency between the statements. In general, respondents agreed that they had a physical environment conducive to learning. While 54.3% of respondents indicated that they were distracted while studying. This phenomenon may not be specific to the emergency, remote online circumstances and could also be prevalent during an ordinary academic year. The difference is that under ordinary circumstances, students are more likely to have alternative options.

TABLE III *Physical environment*

Statement	Strongly Agree (%)	μ	σ
My physical environment was conductve	85.0	1.83	0.735
My study area was quiet	69.8	2.12	0.840
I was often distracted while studying	54.3	2.37	0.844

B. Student's experience of the online teaching and learning environment

An analysis of the statements pertaining to the COI model and assessment used five factors that resulted in minimal cross-loading and in factors that were consistent with our expectations based on literature. The Kaiser-Meyer-Olkin Measure of sampling adequacy was 0.932, above the recommended value of 0.8 [18]. The five factors that emerged related to teaching and learning design, learning behaviours, social interaction, challenges, and assessment. The first three factors relate to teaching, learning, and social presences in the COI model. While statements were formulated to measure the cognitive presence, this did not emerge as a separate factor in the analysis.

1) *Teaching and learning design factor:* The factor that emerged with the highest number of statements relates to the design of the teaching and learning environment. The results are shown in Table IV with a corresponding Cronbach Alpha for this factor of 0.9, indicating a very high level of internal consistency.

The factor average of 2.08 suggests that the respondents agreed that the design of the teaching and learning environment supported their learning experience with many of these statements correlating strongly with teacher presence. The statements that received the lowest strongly agree/agree percentages correspond to the perceived support received from lecturers through guidance, feedback, and approachability. The mode of providing support is very different in an online environment compared to a face-to-face environment and this suggests that a change in approach may be necessary. This was confirmed in the qualitative data where many students indicated that accessibility to lecturers was a challenge. How- ever, several students in the open-ended questions explained how they found lecturers to be "more present" in the online mode. Interestingly, the question with the highest strongly agree/agree response rate relates to the cognitive presence where 89% of respondents indicated that assessments chal- lenged them to reflect critically on the material that was provided. It is also worth noting that this question loaded into this factor and not the assessment factor, perhaps suggesting the important role that assessment plays in overall teaching and learning design.

2) *Learning behaviour factor:* Six statements loaded into a factor that concerns the ability of students to display effective learning behaviours in the online environment. These are included in Table V with a Cronbach Alpha of 0.773 indicating a high level of internal consistency.

These statements correlate strongly with learning presence in the COI model. The factor average of 1.9 indicates that most respondents felt that they were able to function suc- cessfully in the online environment suggesting appropriately developed self-directed learning skills. Interestingly, 37.4% of respondents indicated that they did not like working alone, linking to the importance of social interaction in the learning process.

3) *Social interaction factor:* Social presence is a charac- teristic of good online teaching - the perception of students that they are "real persons" in the online environment. Three statements, shown in Table VI, loaded into this factor, which resembled the concept of social presence with a Cronbach Alpha of 0.636.

For factors with few statements, it may be better to use the mean inter-term correlation (MITC) to indicate internal consistency [19]. For this factor, the MITC is 0.37, which falls within the range of 0.15 to 0.5 and is an indication of good internal consistency. The factor average of 2.3 seems to indicate that the social presence was not strong. The individual statements seem to indicate that respondents were willing to ask classmates for help, perhaps students they considered friends, but that there was not a strong feeling of being part of a group.

4) *Challenges factor:* Many of the survey statements loaded into a factor that we have referred to as challenges. The results are shown in Table VII, with a Cronbach Alpha of 0.816. The average loading for this factor requires the consideration of individual statements. Although the minority, a significant percentage of students indicated that they did not cope with the workload and what was expected from them. The last three statements also show that many students missed the support, most probably provided by peers, staff and the academic environment. These statements allude to a sense of becoming emotionally overwhelmed in these circumstances.

5) *Assessment factor:* Four statements loaded into the Assessment factor (see Table VIII) with a Cronbach Alpha of 0.643 and a MITC of 0.31, which is an indication of good internal consistency. Respondents appeared to have a positive perception of the use of continuous assessment with 81.8% of respondents indicating that they preferred continuous assessments and 80.6% indicating that these continuous assessments gave a true reflection of their knowledge. However, somewhat in contradiction to these responses, 48.8% of respondents indicated that sit-down exams were a better way of assessing their learning. It also emerged that many respondents felt that cheating had an impact on the quality of the assessment process. The preliminary qualitative analysis revealed similar findings with a contrast between the types of assessments that students preferred. Although the change from sit-down exams to continuous assessment occurred as a result of this emergency, remote mode, this type of shift in assessment is a fundamental change to assessment and learning and it may be that students and lecturers have not adequately adjusted.

TABLE IV *Factor: teaching and learning design*

Statement	Strongly Agree (%)	Factor loading	μ	σ
I was satisfied with the support and guidance I received from lecturers	63.7	0.836	2.33	0.860
I received enough feedback from the lecturer to know if I am making adequate progress	57.9	0.829	2.41	0.863
Clear learning outcomes enabled me to understand what is expected of me	76.5	0.662	2.07	0.726
Most of the material provided was suitable for online learning	81.9	0.625	2.01	0.727
All the study material was made available online	80.4	0.568	1.95	0.766
I was encouraged to challenge or critique different ideas	74.7	0.566	2.13	0.708
I felt comfortable to approach lecturers with questions	65.9	0.538	2.23	0.883
The learning activities supported me to gain a deeper understanding of the content	76.8	0.467	2.06	0.729
Assessments challenged me to reflect critically on the material that was provided	89.0	0.427	1.88	0.612
I feel that I have gained skills that are valuable for my future career	87.3	0.408	1.86	0.701
Factor			**2.08**	**0.527**

TABLE V *Factor: learning behaviour*

Statement	Strongly Agree (%)	Factor loading	μ	σ
When I was stuck I searched for different ways to understand the work	94.8	0.688	1.68	0.608
I set goals for myself when I studied	87.6	0.625	1.82	0.650
I have successfully adapted to the online environment	82.9	0.547	1.91	0.753
I could plan my study activities during online learning	84.0	0.506	1.93	0.727
I liked working alone in the online environment	62.6	0.493	2.25	0.928
I am confident that I can apply what I have learned	86.5	0.445	1.87	0.689
Factor			**1.9**	**0.505**

TABLE VI *Factor: social interaction*

Statement	Strongly Agree (%)	Factor loading	μ	σ
I am part of a group who help each other to master module content	60.1	0.848	2.73	0.863
I felt comfortable to ask classmates for help	75.9	0.795	2.04	0.0.817
I did not feel part of the class group in the online environment	44.7	-0.351	2.51	0.913
Factor			**2.30**	**0.505**

TABLE VII *Factor: coping*

Statement	Strongly Agree (%)	Factor loading	μ	σ
I felt overwhelmed by the amount of work when in the online mode	45.6	0.825	2.48	0.842
I feel that there were too many assessments that I had to do	35.3	0.734	2.61	0.762
The lecturer expected too much of us during this time	34.5	0.682	2.65	0.804
I felt that there was less pressure with the continuous assessment approach	69.3	-0.546	2.11	0.910
I was distracted by other things during online learning	55.0	0.472	2.37	0.844
I had to struggle on my own to figure things out	67.1	0.429	2.11	0.822
I found it difficult to stay motivated during online learning	55.6	0.375	2.33	0.936
Factor			**2.49**	**0.582**

TABLE VIII *Factor: assessment*

Statement	Strongly Agree (%)	Factor loading	μ	σ
I feel that sit down exams are a better way of assessing my learning	48.8	0.789	2.49	0.944
Students cheated during online assessments	44.4	0.696	2.56	0.822
I prefer continuous assessments to semester tests and exams	81.8	-0.514	1.83	0.809
Continuous assessments gave a true reflection of my knowledge	80.6	-0.320	1.97	0.761
Factor			**2.81**	**0.585**

V. DISCUSSION

Although respondents generally agreed that their internet quality, the physical environment, and the teaching and learn- ing environment design was adequate; many still found the experience to be overwhelming. This correlates with the Jef- fery & Bauer [9] study that describes the experience of many students as feeling lost or hopeless. This finding suggests that understanding the emotional response of students to a remote online learning environment is important. And although for many factors, the average response may be positive, it is important to consider all responses to ensure that ”no student is left behind”.

Educators should also take into account that the online learning environment should be designed to foster student engagement, not only with the content but also with other students and lecturers, thereby facilitating the development of an online learning community. Many students raised ac- cessibility of lecturers and interaction with other students as a concern during this period. While many students indicated that they formed part of a group and were comfortable to ask classmates for help, a significant number of students did not feel part of the class group, and most students indicated that they needed to struggle on their own. Teaching and learning is by nature a social activity, and educators should consider techniques to establish a strong social presence through two- way communication, group cohesion, and effective expression [20]. The development of a strong community also has the potential to enhance independence, agency, and motivation [13].

Furthermore, self-directed learning skills are also a requirement for online learning [11] and interventions to develop these skills could mitigate some of the challenges raised by respondents and opportunities should be considered to assist students with this [12].

VI. CONCLUSIONS

The findings reveal some gaps in the presences from the Community of Inquiry model [10] and suggest how these influence the student experience and learning. It is however encouraging to see that many students believe that the gained skills that were valuable for their future careers and that they were challenged to reflect critically on the material which infers the development of higher-order thinking skills [10].

This study has provided useful insights that can be used by educators in similar interventions in the future and the design of online learning environments more broadly. This study also provokes thinking around teaching and learning spaces and how these influence student learning.

REFERENCES

[1] B. Davey, K. Elliott, and M. Bora, “Negotiating pedagogical challenges in the shift from face-to-face to fully online learning: A case study of collaborative design solutions by learning designers and subject matter experts.” Journal of University Teaching and Learning Practice, vol. 16, no. 1, 2019.

[2] J. S. Goodman, J. Melkers, and A. Pallais, “Can online delivery increase acces to education?.” 2017.

[3] M. Anshari, Y. Alas, N. Hj Mohd Yunus, N. Pg Hj Sabtu, and M. Sheikh Abdul Hamid, “Online learning: Trends, issues, and challenges in the big data era.” Journal of E-Learning and Knowledge Society, vol. 12, no. 1, pp. 121–134, 2016.

[4] M. Shah, E. Goode, S. West, and H. Clark, “Widening student participa- tion in higher education through online enabling education,” Widening Participation and Lifelong Learning, vol. 16, no. 3, pp. 36–57, 2014

[5] A. Andreatos, The use of MOOCs in the continuing education of individuals and organisations. Hellenic Air Force Academy: IGI Global, 2015.

[6] M. Frydenberg and D. Andone, “Learning for 21st century skills.” International Conference on Information Society (i-Society 2011), In- formation Society (i-Society), 2011 International Conference on, pp. 314 – 318, 2011.

[7] J. Bourne, D. Harris, and F. Mayadas, “Online engineering educa- tion: Learning anywhere, anytime.” Journal of Engineering Education, vol. 94, no. 1, pp. 131–146, 2005.

[8] C. Hodges, S. Moore, B. Lockee, T. Trust, and A. Bond, “The difference between emergency remote teaching and online learning,” Educause Review, vol. 27, 2020.

[9] K. Jeffery and F. Bauer, “Students’ responses to emergency remote online teaching reveal critical factors for all teaching,” J. Chem. Educ., vol. 97, pp. 2472–2485, 2020.

[10] D. Garrison, T. Anderson, and W. Archer, “Critical thinking, cognitive presence, and computer conferencing in distance education,” American Journal of Distance Education, vol. 15, pp. 7–23, 01 2001.

[11] P. Shea and T. Bidjerano, “Learning presence as a moderator in the community of inquiry model,” Computers and Education, vol. 59, no. 2, pp. 316–326, 2012.

[12] J. Pool, G. M. Reitsma, and D. N. Van den Berg, “Revised community of inquiry framework: examining learning presence in a blended mode of delivery,” 2017.

[13] L. Arasaratnam-Smith and M. Northcote, "Community in online higher education: Challenges and opportunities." Electronic Journal of e- Learning, vol. 15, no. 2, pp. 188–198, 2017.

[14] L. Kelly, J. A. Keaten, M. Hazel, and J. A. Williams, "Effects of reticence, affect for communication channels, and self-perceived competence on usage of instant messaging," Communication Research Reports, vol. 27, no. 2, pp. 131–142, 2010.

[15] R. Bary and M. Rees, "Is (self-directed) learning the key skill for tomorrow's engineers?." European Journal of Engineering Education, vol. 31, no. 1, pp. 73–81, 2006.

[16] A. Jezegou, "Community of inquiry in e-learning : A critical analysis of garrison and anderson model." 2010.

[17] L. Cohen, K. Morrison, and L. Manion, Research Methods in Education.
Routledge, 2011, vol. 7th ed.

[18] A. P. Field, Discovering statistics using IBM SPSS statistics and sex and drugs and rock 'n' roll. SAGE, 2013.

[19] J. Pallant, "Spss survival manual 4th edition: A step by step guide to data analysis using spss version 18," Maidenhead, Berkshire: Open Uni- versity Press. Retrieved on from http://www. allenandunwin. com/spss, 2011.

[20] A. T. Tolu, "Creating effective communities of inquiry in online courses," Procedia-Social and Behavioral Sciences, vol. 70, pp. 1049– 1055, 2013.

Technical Papers

Discussion forums in Vector Calculus: Reflecting on the quality of engineering students' online interactions

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***Abstract*—As a result of a worldwide pandemic, academics were guided to take their courses online. Making the Vector Calculus course fully online whilst limited to low tech options, all students can access, the aim was to create an engaging and inclusive environment for students to learn mathematics. Acknowledging the important role that mathematics plays in engineering there was an imperative for the online engineering mathematics provision to include in addition to basic knowledge the fostering of skills such as problem solving, critical thinking, collaboration and communication, all arguably important for the development and expertise of future engineers.**

Discussion forums have long been used in education enabling students to easily and asynchronously access and respond to what their peers, tutors and lecturers have posted and in so doing creating an interactive online classroom. Although much is written about the use of online discussion forums in higher education, few studies refer to its use and how effective these online interactions are to the teaching and learning dynamic especially in Mathematics courses.

This research study rooted in constructivist theories of learning employed a conceptual framework to assess the quality of students' participation in this community of learning. The three-pronged framework assesses content, interaction quality and objective measures.

The findings demonstrate the benefits of discussion forums in creating an interactive community of learning in a Vector Calculus course and the lessons learnt could inform future design and best practice for online discussion forum use in higher education mathematics classrooms.

Keywords—Discussion Forums, Mathematics, Vector Calculus, Engineering students, Higher Education

I. INTRODUCTION

Online discussion forums have gained much popularity in blended and fully online contexts in higher education. An online discussion forum is defined as a "virtual platform for people to exchange information on given topics in a hierarchical or threaded structure" [1]. Discussion forums have the potential to create an active learning community for high quality learning to take place where students have time to reflect on and research topics before they respond, their posts remain online for others to access anytime and students can interact with the posts of their lecturers, tutors and peers.

Much research has been done on discussion forums and this and the foregoing reasons made it a useful technology-based pedagogy in the fully online remote context we found ourselves in due to the global covid 19 pandemic.

Mathematics is fundamental to the study of engineering courses and has an important bearing on the success of engineering students. Research suggests that Vector Calculus is one of the important and difficult courses in undergraduate mathematics studies, challenging for many students. Therefore, it was imperative to provide support for students' learning and success and a need to shift to a more personalised, social, open and dynamic "student pull model of learning" [2]. In our context that shift was the implementation of discussion forums providing a much- needed online tool to maintain the communication of participants in the course, encourage engagement with course content, offer support to students and facilitate student learning.

At the core of online discussion forums in education is student interactions. Not only is interaction an important factor influencing learning in face to face contexts, it is found to be equally so in online contexts [3] yet students' interaction with each other is an aspect underestimated in the teaching and learning dynamic [4]. Interaction in a discussion forum is defined as "a voluntary presence in an internet -mediated discussion including mandatory presence under a course requirement" [1]. Student interaction is considered an important factor for a successful online educational experience [5] and a high amount of interactions signifies a higher level of effective learning [6].

In a fully online learning context, an awareness of what contributes to successful discussion and constitutes effective learning is important. Quality online learning environments are characterised by constructivism and knowledge building, reflective and collaborative learning and supported by scaffolding [7]. To make sure these important notions are well represented it is important to assess the quality of the discussion forums.

Although much is written on discussion forums, little research is undertaken on discussion forums in Mathematics and on how to assess the quality of the interactions therein. This research was undertaken to explore this technology- based pedagogy to maximise the benefits for mathematics students and to ensure effective teaching, learning and assessment in Mathematics courses.

This research was carried out in a support program for engineering students at a South African university. As students had different levels of access to technology, the internet and Wi-Fi connectivity, low tech and low data options had to be considered in the instructional design of the course. The discussion forums were asynchronous allowing students over a period to participate at their own pace and convenience. Research shows that asynchronous discussions tend to be more structured and cohesive than synchronous discussions. To encourage students to participate the discussion forums were attached to a course

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grade as research on measurement of participation in discussion forum cites the connection to grades as the most influential factor impacting participation [8].

Research recognises the benefits of face to face discussions yet not much is written on the benefits of online asynchronous discussion forums [9]. To maximise the benefits to student learning the quality of online discussion forum threads is important. "The dedication to analyse the content of forum participation has overshadowed detail into how quality can be evaluated and how to increase productive student participation" [10]. Upon reflection on the instructional design of a fully online remote Vector Calculus course there was a need to whilst encouraging engagement with the course content to determine the quality of student learning. We were conscious of the fact that this was for many students their first experience with discussion forums and more so in mathematics courses. This paper is a reflection on the quality of interactions of students in discussion forums in a Vector Calculus course. This was done to inform the design of future iterations of discussion forum use in the Vector Calculus course and to provide a guide to student participation therein.

II. THEORETICAL FRAMEWORK

The theoretical lens for this research study is framed by social constructivism, the community of inquiry model and a conceptual framework for assessing quality of interactions.

A. Social Constructivism

Constructivism's central idea is that human learning is constructed. It encourages, acknowledges and accepts that students are independent, constructing new understanding based on their existing knowledge and that their learning is active rather than passive [11]. The forgoing notions are important in the light of the 2020 Vector Calculus course where students had to take responsibility and regulate their own learning in a fully online remote context.

A partnership between constructivism and technology is advantageous to instructional course design and ensures the building of "more intimate supportive environments" [12]. The Vector Calculus online course design from a constructivist perspective provided opportunities such as discussion forums enabling students to discover and collaboratively construct meanings, respected that students were individuals, supported them through the learning process and encouraged dialogue between all participants.

B. Community of Inquiry Model

From an educational perspective, a community is composed of facilitators, tutors and students facilitating, constructing, and validating understanding, and developing capabilities leading to further learning [13]. The community of inquiry framework proposed by [14] is based on two ideas- community and inquiry where community distinguishes the social nature of education and the function that 'interaction, collaboration and discourse play in constructing knowledge' while inquiry reveals the 'process of constructing meaning through personal responsibility and choice'. A community of inquiry as 'a cohesive and interactive community whose purpose is to critically analyse, construct, and confirm knowledge' [15]. The three core elements of the community of inquiry are social presence, cognitive presence and teaching presence.

Social Presence values that the creation of trust amongst students will lead to open and meaningful communication creating camaraderie and fostering a sense of belonging to the group. It supports interaction, and encourages questioning, interaction with peers and small group discussions.

Cognitive presence is "the process of collaboratively constructing meaning and confirming understanding in a sustainable community of inquiry" [15]. It is fundamental to the inquiry process since inquiry is the integration of reflective and interactive process the cognitive presence plots the cyclical pattern of learning from experience through reflection and conceptualisation to action and then to further experience.

Teaching presence is defined as the design, facilitation, and direction of cognitive and social processes for the purpose of realizing personally meaningful and educational worthwhile learning outcomes [15]. Teaching presence has three components: 1) instructional design and organization; 2) facilitating discourse, and 3) direct instruction. Instructional design and organisation establishes the curriculum, approaches and methods. Facilitating discourse is the means by which students are engaged in interacting about and building upon the information provided in the course instructional materials. Direct instruction is viewed as the instructors' provision of academic leadership through the sharing of their subject matter knowledge with the students.

In this research the discussion forum guidelines are rooted within the community of inquiry framework. Although [15] use this framework as a map for the integration of face to face and online learning activities, this research study adapted this framework to focus on a fully online remote course. The emphasis in this iteration of discussion forum use was on the cognitive presence.

C. Conceptual Framework for assessing quality of interaction

A conceptual framework for assessing the quality of interactions in online discussion forums categorises criteria for quality into three broad categories: (1) Content relates to what extent students postings indicate their mastery of the course topics, (2) Interaction quality defines how students interact in a constructive manner when discussing course content and (3) Objective measures notes the frequency and consistency of students participation [16] . The framework relates to student participation in discussion forums and consists of 12 criteria under the three categories. The framework used in this research to assess the quality of students' interaction in discussion forums provides subcategories and indicate poor, satisfactory, good or excellent performance against the criteria.

III. METHODOLOGY

In this section the research question and research design are presented.

A. Research Question

The research is guided by the question: "What is the quality of students' interactions in online discussion forums in Vector Calculus?".

B. Research Design

The participants of this research study were eighty-nine engineering students enrolled for a one semester Vector Calculus course at a South African university in 2020. The course covers functions of several variables, partial derivatives, multiple integrals, vector functions and vector calculus and is taught over a 12-week period with mainly face to face activities including daily lectures, daily problem- solving sessions and weekly tutorials. Online activities included online assessment and access to online resources. Five weeks into the semester universities in South Africa closed, and teaching and learning moved remotely fully online. The dilemma for the teaching corps was how to maintain the communication and interaction in a fully online space and ensure that learning was authentic and effective. This was exacerbated by students' lack of devices, Wi-Fi connectivity and internet access.

Free student access to the university learning platform promised options such as the asynchronous online discussion forums to be used to maintain interaction with participants and provide an alternative to the face to face in class discussions. The lecturer provided the rubric for participation, set up the structure of the discussion forum and in some instances initiated discussion forums by posting interesting questions, videos, challenging students to productively and effectively engage with the course content [17]. Students responded by posting solutions, asking and answering questions and suggesting methods of interpreting in attempting questions.

Four tutors, the main facilitators in discussion forums supported students scanning the discussion forums for student threads, raising issues, commenting on and directing the discussions in a relevant direction. Besides the limited and irregular internet usage students experienced, the rationale for adopting an asynchronous format of the discussion forums was that students might derive maximum benefit from a well thought through rapport with suggestions, references and answers to their questions and therefore contributing to their effective learning[18].

Ethics approval was obtained for this study and students consented to be surveyed and their information used. Data was collected via learning platform analytics, end of semester student surveys, and students' discussion forum threads. Discussion threads were analysed using qualitative data analysis by coding of threads according to the assessment of quality conceptual framework to see what trends emerged that would inform future design.

IV. FINDINGS AND DISCUSSION

The findings and discussion of this research study are framed with students' initial perceptions of discussion forums. In an online check-in to gauge how students were coping with this sudden move to remote online learning they were asked what difficulties they experienced and suggestions for enabling a supportive online learning situation. Seventy-seven students responded and many raised the issue of discussion forum participation. Although some comments on discussion forums were positive many were not. Those students who embraced this new way of interacting made comments such as "getting familiar with classmates as we work as a team" to "helps me engage with my peers and tutors". The negative perceptions focussed on their difficulty adjusting to a new way of participating, experiencing difficulties keeping up, experiencing stress, finding discussion forums not helpful, feeling uncomfortable using their names, having difficulty expressing questions and answers, not in favour of the lag time in response to questions, and was summed up by

> *"It's hectic and the fact that this online thing is all new to us, it affects how we study. I know that the aim is to engage everyone and get help where possible but for me I feel it creates a lot of pressure."*

In addition, student responses in the end of course survey relating to participation suggested that only 36 percent felt comfortable participating in discussion forums, 28 percent felt comfortable interacting with other course participants and 24 percent felt comfortable disagreeing with others. It is very likely that for many students this was the first experience with discussion forums. In the sudden pivot to remote online learning students were challenged to change their learning styles and it is possible that not all students embraced this 'new normal' taking them away from their comfort zones.

A. Survey

Sixty-four students responded to an online Community of Inquiry survey administered at the end of the course. The findings refer to the Cognitive Presence in the community of inquiry model may have a bearing on the quality of discussion forum threads are reflected in Table 1.

TABLE I *Students response to statements on cognitive presence*

Cognitive Presence	
Statement	***Agree and strongly agree***
The mathematics problems in the discussion forums increased my interest in the mathematics topics covered in the course.	42%
The discussion forums increased my curiosity.	41%
I was motivated to explore content and related questions.	52%
I used a variety of information sources to explore mathematics problems in this course.	80%
I felt that brainstorming and finding relevant materials helped resolve content related issues.	62%
I felt that discussion forums were valuable in helping appreciate different perspectives.	48%
Combining new information from discussion forums helped answer assessment questions.	53%
Discussion forums helped construct explanations and solutions.	57%
Reflecting on course content and discussions helped me understand concepts taught in this course.	60%
I can describe ways to test and apply knowledge created here to other courses.	59%
I have developed solutions to course problems which can be used in practice	53%
I can apply the knowledge created in this course to other non course related activities.	56%

The survey results suggest that little more that 40 percent felt that discussion forums increased their interest or curiosity in mathematics, between 50 and 60 percent responded positively to statements relating to exploring more content and questions, using information from discussion forums to help construct explanations and solutions to answer assessment questions, although 80 percent used a variety of information sources to explore mathematics concepts.

B. Learning Platform Analytics

Participation on the various learning platform tools is shown in figure 1, and it can be seen that discussion forums recorded the highest participation. In future research we should consider to what extent this low positive response in the community of inquiry survey can be explained by the survey takers low participation rate both by the number of threads authored and the number of posts read.

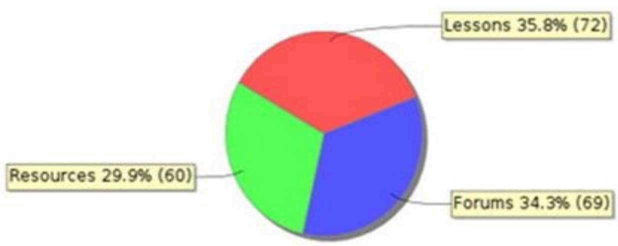

FIGURE 1 *Student activity on various tools on course site.*

Participation, although initially slow increased as the semester progressed as can be seen in figure 2. The discussion forum analytics show this is the case both in the number of participants as well as the number of interactions in the discussion forums increasing. The possible reasons for this could be that more students recognised the benefits of discussion forums, or they participated to satisfy the grade requirements of the course.

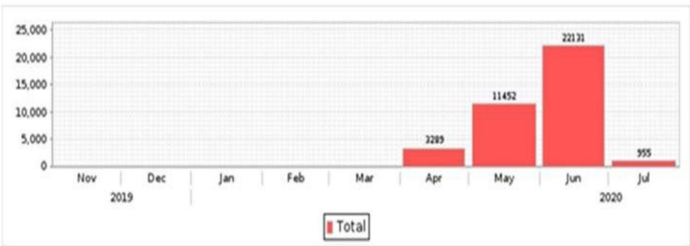

FIGURE 2 *The number of visits to the forum tool on the course site since the site creation in mid April to the course end in mid July.*

Research says that there are three levels of participation in discussion forums:

1) "Lurkers" [19] who just read the threads not interacting with others. They may learn by reading the posts and applying their understanding and ideas into their assessments.
2) Students who simply post their own threads and have limited interaction with others' posts.
3) Participation is interactive and used to its maximum potential.

During the 9-week course approximately a third of the class authored less than 5 posts with 10 students not authoring any posts. Twenty five percent authored the required 16 posts or more, with 2 students authoring more than 50 posts. Four students did not read any posts, over a third read less than 10 percent of the posts, a fifth read between 11 and 20 percent, a sixth read between 21 and 30 percent with 9 students reading more than 50 percent of the posts. Three students read over 90 percent of the posts. There were many "lurkers" as the participation in reading was by far higher than authoring posts, but it is positive to note many who posted threads were interactive with other posts. Some of this lack of participation can be explained by issues with devices and internet connectivity, however this resolved itself in most cases a few weeks into the course.

C. Discussion Threads

Qualitative data analysis was undertaken, and discussion will be presented under the constructs of Nandi's framework for assessing the quality of online discussion forums: content, interaction quality and objective measures [16].

1) Content: The majority of the content of the discussion forums revolved around students asking and answering Vector Calculus questions they encountered in homework assignments, assessments, course and other resources in their studying of the concepts in the course. The questions were an indication that students were engaged in studying the concepts and this was further confirmed by the way in which they immersed themselves in discussion, making it easy to deduce their ability. Their questions and answers were largely well presented and clearly articulated both in terms of language and mathematics. Some students presented diagrams and graphs or attached screenshots and pdfs to put forth their arguments as seen in figure 3.

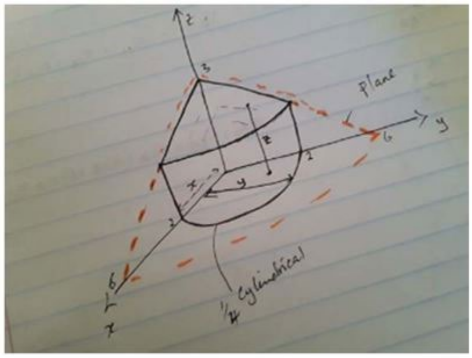

FIGURE 3 *Students' use of graphs and drawings in explanations during discussions.*

i. **Clarifications** were present in that students contributions were very clear, well thought through and showed good understanding of the concepts, some in the way of correcting others such as shown in figure 4, some in the presentations of 'this is what I have learnt' and others detecting and alerting others to errors in resources.

> This is almost correct however its the square distance from the origin you talking about:
> $d^2 = x^2 + y^2 + z^2$
> $therefor,\ d = \sqrt{x^2 + y^2 + z^2}$

FIGURE 4 *Student correction of posts by others.*

In some cases the answers wer arrived at after much engagement in discussions. In most cases **justifications** were visible in the provision of proofs, diagrams and theorems stated. As is the nature of mathematics the **interpretation** was clearly visible in many of the responses with students drawing conclusions and making proposals based on their previously studied mathematical content as can be seen by the well presented interpretation of the polar and rectangular bounds of a double integral in figure 5. The following student response is an indication of **application of knowledge** regarding limitations:

"In the usual applications of polar coordinates where the region is circular (or an ellipse), I would advise to use the formula for the integral as given in the text. Remember that 0≤θ≤2π, but we can only find inverses for cos and sin on intervals of length π. When the limits of integration are functions, they must be well-defined and it is natural to define r as a function of θ. Let me know if this helps."

Discussion focused on key issues an indication that students were able to **prioritise** and understand the fundamental theories in the study of Vector Calculus concepts. Many of the discussions brought to the fore new insights, alternative solutions presented and new ways of thinking of the old problems. Many students exhibited their **breadth of mathematical knowledge** in attaining this level of discussion by posing and answering relevant questions.

2) *Interaction*: Students interacted with each other in constructive ways asking and answering questions and in collaboratively contributing to discussions. Students showed **critical discussion of contributions** of theirs and of others as is seen by this comment "My attempt is similar but unnecessarily explicit" where a student whilst showing appreciation for another response is critical of his own contribution. They worked together, some using new ideas they may have encountered in additional resources, debating to arrive at solutions they acknowledged and accepted. **Sharing of knowledge** took the form of previous experiences, their way of solution and information they would have regarding a particular topic. **Social cues** were used to engage others in asking for help,: " I am struggling to understand...", making an assertion about a concept or complementing one another in ..." very well thought out, thanks". It is important to note that many of the students who participated in the discussion forums did so not only for their own benefit but were instrumental in creating a community of learning in Vector Calculus, challenging and supporting.

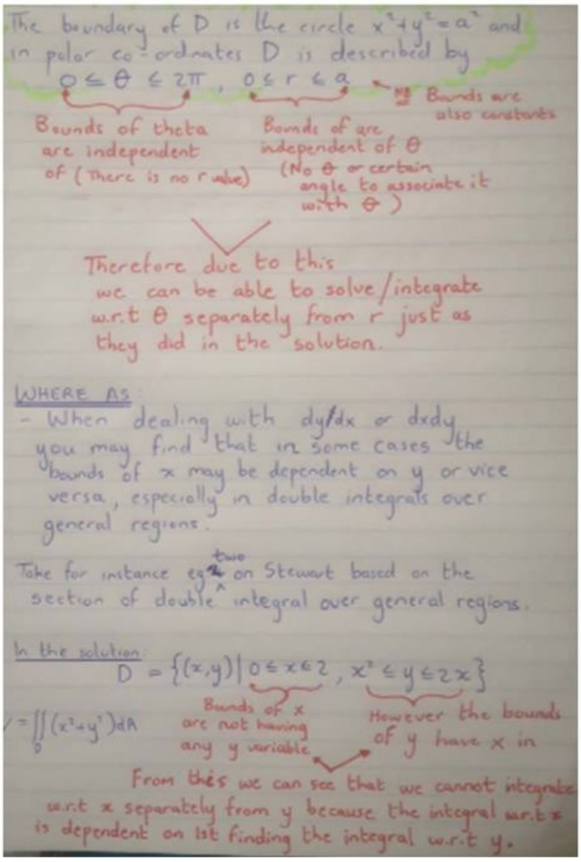

***FIGURE 5** Student post displaying interpretation.*

3) *Objective Measures*: Those students who participated did so regularly and consistently.

V. CONCLUSION

This research was done to gauge a reasonable rate of participation and expectation for posts and quality that would optimally inform the design of the discussion forum in the vector calculus course going forward and impact student success in the course.

Although it is difficult to address the learning preferences of all students, and could not enlist the participation of all, discussion forums nonetheless implemented a valuable strategy for teaching and learning and engaged a wide population of students. Discussion forums in the absence of face to face contact between participants as was the case in our context provided a human interaction in the teaching and learning space. It encouraged a community of learning and presented support for student learning in Vector Calculus.

The limitations of this research are that its focus is a single cohort, however the findings provide important insights that will impact future practice in this course. The discussion forum structure described in this research was an initial iteration and will be adapted in the next iteration of this course. Many factors will need to be considered to promote consistent and active student-student and student-facilitator interactions in the learning process.

The pivotal role of the instructor in carefully crafting the discussion requirement to align with the purpose for the discussion forums, to maintain good participation of students, to establish a structure for the discussion forums, provide a kickstart and to ensure a presence but not to dominate the discussion forum is an important consideration [20]. Tutors acted as facilitators and it is important to stress that tutor training should be included in the setting up of effective discussion forums. Not only should the facilitator be a content specialist they should also have pedagogical expertise. A content specialist will enhance the level of discussion forums by directing discussions appropriately and will be well positioned to provide well informed feedback, referring to theory and relevant resources, spotting misconceptions and scaffolding learning. In addition, the pedagogical expert will carefully craft and appropriately provide the support and scaffolding necessary for student learning.

Communication skills in online discussion forums are assumed and not made explicit [9]. It will be important in future iterations of discussion forums to acknowledge that not all students would have encountered this interaction and may be experiencing discussion forums for the first time and therefore they will need to be initiated into this new pedagogy by a period of preparation factored into the course at the beginning. Evidence from this research suggests the guidelines and rubric for participation presented to students spurred their participation in the discussion forums and that they appreciated that the structure of the forums was provided for this participation to take place. The point to note also is that the connection to the grade was the most important factor driving participation. In addition, in conceptually difficult courses like Vector calculus students who do not understand basic concepts may not participate and hence there should be some provision for scaffolding their learning.

Participation increased as time progressed and a community of learning was developed with students not simply asking questions of each other but supporting each other's learning, encouraging, praising and building confidence. Future iteration should include an introduction component which may influence early participation by inculcating trust and familiarity from the outset [21].

Whilst the limiting factors for participation in online discussion forums are well documented, the advantage is that it can transcend many factors allowing students who in a face to face context may not have interacted to interact with each other [22]. The increased engagement increases their access to learning in the course and can hence make the course more accessible to them. This accessibility was further enhanced by the discussion forums staying open for the duration of the semester allowing students to ask, answer and read questions and content.

Students developed many skills evidenced by their postings. This included writing, communication, social and mathematical skills. These were exhibited by the logical mathematical structure of solutions presented, referencing correct theorems, using diagrams and graphs to make a point, and in the use of MathType.

If we strive for more engagement in Mathematics that result in conceptual understanding in mathematics, then this research offers preliminary evidence that discussion forums support that goal. It is imperative that discussion forums be assessed to ensure quality discussion and engagement is taking place. Since empirical research over a large sample of students supports the notion that students who engaged interactively performed better than those who studied individually [23].

Future research should investigate students' perceptions and performances on discussion forums and the relationship to course outcomes and grades.

REFERENCES

[1] H. Zhou, "A systematic review of emperical studies on participants interactions in internet- mediated discussion boards as a course component in Formal higher education settings,"Online Learning Journal, vol 19, n3, p181-200, 2015.

[2] A.C. Chatti, M.R. Augustian, M Jarke, and M. Specht, "Toward a personal learning environment framework", International Journal of Personal and Virtual Learning Environments, 2010.

[3] I.E. Allen, and J. Seaman, "Changing course: Ten years of tracking online education in the United States", Sloan Consortium, 43(3), 47, 2013

[4] T. Roger and D.W. Johnson, "Cooperative learning: two heads better than one", In Context, vol 18, 1988.

[5] G. Trentin, "The quality-interactivity relationship in distance education', Educational Technology, vol 40 (1), pp17-27, 2000.

[6] M.G. Moore, Editorial: Three types of Interaction, The American Jouranl of Distance, vol 5 (3), pp1-6, 1992.

[7] T.Miyazoe and T. Anderson, "Learning outcomes and students perceptions of online : simultaneous implementation of a forum, blog and wiki in an EFL blended learning setting", System, vol 30(2), pp185-199,2010.

[8] P. Gerbic, "To post or not to post: Undergraduate student perceptions about participating in online discussions, In Who's learning? Whose technology?" Proceedings ascilite, Sydney 2006. http://www.ascilite.org.au/conferences/sydney06/proceeding/pdf_papers/p124.pdf.

[9] J. Delahunty, "Connecting to learn, learning to connect: Thinking together in asynchronous forum discussion", Linguistics and Education, Vol. 56, pp 12-22, 2018

[10] S. Blignaut and S.R Trollip, "Developing a taxonomy of faculty participation in asynchronous learning environments—An exploratory investigation", Computers & Education, vol 41, 149–171, 2003.

[11] W.A Hoover, "The Practice Implications of Constructivism". SEDLetter, 9 (3), 1996.

[12] D.N. Perkins, "Technology and constructivism: do they make a marriage?" Constructivism and the Technology of Instruction. Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers, 1992

[13] D.R. Garrison, and T. Anderson, E-learning in the 21st century: A framework for research and practice. London: Routledge/Falmer, 2003.

[14] D.R Garrison, T. Anderson, and W. Archer, " Critical inquiry in a text based environment: Computer conferencing in higher education, Internet and Higher Education, 2(2-3), pp87-105, 2000

[15] D.R. Garrison, and N.D Vaughan, Blended learning in higher education: Framework, principles, and guidelines. Jossey-Bass, 2008.

[16] D. Nandi, S. Chang, S. Balbo, "A conceptual framework for assessing interaction quality in online discussion forums", In Same Places, Different Spaces, Proceedings ASCILITE, Auckland, New Zealand, 2009.

[17] A.P. Rovai, "Facilitating online discussions effectively". The Internet and Higher Education, 10(1), 77-88, 2007

[18] M.L. Fernandez, "Communication and instruction in an online graduate education course". Teaching Education, 18(2), 137-150, 2007.

[19] G. Salmon, E-tivities: The key to active online learning. London: Kogan Page, 2003.

[20] J. Orlando, What research tells us about online discussion. Faculty Focus: Higher Ed Teaching Strategies from Magna Publications, 2017.

[21] A. Beuchot and M. Bullen, "Interaction and interpersonality in online discussion forums", Distance Education, 26:1, pp67-87, 2005.

[22] B. Gilbert, Online learning revealing the benefits and challenges. Education Masters, Paper 303. http://fisherpub.sjfc.edu/education_ETD_masters/303, 2015

[23] R.D.Owston, and D.N. York,. "The nagging question when designing blended courses: Does the proportion of time devoted to online activities matter?" Internet and Higher Education, 36, pp22-32, 2018.

Technical Papers

Supporting departmental innovation in e-Learning during COVID-19 through e-Learning champions

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***Abstract—*While the adoption of blended or online learning has been spreading across the world, it is not always implemented in a way that transforms teaching and learning. More often than not, technology is used to support traditional ways of teaching and learning. At our institution we have adopted a blended learning definition, that rather focusing on tools and technologies, highlights the importance of pedagogical considerations. Following Gilly Salmon's Carpe Diem design process we encourage lecturers to carefully think about learning design, emphasizing learner needs and disciplinary and institutional context. This study follows six lecturers in the Faculty of Engineering and the Built Environment, who are known as so-called 'e-learning champions'. e-learning champions are "individuals who emerge to take creative ideas (which they may or may not have generated) and bring them to life. They make decisive contributions to the innovation process by actively and enthusiastically promoting the innovation, building support, overcoming resistance, and ensuring that the innovation is implemented" [1]. We are interested in the role these e-learning champions played when supporting their departments before and after COVID-19 with moving teaching and learning online. At the beginning, novice lecturers saw online teaching as simply transferring their face to face teaching strategies online. How to design for interactive online content, student engagement and appropriate online assessment was an unfamiliar territory. The findings are in it's initial stage however many themes emerged here like role of e-learning champion and their contribution towards peer learning. It also speaks about the complexity involved and support from the institution, etc. The paper will conclude with recommendations about future research.**

Keywords—E-learning champions, online teaching, pandemic, academic staff development

I. INTRODUCTION

The Internet has become a common medium for interaction, communication and collaboration within which learners and lecturers engage. Increase in the number of online course offerings are changing the role of the lecturers and the nature of teaching with more staff support required for online teaching [2]. The online environment changes the fundamental nature of the interaction between the teacher, student, and content, requiring a re-examination of the roles lecturers take in enhancing students' learning. Researchers have identified various reasons for the limited understanding in nurturing higher-order thinking in the online classroom. One of the critical reasons is the tendency of carrying over the traditional educational practices into the online environment [3]. Lecturers often rely on traditional pedagogical approaches that they develop in emulation of colleagues or Profs they consider as effective teachers. Support and development programs are critical in helping teachers engage in the process of pedagogical inquiry and problem solving as they reflect upon the interactions between content, online technologies, and pedagogical methods within their unique teaching contexts. Lecturers are expected to adopt more facilitative approaches in creating learner-centered online classrooms [4][5]. While it is seen that there is still a strong focus on the responsibilities of lecturers in online courses, the lecturer moves from being at the center of an interaction or from being the source of information to the 'guide', which implies that lecturers design, organize, and schedule the activities and the learners assume greater responsibility for their learning by coordinating and regulating their learning activities [6][7].

The global pandemic, 'COVID-19' has hit South Africa particularly hard. South African Higher Education (HE) has already been facing disruptions over the last few years. The student protests in the past years have highlighted the inequality that persists in the country's HE system and pointed towards the need to rethink approaches when it comes to teaching and learning. In particular, the protests have drawn attention to the need to not only widening access for previously disadvantaged students, but also create epistemic access for diverse communities of students. During these difficult times e-learning champions have a crucial role in supporting colleagues in their respective departments in the form of motivation, support, assistance, etc. This study is part of a larger study exploring e-learning champions' roles at supporting innovation in teaching and learning in their departments. The-Learning champions as 'academics known in their departments to use technology innovatively and they serve an important function of connecting to the Centre for Innovative Educational Technology with departments and faculties' [8]. This paper will focus on e-learning champions in the Faculty of Engineering and the Built Environment and present initial findings on the contributing factors to adoption of innovation among colleagues.

II. LITERATURE

Online learning has grown dramatically over the past 20 years in higher education settings. Research has found that teaching online requires different competencies, and skilled face-to-face lecturers do not necessarily make quality online teachers [9][10]. This means there is a need for academic staff (lecturers) development to create a meaningful impact on faculty members' ability to design and teach online courses. In order to provide professional development, universities must first identify the knowledge and skills required to teach online. Many researchers have developed and written about the types of knowledge required to teach online courses e.g. context, content taught, student background, level taught, etc. one way to change instructors' attitude towards online teaching and learning is to engage them in online professional development

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experiences that effectively model the benefits and possibilities available in the online learning environment [11].

Few researchers have echoed that through social cognitive theory, instructors can learn new behaviours by observing someone else perform those behaviours and then imitating them. The effectiveness of social models in both observations and social interactions [12]. They also provide secure space to explore the technology and experience satisfaction with its affordances, while observing best practices by the instructor [13]. Therefore, a combination of observation and active process of doing is an important component when preparing lecturers for online courses [12]. Peer modelling is thereby seen to impact others' motivation and behaviors. As a result, professional development that facilitates learner-learner interactions, i.e. peer learning among colleagues, may be particularly effective at changing participants' attitudes and perceptions of online learning [14]. However, only a few existing studies relied on modeling best practices for online teaching and learning through the delivery of online professional development through colleagues. While it might take some instructors longer to adopt online teaching [e.g., 15], the aforementioned studies reported that online professional development increased knowledge and improved faculty perceptions. As online learning technology continues to develop, little information exists on the effectiveness and preference of an online format to foster interactive professional development for instructors preparing to teach online [11] [16] [17]. While the topic of preparing faculty for online teaching is popular in the literature, many studies focus on what to teach rather than how to teach it. Faculty professional development can occur in both synchronous and asynchronous modes that establish online learning communities or focus more on independent and flexible learning.

This paper discusses the role of certain colleagues in the supporting the adoption of blended learning in departments, whom we call 'e-learning champions'. To define these academics, we use Beath's [1] seminal definition of technology champions. According to Beath, champions are "individuals who emerge to take creative ideas (which they may or may not have generated) and bring them to life. They make decisive contributions to the innovation process by actively and enthusiastically promoting the innovation, building support, overcoming resistance, and ensuring that the innovation is implemented". In previous studies we found out that these e-learning champions share a common mindset, that mirrors a design thinking mindset, such as demonstrating a strong empathy for their learners, a preference for collaboration, experimentation and resilience [12]. During the student protests (2015, 2016 & 2017), the institutional shut down for various months, which meant for e-learning champions an opportunity to explore the use of online learning to keep engaging with their students. These experiences proved helpful when COVID-19 hit the institution. Being a large institution, the student population comes from diverse backgrounds, but also from both urban and rural contexts. Many of our students rely on resources offered on campus and in residences, and therefore it could not be assumed that students would have the kind of access to devices, data, and a conducive study environment necessary for continuing the academic project online under lockdown.

The Minister of HE announced in April 2020 that South African universities would need to move to 'multi-modal remote learning systems including digital, analogue and physical delivery of learning materials in order to provide a reasonable level of academic support to all our students at all institutions in order to save the academic year' [18]. This gave lecturers some time to prepare their multimodal teaching and learning strategy, offering not only online learning, but also print-based materials, for students without access to digital technology, data and network connectivity. However, it also meant uncertainty over many weeks and months as the way forward seemed bleak. This is when e-learning champions' roles along with support from the central support units such as the Centre for Innovative Educational Technology (CIET) came to the fore in terms of advising and supporting departments. While CIET offered institution-wide support in the form of webinars, e-learning champions translated this knowledge and these skills into their own context.

III. METHODOLOGY

In this paper, we explore the impact exhibited by innovative HE practitioners i.e. e-Learning champions, within their department in supporting their colleagues during the move to remote teaching and learning during COVID-19. Participants i.e. e-Learning champions, in the project, were selected on the basis of their reputation as innovators, such as winning teaching excellence awards either at the departmental, faculty or institutional level within the Faculty of Engineering and the Built Environment. Interviews of 30– 60 min were facilitated by the members of the research team. Questions in this interview focused on how e-learning champions responded to COVID-19 in order to prepare for remote teaching and learning both in their own teaching practice, but also how they supported their departments in the move to remote teaching and learning. For this paper we define e-learning champions as academics known in their departments to use technology innovatively and who serve important functions of connecting central service units such as the Centre for Innovative Educational Technology within their departments and faculties. It is important to clarify that these are not teaching and learning or technology experts, but academics, who have been using technology for a while and in innovative ways.

Interview questions were designed to gather insights and perspectives on departmental buy-in, particularly on the impact of formal and informal academic staff development, and departments' adoption of e-Learning tools and platforms. Following this phase, interviews were transcribed and later analysed independently by the authors. As a flexible method interviews can provide the researcher with a rich and nuanced account of complex data. . Data was analysed in a deductive way, using literature on learning design and design thinking was an analytical framework. Ethical clearance was sought through appropriate institutional channels. For purposes of confidentiality, participant details are anonymized.

IV. FINDINGS

From an initital analysis of the interview data, initial themes emerged which are described below.

A. Being an eLearning champion is a balancing act

In their responses eLearning champions share an understanding of the difficult position they are placed in. This finding sort of aligns with Beath [1] in terms of what she says about eLearning champions. Although they are known as being innovators, and 'go-to-persons' in their departments, when it comes to questions related to e-learning, they need to negotiate this space carefully, when bringing their colleagues on board. If e-learning champions are positioned too far ahead of their colleagues, it becomes difficult to motivate them to catch up and change and innovation is placed in their sphere of responsibility, rather than being shared. This means sometimes 'underplaying' their roles, stepping back and letting others lead in order to bring in more colleagues.

B. The importance of peer learning

From their responses we could also gather that it helps if there is a team of e-learning champions in a department. Participating as colleagues in a course or co-designing courses and sharing projects, helps gathering support for more innovative teaching and learning approaches. This is inline with what Borup and Evmenova [14] echoed, which is peer learning and it's effectiveness in changing attitudes and perceptions of peers (colleagues in this case).

C. Reducing complexity

E-learning champions share a specific mindset as mentioned before. They like uncertainty and the messiness of unknown situations, such as the lockdown. However, it is also clear that not all their colleagues share a similar approach to innovation. While they strive in these 'liminal spaces' [19], others might feel lost or alienated. In their responses e-learning champions reflected on the importance of reducing complexity for their colleagues and that's where they saw much of their work - in selecting tools to engage with, creating supporting documents and resources, such as course outlines or other structures colleagues could follow.

D. Institutional support

They also all agreed that support by their HOD was crucial in ensuring departmental buy-in. While e-learning champions might thrive in in-between spaces or move easily beyond their departmental, faculty or even institutional boundaries, if they encounter pushback or lack of support within their own departments, the support of management is essential for adoption of innovation.

E. Finding your tribe

Finally, they reiterated the importance of creating platforms across the institution to find like-minded individuals, share strategies and successful practices, but also to offer emotional support and a space where they could be their authentic selves, without having to constantly consider strategic moves in engaging with their colleagues.

V. CONCLUSION

This paper set out to explore the role of eLearning champions in supporting their departments in moving towards remote teaching and learning during COVID-19. Initial findings show the important role that these eLearning champions can play in modelling and scaffolding context-sensitive solutions for their department, when they are aware and reflective of the very specific role they are playing. By translating/adapting generic academic staff development strategies to their specific departmental needs, they can play an important supportive role in departmental buy in into online / blended learning.

A. Recommendations for future research

This study included a small set of participants; thus, while insightful, the findings cannot be generalized and should be considered within the context of this research carried out. Future studies might incorporate some observations that show how much knowledge that lecturers have acquired is actually transferred to their departments. Even studying long-term effects on professional development can be considered. Finally, this study only considered lecturers or instructors therefore future research may benefit from including student voices to see if any changes are happening in the lecturers' knowledge, skills, attitudes, perceptions and are ultimately resulting in improved student outcomes. Seeing these benefits it might interest the lecturers to shift their focus and seek opportunities for high-quality professional development.

REFERENCES

[1] Beath, C. M. (1991). Supporting the information technology champion. MIS Quarterly, 15, 355–372. 10.2307/249647. Retrieved from http://www.jstor.org/stable/249647

[2] Arinto, P. (2013). A framework for developing competencies in open and distance e-learning. IRRODL, 14(1), 167 - 185.

[3] Kreber, C., & Kanuka, H. (2006). The scholarship of teaching and learning and the online classroom. Canadian Journal of University Continuing Education, 32(2), 109 - 131.Retrieved from http://www.extension.usask.ca/cjuce/

[4] Salmon, G. (2004). E-moderating: The key to teaching and learning online. London: Routledge Falmer

[5] Smith, T. (2005). Firty-one competencies for online instruction. The Journal of Educators Online, 2(2), 1 - 18. Retrieved from http://www.thejeo.com

[6] Anderson, T., Rourke, L., Garrison, D., & Archer, W. (2001). Assessing teaching presence in a computer conferencing context. Journal of Asynchronous Learning Networks, 5(2), 1 - 17. Retrieved from http://www.sloanconsortium.org/publications/jaln_main

[7] Berge, Z. (2009). Changing instructor's roles in virtual worlds. Quarterly review of Distance Education, 9(4), 407 -415. Retrieved from http://www.infoagepub.com/quarterly-review-of-distance- education.html

[8] Ivala E. (2016). Educational technology training: Staff development approaches. International Journal of Educational Sciences, 14(3), 195– 204.

[9] Barbour, M. K. (2012). Training teachers for a virtual school system: A call to action. In D. Polly, C. Mims, and K. Persichitte (Eds.), Creating Technology-rich teacher education programs: Key issues (pp. 499 - 517). Hershey, PA: IGI Global.

[10] Allen, I. E., and Seaman, J. (2017). Digital learning compass: Distance education enrollment report 2017. Babson Survey Research Group. Retrieved from http://onlinelearningsurvey.com/reports/digitallearningcompassenroll ment2017.pdf

[11] Elliot, M., Rhoades, N., Jackson, C. M., and Mandermach, B. J. (2015). Professional development: Designing initiatives to meet the needs of online faculty. Journal of Educators Online, 12, 160 - 188.

[12] Gachago, D., Morkel, J., Hitge, L., van Zyl, I., and Ivala, E. (2017). Developing eLearning champions: A design thinking approach. International Journal of Educational Technology, 14(1), 1 - 14.

[13] Walters, S., Grover, K. S., Turner, R. C., and Alexander, J. C. (2017). Faculty perceptions related to teaching online: A starting point for designing faculty development initiatives. Turkish Online Journal of Distance Education, 18(4), 4 - 19.

[14] Borup, J., and Evmenova, A. S. (2019). The effectiveness of professional development in overcoming obstacles to effective online instruction in a college of education. Online Learning Journal, 23(2), 1- 20.

[15] McQuiggan, C. A. (2012). Faculty development for online teaching as a catalyst for change. Journal of Asynchronous Learning Networks, 16, 27 - 61.

[16] Norton, P., and Hathaway, D. (2015). Teachers' online experience: Is there a covert curriculum in online professional development? Journal of Technology and Teacher Education, 23, 509 - 533.

[17] Bedford, L. A., & Rossow, K. A. (2017). Facilitating professional learning communities among higher education faculty: The Walden Junto Model. Online Journal of Distance Learning Administration, 20(2).

[18] Timeslive (2020). Blade Nzimande's statement on government plans to save the 2020 university year. Times Live,30April. https://www.timeslive.co.za/news/southafrica/2020-04-30-in-full- blade-nzimandes-statement-on-government-plans-to-save-the2020-university-year/. Accessed July 22 2020.

[19] Berger, J. G. (2004). Dancing on the Threshold of Meaning: Recognizing and Understanding the Growing Edge. Journal of Transformative Education, 2(4), 336–351. https://doi.org/10.1177/1541344604267697.

Technical Papers

Skills obsolescence and education global risks in the Fourth Industrial Revolution

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Abstract—**The thrust of the Fourth Industrial Revolution and the pressure of industry stakeholders require employers to develop and implement new workforce strategies. In the engineering field, current requirements must address the additional challenges related to planned obsolescence in technology. This phenomenon has represented in recent years a triggering risk for other labor obsolescences, with devastating effects for many companies and educational institutions that were unprepared for these cataclysmic changes. The current panorama is frantic and especially damaging for educational institutions in Latin America, to the point that the worst facet of technology obsolescence, known as systematic, causes a kind of "mirror" obsolescence in academic programs in engineering institutions. The objectives of this Work-in-Progress study are to: (i) identify problems related to technological change skewed by skills in the technology sector labor markets and (ii) assess different initiatives that educational institutions in engineering have addressed, including Higher Education and Continuing Education. This document also briefly presents a statement of the implications for educational practice with focus on actions, possible frameworks of teaching and learning techniques, and a summary of the research preliminary results and findings.**

Keywords— educational innovation, education 4.0, higher education, job obsolescence, lifelong learning.

I. INTRODUCTION

Skills obsolescence is an integral part of technological progress that has become more troubling as jobs in the tech sector have grown increasingly demanding and complex. As technology evolves exponentially in the Fourth Industrial Revolution, this trend is expected to accelerate in coming years. While there are several mathematical models on the effects of technological change, training, and learning at work and its effects on competitiveness and job stability, the matter of skills obsolescence has worsened and transformed in unexpected ways during the COVID-19 pandemic, which continues to impact the labor market unpredictably and require employers and employees to almost immediately implement global digital transformation in the form of online work and remote education [1,2]. A challenging problem that arose in recent months is the need to define new models of obsolescence in education in the framework of the Fourth Industrial Revolution and the management of different forms of labor obsolescence that, in times of COVID-19, have surfaced abruptly. In this historical moment, which some have called *The Great Reset*, the authors believe it is essential to rethink the validity of existing dynamic models, in which the obsolescence of skills and lifelong learning reinforce each other, driven by technological change in the workplace [3].

Extensive literature has over time developed on labor obsolescence in the technological field, but a number of questions regarding the current panorama of education in Latin America remain to be addressed: firstly, to identify the dynamic models that best explain global risks that technological changes can lead skills obsolescence; and secondly, how the redesign and flexibility of higher education and lifelong learning programs in engineering can mitigate these effects and help stimulate economic recovery in the technology sector [4].

This *Work-in-Progress* study seeks to expose the difficulties of the circular economy to retrain the workforce in the post-COVID-19 era and describe the potential roles of different stakeholders. This research study presents a proposal to analyze the obsolescence processes, determine the variables involved, and propose a methodology to establish how engineering education can help develop the necessary skills to decrease staff obsolescence in the workforce.

II. LITERATURE REVIEW

A. Skills Obsolescence and Workforce

In the 1970s, Kaufman had already defined skill obsolescence as the "degree to which professionals lack the up-to-date knowledge or skills necessary to maintain effective performance in their current or future job roles" [5]. In that era of incremental technological advances, *Physical skill obsolescence* or *organizational forgetting* were the types that received the most attention [6]. In our current era of disruptive technological advances, greater attention should be given to the *Economic skill obsolescence* (skills previously demanded are no longer required or have declining in importance) or even to Perspective's obsolescence (obsolete opinions and beliefs about work and the work environment). The concept of obsolescence also included workers such as human resources and the skills and competencies of human capital that market forces left obsolete unpredictably and unplanned. Currently, the incorporation of new technologies in the framework of the Fourth Industrial Revolution is causing unexpected *domino effects* on the socioeconomic and technological drivers of change, the shortening of product life cycles, the increase in environmental costs, and finally the imperative to develop circular economy strategies. As jobs have become more demanding and complex, *skills obsolescence* is an integral part of technological progress that has become more worrying. This trend is expected to accelerate in coming years as technology advances exponentially in the Fourth Industrial Revolution [7].

The risk of skills obsolescence is especially high in industries that deploy rapidly changing technologies. One of the most feared

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consequences is that skills obsolescence will lead to greater job insecurity throughout life, which will make it difficult for older workers to maintain an adequate level of participation in the labor market. It is evident that skills obsolescence and knowledge obsolescence will determine the strategies needed to reskill the workforce: because technological change induces skill & knowledge obsolescence, this will greatly condition lifelong learning initiatives.

Low-skilled workers and workers who lack opportunities to develop their skills throughout their careers are at the greatest risk of obsolescence. Even highly skilled (white collar) workers are not immune. For example, the qualification levels of the European workforce have increased to 2020 with more than 47% of the workforce possessing university qualifications or high-level equivalent. The European challenge for the next decade is to prevent high-level skills wastage, and maintain the competitiveness of its labor market. On the other side of the globe, in Latin American labor markets, the picture is very different: an estimated average percentage of around 20% of the workforce is white collar, so the expectations of maintaining global competitiveness will depend on reskilling and upskilling strategies that are jointly implemented between stakeholders in each country, as shown in Table 1.

TABLE 1 *Comparative workforce Indexes for some countries in Latin America and Europe*

LATIN AMERICA	***Total Workforce (in millions) ****	Percentage of Highly Skilled**	*EUROPE*	Total Workforce (in millions)*	Percentage of Highly Skilled**
Argentina	20.77	24.3%	Austria	4.61	40.8%
Chile	9.58	25.6%	Denmark	3.03	45.9%
Colombia	26.79	18.9%	Ireland	2.42	40.1%
Costa Rica	2.47	22.5%	Netherlands	9.27	47.9%
Guatemala	6.85	9.8%	Norway	2.82	51.5%
Mexico	57.14	18.9%	Serbia	3.22	29.5%
Nicaragua	3.05	18.2%	Sweden	5.47	50.3%
Panama	2.07	25.8%	Switzerland	4.98	52.5%
Uruguay	1.76	21.8%	United Kingdom	34.53	48.2%
Average percentage of Highly Skilled in Latin America		**19.91%**	Average percentage of Highly Skilled in Europe		**47.03%**
Total workforce highly skilled in Latin America (in millions)		**26.11**	Total workforce highly skilled in Europe (in millions)		**36.47**

Sources: *World Bank Open Data (2019) [8] **ManPowerGroup Total Workforce Index (2017) [9]

B. Education 4.0: Global Framework versus Global Risks

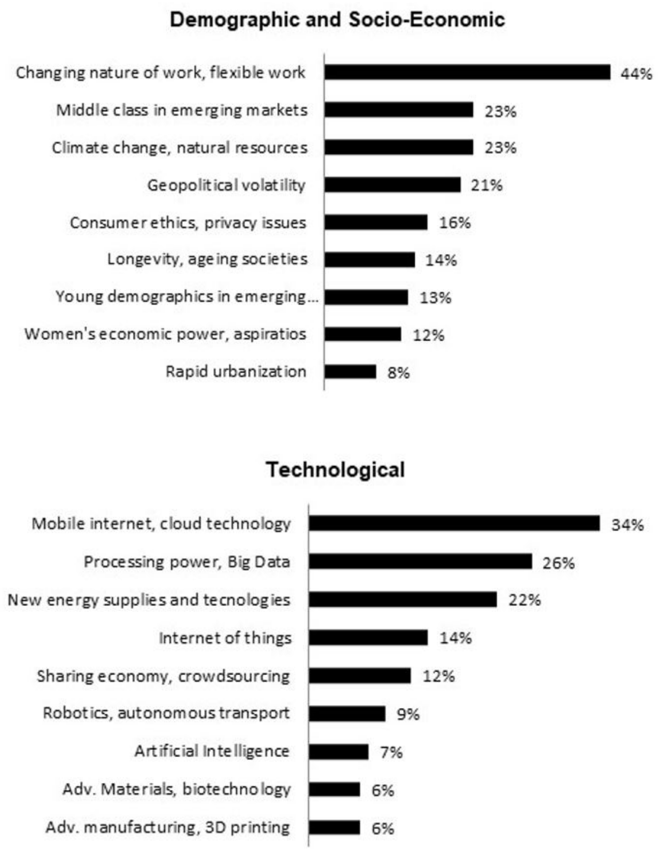
As rapid technological advances continue to transform the world of work, education systems play a critical role in preparing the global workforce of the future. Today, with the emergence of unpredictable global risks, such as the COVID- 19 crisis, the educational models of higher education and continuing education institutions must be flexibly adapted to equip workers with the necessary tools to mitigate skills obsolescence and identify viable models of quality education. Education in the Fourth Industrial Revolution can be identified with the following four skills and four learning characteristics of high-quality learning as **Education 4.0 Framework** [10]:

	Global citizenship skills
Skills	Innovation and creativity skills Technology skills Interpersonal skills
Learning Characteristics	Personalized and self-paced learning Accessible and inclusive learning Collaborative learning Student-driven learning

It is of interest in this study to know what are the internal forces of these systems, who are the relevant stakeholders and finally, what weight some of the characteristics in the Education 4.0 framework have, in these conceptual models. The 21st Century featured irreversible transformations that generated substantial changes in workforce development. International organizations including the Organization for Economic Co-operation and Development (OECD), and World Economic Forum (WEF), in their pre-2020 reports, presented the situation as a global challenge: meeting new demands requires focusing on the nature of future work and on the skills of the workforce to perform adequately those works [4,11].

Thomas Friedman in his famous work showed that 2007 was a year of a great disruption in technology: the iPhone hit shelves, Twitter reached global scale and Airbnb was created in a San Francisco apartment [12]. While technology changed the business environment, were those changes similar in all industries? WEF introduces their survey results of the expected impact of the drivers of change and show how senior executives estimated how those drivers of change would influence different industries [13]. WEF found two kinds of drivers: the demographic & socioeconomic and the technological, shown in Table 2. The first are led by "changing nature of work, flexible work" in a 44%. What is remarkable about the WEF report is the perception about the different impact that those drivers have in the diverse industries. What do these differences mean? The obsolescence of some skills is not universal across all the industries. In observance of the average of the different technological drivers, the industry that will change most is Information and Communication Technology and the industry where technology is expected to change less is Consumer. In Latin America, different stages of technology coexist in industries. While COVID-19 may have changed some of that data due to the forced digital transformation mentioned above, technological adaptation over different industry sectors will inevitably continue.

TABLE 2 Drivers of change



There are big sectors with high tech equipment and advanced levels of digital transformation and others that continue with old technologies. For that reason, what WEF shows about the different needs of reskilling in Latin America is more evident. Workers whose skills development has stagnated or deteriorated are more likely to worry about losing their jobs, have a temporary contract or be less likely to progress in their career. Different surveys show similar results that confirm the pressure workers feel [6]:

- An average of 16% of workers believe their skills have become obsolete in the last two years due to technological developments or structural reorganization.
- Around 18 to 20% of workers indicated an inability to handle cognitive aspects related to the knowledge of their work, as they did two years ago.
- 34% of workers who did not receive training in the previous year are affected by the obsolescence of the skills, and even 22% of those who had participated in the training feel affected by it.

We believe it is essential to understand how to calculate a reasonable lifespan for educational products (such as courses and workshops), why and how workers accept that such trainings have an increasingly ephemeral validity in their lifelong learning, and in parallel to better understand the underlying causes driving the increase in the generation of continuing education products and providers [14]. As the WEF report mentions, Professional Services in Engineering is the second industry affected by the new technologies. These workers are highly skilled and they work globally. This is why many professionals with undergraduate degrees, masters or even PhDs, require education in new technologies. Some schools offer online and offline courses in their executive education. Established platforms like Coursera or EdX already offer such courses; during the pandemic, new companies joined their ranks. As professionals in various jobs sought to adapted to remote work, webinars are winners in the current telework era. Harvard Business School Online organized webinars to teach Profs how to use their case studies online [15].

While a few years ago, during the Knowledge Economy, Latin American countries had the highest risk of skills obsolescence in their workforce; today, driven by the Fourth Industrial Revolution, the risks of skills obsolescence are global and particularly deleterious in two sectors where the workforce is highly qualified: (i) industries heavily dependent on technological changes; and (ii) institutions offering engineering programs, including those from higher education and continuing education. Some research questions were introduced and investigated in the study:

To what extent technology change and obsolescence induce risk of skills obsolescence in highly skilled workers?

To what extent can the introduction, application, and/or implementation in higher education of some of the learning characteristics of the Education 4.0 Framework reduce this risk?

How should be incorporated some of the skills of the Education 4.0 Framework into continuing education programs to meet the workforce post-pandemic demands of reskilling and upskilling?

III. METHODOLOGY

Methodological design. The design chosen for the study was mixed (qualitative/quantitative) experimental based on a 4- group Solomon model [16]. With this type of design interaction effects can be controlled by adding to the PreTest- PostTest control group design two more groups that do not experience the PreTest measures. The group criteria were the following:

EG-PreT: Experimental Group with PreTest and Treatment
EG-T: Experimental Group without PreTest, only Treatment
CG-PreT: Control Group with PreTest
CG: Control Group without PreTest

Participants. A total of 135 participants are still involved over six semesters (S1 to S6), from August 2018 to June 2021. Of them, 90 are undergraduate: 47 students enrolled in Sustainable Development Engineering, SDE program, and 43 enrolled in Mechatronics Engineering, MET program. All the students who participated in the study worked as interns in technology companies with contracts of less than 25 hours a week. Additionally, 45 junior engineers from masters' programs are participating since August 2020 and will finish the study in February 2021, as shown in Table 3.

TABLE 3 Methodological data used in this study

Group Type	*Total sample*	*Students per course*	*Program & Semester ID*
EG-PreT	35	12	SDE - S1 (Aug'18)
		15	MET - S2 (Feb'19)
		8	SDE - S4 (Feb'20)
CG-PreT	16	16	SDE - S3 (Aug'19)
EG-T	56	11	SDE - S1 (Aug'18)
		12	MET - S3 (Aug'19)
		8	MET - S4 (Feb'20)
		25	**Master - S5 (Aug'20)**
CG	28	8	MET - S1 (Aug'18)
		20	**Master - S6 (Feb'21)**
	135		

Instrumentation. Different types of instruments were considered for the study. Some PreTests and PostTests for data collection and research were: questionnaires, interviews, surveys, observation lists, rubrics and other tools to handle parametric data statistically as shown in Figure 1.

In the preliminary stages of the study, two possible conceptual models were considered: The Static Model and the Dynamic Model [1].

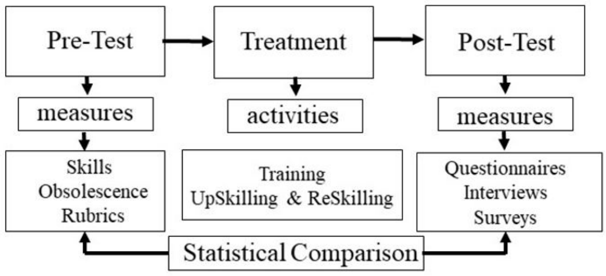


FIGURE 1 *Procedure design*

STATIC MODEL. Training participation and on-the-job learning are exogenous; therefore, the organizational setting drives training and has direct implication on employees' psychological and behavioral consequences.

DYNAMIC MODEL. Skill obsolescence and continuing education mutually reinforce each other, driven by technological change that takes place in the workplace; therefore, the employee sets the endogenous driver and impacts workplace performance.

We have observed in our preliminary studies that workers' skill levels are not static, and that both the decision to train and the decision to organize work to promote learning-by-doing do not appear to be independent of technological change. We have also verified that the static model cannot explain how technological changes cause skill mismatches that lead to innovative learning situations. Considering the aforementioned arguments, we decided to use the Dynamic Model, since it could predict what happens when workers experience the obsolescence of skills more or less continuously in their work. This would lead to a beneficial dynamic effect, in which technological change allows workers to: *(i)* become actively involved in their own learning process; *(ii)* feel truly encouraged and committed to adequate training; and finally *(iii)* become aware of increased productivity at work.

Regarding the PreTests, these were designed to evaluate the level of development of eight competences in engineering students in the last year before graduation: Creativity, Interpersonal skill, Self-awareness, Emerging Technology handling, Criticality, Cultural Framework, Broad Perspective, and the predisposition of Taking Risks. The initial research was conducted to establish correlation between different experimental variables:

- changes in the emerging technology landscape that can contribute to reduce costs, improve efficiency, and be more competitive
- variety of offer for training, upskilling and reskilling in the so called "soft skills" (Criticality and Self-awareness)
- three of the critical characteristics of Education 4.0 framework presented in Sub-Section II.B (Creativity, Interpersonal skills and Teamwork).

The events unleashed by the COVID-19 crisis, led to the inclusion of PostTest different from those initially considered, to evaluate the influence of global risks drivers as an unexpected risk factor for job obsolescence. These were conducted through interviews, questionnaires in focus groups and Specific Interest Groups, SIGs, in videoconference sessions during the months of April to July 2020.

IV. PRELIMINARY FINDINGS AND FUTURE WORK

In the study, obsolescence processes were analyzed, the variables involved were determined, and it was raised how continuing education can help develop the skills that make workers less likely to become obsolete in the workforce. To verify that the students began the study with similar conditions for the development of competencies, we compared the PreTest results in both groups, as shown in Figure 2.

The initial comparison between 51 students (35 EG- PreT and 16 of CG-PreT) revealed that there were no significant differences between both groups. The results also show that the students presented the highest level of development in a skill associated with technical aspects, such as Emerging Technology Handling; but the lowest level of performance in a soft competition, Criticality. On the one hand, the strongest correlation, calculated by means of the Pearson coefficient, could be verified between the reskilling and upskilling of Creativity and Interpersonal Relations and, the Efficiency at work and greater Competitiveness. On the other hand, the characteristics of Education 4.0 that most correlate with job stability were the ability to Take Risks and the attitude of Student-driven Learning.

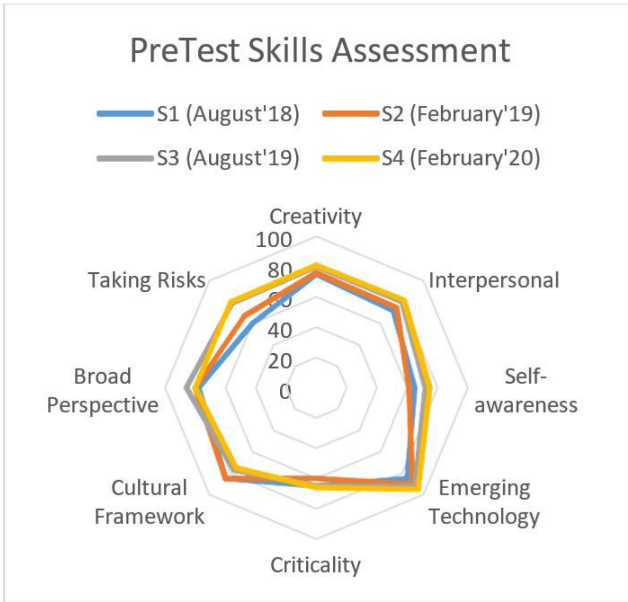


FIGURE 2 *Pretest skills levels measured in semesters S1-S4*

Preliminary results among engineering students connect well with the idea that workers in changing organizations are likely to be exposed to a wider variety of experiences, allowing them to learn new skills informally. We have also observed that employers can enable companies to respond quickly to changes in technology by offering more incentives for recently graduated employees to participate in continuous training programs.

The PostTests on the ability to face a learning process alone, the commitment with training and the awareness of one's own productivity, using VALUE Rubrics (Valid Assessment on Learning Undergraduate Students), showed that the experimental group attained 41% improvement in comparison with the students of the control group in the upper "Capstone" level and a 38% decrement in the number of students who remained at the lowest "Benchmark" level of the rubric. These results are shown in Table 4.

TABLE 4 *Value rubrics distribution for EG and CG*

PostTest Value Rubrics Assessment				
Groups	Capstone 4	Milstones		Bench-mark 1
		3	2	
EG	27 %	38 %	22 %	13 %
CG	16 %	33 %	28 %	21 %
	+ 41 %	+ 15 %	- 21 %	- 38 %

A review of the comments made by interviewees and other stakeholders in the PostTests conducted during the current global crisis situation revealed certain gaps and shortcomings when trying to assess the effects of technological change, training and learning, competitiveness and job stability. Despite this, a recurring position was that the industry will need to work collaboratively with the academy so that workers can continuously reskill and upskill in the post-pandemic world. Our intention is to use the present study as a springboard for future work, to offer final results in June 2021 using the data that remains to be collected to feed the Dynamic Model.

V. CONCLUSIONS

In the days of COVID-19, the Fourth Industrial Revolution has become a catalyst for new strategies involving both, the engineering workforce and education sector, including Higher Education and Continuing Education. The findings support the evidence that skills obsolescence can be considered a Global Risk with devastating effects for those companies and educational institutions that are not prepared for the change. The current panorama is especially detrimental for educational institutions in Latin America, since technological obsolescence accelerates the expiration of academic programs that are not flexible enough. In this particular circumstance, the need to explore new models for evaluating and mitigating the obsolescence of skills becomes evident. This *Work-in-Progress* research seeks to identify the problems related to technological change biased by skills, in the labor markets of technology sectors and the evaluation of new initiatives in the educational field, including innovative approaches within the Education 4.0 Framework.

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REFERENCES

[1] J. Allen, A. De Grip. Does skill obsolescence increase the risk of employment loss? Applied Economics, 2012, vol. 44, no 25, p. 3237-3245.

[2] World Economic Forum Global Risks 2020 Report, Retrieved from https://www.weforum.org/reports/the-global-risks-report-2020.

[3] K. Schwab and T. Malleret. COVID-19: The Great Reset. Geneva: World Economic Forum, 2020.

[4] K. Howells. The future of education and skills: education 2030: the future we want, 2018.

[5] H. G. Kaufman. Obsolescence & Professional Career Development. 1974.

[6] R. Lawlor. Delaying obsolescence. Science and engineering ethics, 21(2), 2015, pp.401-427.

[7] CEDEFOP. Briefing Note: Preventing skill obsolescence. Retrieve from https://www.cedefop.europa.eu/files/9070_en.pdf , 2012.

[8] The World Bank Open Data. Retrieved from https://data.worldbank.org/indicator/SL.TLF.TOTL.IN, 2020.

[9] ManPowerGroup. Total Workforce Index 2018. Retrieved from https://www.manpowergroupsolutions.com/twi/regional- results/regional-results, 2019.

[10] World Economic Forum. Schools of the future. Defining New Models of Education for the Fourth Industrial Revolution. World Economic Forum, Geneva, Switzerland, 2020.

[11] World Economic Forum Boston Consulting Group (BCG). Towards a reskilling revolution: a future of jobs for all. World Economic Forum, Geneva, Switzerland, 2018.

[12] T. Friedman. Thank you for being late, Farrar, Straus and Giroux. ISBN: 9780241301449, 2016.

[13] World Economic Forum. Centre for the New Economy and Society Boston Consulting Group (BCG). Towards a reskilling revolution: industry-led action for the future of work. World Economic Forum, Geneva, Switzerland, 2019.

[14] V. Ratcheva, A. Till, and Z. Saa. "Jobs of tomorrow: mapping opportunity in the new economy." World Economic Forum, Geneva, Switzerland, 2020.

[15] Harvard Business School Online, 2020. Retrieved from https://online.hbs.edu/blog/post/coronavirus-tips

[16] L. Cohen, L. Manion and K. Morrison. Research methods in education. Routledge, 6th edition, 2007, pp.278-279.

Technical Papers

Student industrial secondments in East Africa: Improving employability in engineering

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***Abstract*—Relative shortage of engineering practitioners in Sub-Saharan Africa has been a big concern for many studies on industrial and technological development. However, the region that suffers from this shortage simultaneously has a significant number of existing engineering graduates who find it difficult to land employment in engineering fields. While that situation reflects inability to have enough human capital in industrial processes, two scenarios partly explain the situation: a relative deficit (real or perceived) in the competency of local engineering graduates in ever-advancing areas of science, technology, engineering and mathematics (STEM), and/or scarcity in opportunities to hone and demonstrate competency of local engineering graduates in the labour market. Consequently, local engineering graduates have inadequate hands-on experience needed in industries as well as for establishing start-up engineering firms/businesses. To address this situation, it was postulated that promoting engineering student industrial secondment (SIS) programs can be a suitable approach to strengthening the linkages between engineering study, practice and employability. Since completing academic engineering majors is apparently not enough by itself to bridge the skill gap and prepare most engineers to enter their countries' engineering practice fields, and the currently existing student placements seem to have some serious flaws, the present study was launched with the aim of exploring best practices, for evidence-based policy learning in establishing and running robust engineering SIS programs coordinated between universities and industries – and perhaps with support from the public sector – to serve both industries and students. Using innovation systems and systems thinking as conceptual and theoretical framework approaches, the study included surveying in Tanzania, Kenya, Uganda and Rwanda in addition action research by piloting four SIS placements in Tanzania and Rwanda; the main objective being to observe closely, try potential modules, and learn and synthesize effective experiences of SIS program from developing countries.**

Keywords—East Africa, employability, engineering education, student industrial secondments

I. INTRODUCTION

Engineering fields play a crucial role in developing solutions to the world's technical issues; they bring ideas into reality and particularly contribute to strengthening the capacity of the industrial sectors (SDG 9) which is critical for sustained economic growth (SDG 8). In addition, improving the status of engineering is linked to achieving SDG 4 on knowledge and skills acquisition that would address both qualitative and quantitative knowledge deficits in science, technology, engineering and mathematics (STEM), which stimulates efforts to revitalize interest in paying more attention to engineering in developing countries [1]; [2]; [3] and view engineering as catalyst of technological change. On the other hand, technological change is essential for economic growth and human development. Engineering in this sense is the process of digesting and combining knowledge, resources and arts to create and operationalise technology [4].

Historically, engineering education in East Africa (EA) began later than many other disciplines, such as the social sciences. With the ambition to increase high-output labour (i.e. high-skill labour) in order to push economic growth forward, engineering education at post-secondary levels was established to increase local engineering practitioners. The formation of the East African Community (EAC) in 1967, shortly after independence, helped unify the education system across the countries in the region, especially that higher education institutes were not many [5]; [6]. At the time, engineering students from Tanzania and Uganda used to study at the University of Nairobi, Kenya, as the nearest engineering school in the region.

Things evolved from there and the number of engineering schools and graduates increased as well, however, not in concert with the increasing needs for qualified engineering practitioners in EA [7]. Structural adjustment programs, promoted by in the 1980s by the World Bank and International Monetary Fund (IMF), affected the education sector in African countries in visible ways. "The back on full state funding saw cost-sharing introduced across most levels of the [education] system; the gains in expansion particularly of schooling stagnated and even reversed in the economic decline of the 1990s" [8]. Tanzania, for example, received a significant blow to university-level education quality, and sought to mitigate it by increasing classroom size, introducing measures of cost-sharing with student families, and even cutting budgets on items and services such as maintenance of laboratories and updating curricula; Kenya was not a very different case as well [8]. The picture in EA, however, is not different from the average situation in the continent. A global report by UNESCO, published 2010, emphasized that Africa was struggling with a serious shortage of engineers and technicians – i.e. engineering practitioners – compared to the needs of development, and estimated that, for example, 2.5 million more engineering practitioners are needed to meet the millennium development goals (MDGs) for water and sanitation alone [2]. Later on, surveys from academia and industry

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indicate both numbers and competencies of local engineering practitioners in the continent require improvement [10]; [11].

Nevertheless, where EA and SSA overall experience such a relative shortage of engineers, there are also plenty of graduate engineers who do not land employment in their fields. It is also common that foreign agencies involved in engineering-related activities in the region (as private companies, transnational corporations, NGOs or international agencies) resolve to hiring expatriate engineers and technicians before hiring a satisfying quota of local engineering practitioners, citing limited competency and knowledge of industry's standards among local engineers (particularly young and early-career ones) as reasons for doing so. At country levels, the status of engineering in EA shows varieties of differences between demand and existing opportunities.

A logical question arises from the two realities (of relative shortage of engineers and inability of many existing engineering graduates to land engineering employment): if significant numbers of the existing engineering graduates find it difficult to find employment in engineering fields, how can it be concluded that African economies require more engineering graduates? There must be a gap that is responsible for this dissonance.

Some studies point towards a possible explanation that, for engineering education to produce favourable results in bridging theory and practice, practical training has to be integrated in a number of co-curricular activities such as industrial training/ attachment, internships with industries after graduation, voluntary activities related to field of study, and joint clubs or organizations [12]. Literature in North America and Europe has widely shown the importance of co- ops –what we call student industrial secondments (SIS) – and industrial attachment programs in increasing capacities of students in solving real-world problems.

Studies indicate that such co-curricular activities particularly enhance leadership skills and ethical development [12], enable satisfaction of both students and employers [13]; [14], increase chances of employability shortly after graduation [15]; [14], and reduce companies' training costs for newly hired graduates due to hiring better prepared graduates [14, p.6]. Other pedagogical approaches, particularly in Europe and Africa, that complement co-curricular activities in order to produce competent, work-ready engineering graduates include the context-based curriculum design [8] and problem-based learning (PBL) [16].

The context-based curriculum approach takes into account the level of technological capabilities, as well as needs and priorities in the country/region so that they reflect on such context and help graduate students that are familiar with it and can positively influence it. PBL, on the other hand, has shown relevance and utility in addressing development challenges at both local and global scales, whereby students are engaged in projects taken from real- world cases (past or on-going) to work on. The projects need to be exemplary, that is "learning outcomes achieved during concrete project work are transferable to similar situations encountered by students in their professional careers." [16] Engineering education programs in EA and Africa at large have experience with implementing co-curricular activities and practical training programs.

In some countries such as Uganda most local engineering graduates find employment within one year of graduation [22] while other countries report a significant number of local engineering graduates finding it difficult to land jobs within their fields [11]; [23]. Studies have therefore called for investigation of the competence of engineering graduates as the findings have revealed deficiencies whereby in Uganda at 63% of graduates lack job market skills, while in Tanzania, 61% were found to be ill prepared. In Burundi, and Rwanda 55% and 52% respectively were perceived to be incompetent, and 51% of graduates in Kenya were believed to unfit for jobs [7]. Other sources [24] similarly report weak linkages between foreign investments, local skills and capabilities were partly explained by limited technological capabilities of local labour and firms in the Tanzania manufacturing, agriculture and mining sectors. Other studies [11] report existence of very little exposure to engineering practice in industries and public works, and described the teaching as dominated by "chalk and talk" as opposed to PBL and more practical/engaging style of learning.

One way of approaching these challenges in engineering education in EA is to look at it within "engineering ecosystems". The notion of 'ecosystem' implies many things, such as multiple actors with interdependency between them, and the important role of aspects of systems, such communication channels, feedback loops, timeframes (short- term, medium-term and long-term), unintended consequences, and so on. It is a promising approach because it admits complexity and seeks to navigate ways of dealing with it, instead of reducing it into separate components (often referred to as 'analysis') to identify problems located in components separately, while such problems are likely located in how components interact in a complex system than located in one particular component [3]; [9].

A critical question is therefore "what are the opportunities and challenges to enhancing students' employability?" The discussion around the best practices is an important aspect of responding to the question..

In this study, we take the critical question above as our research question, and we examine the best practices, and the findings are relevant for evidence-based policy learning in establishing and running robust engineering SIS programs coordinated between universities and industries – and perhaps with support from the public sector – to serve both industries and students. The study aims at contributing toward measures with which EA policies (national and regional) could explore the approach of enhancing SIS programs.

II. METHODOLOGY

This study used innovation systems (IS) (as a conceptual framework) and systems thinking (as a theoretical framework) to gain knowledge and understanding of the potential of tertiary student industrial secondment (SIS) programs in strengthening engineering ecosystems in East Africa. IS is important in organizing the productive forces and structures, and the flow of information and skills in order to increase the output of innovative solutions to development constraints [27]. It involves a careful investment in education systems, enterprise support and labour markets [28]. Systems thinking, on the other hand, overlaps with such understanding of IS, and views various phenomena as "systems", i.e. sets "of things – people, people, cells, molecules, [machines, procedures, etc.] – interconnected in such a way that they produce their own pattern of behavior over time [29]. The use of these approaches was meant to strengthen the linkage between engineering study, practice and employability through understanding leverage points in engineering ecosystems, as the study postulate that promoting engineering SIS programs can be a suitable approach to strengthening these linkages. The study mainly aimed at observing closely, trying potential models and learning and synthesizing effective experiences of SIS programs from East African countries.

Methodologically, the study used a qualitative approach - historical case study strategy - and employed both primary and secondary data through survey and review of different reports that synthesize effective experiences of SIS programs in EA and from other parts of the world. The survey exercise was conducted in the four (4) EA countries of Tanzania, Kenya, Uganda and Rwanda in terms of previous and current experiences of engineering, undergraduate SIS programs and their indicators of effectiveness (qualitative and quantitative).

In Tanzania, we conducted key-informant interviews with university faculty, state officials in research councils and engineering boards, and industries and industry bodies that were involved in and familiar with engineering students' practical training programs. A similar process – on a smaller scale – took place in Kenya. In Rwanda and Uganda we had general meetings with engineering university faculty and public officials in research councils who were able to provide us with lists of public sources of information and comprehensive studies (i.e. secondary data) that were relevant to our research questions.

The secondary data were collected from the public documents in relation to the study objectives. Generally, data focused the history of the practices in EA and on the best practices among the reviewed programs (within EA) as well as best practices known in other countries with comparable industrial conditions to EA, to recognize gaps in the status quo. These activities were meant to produce critical findings on ways to design and implement engineering SIS programs in EA.

The study is currently half-way through and as of now has completed phase I (survey activities), which is treated in this respect as stand-alone. Phase II (pilot – action research) is ongoing, after which synthesis and learning from both phases will be combined to produce policy lessons.

III. PRELIMINARY FINDINGS AND DISCUSSION

Preliminary findings indicate several similar experiences with student industrial training programs and initiatives in terms of models, challenges, feedback loops and perspectives of stakeholders. SIS models are the same and have been so since engineering departments were established in most of the East Africa region.

A. Arrangement between academia and industry in involving engineering students

The arrangement between academia and industry in major EA engineering programs, in universities and institutes of technology, that involve engineering students or fresh graduates shows that the period for practical training program has been designed in a way to build engineering experience from artisans/hands-on to higher levels of engineering practices. Engineering schools prepare first year students as artisans, second year as technicians and third year students as engineers. In Tanzania, for example, on average, 2500 students from the Dar Es Salaam Institute of Technology (DIT) and 1800 students from the University of Dar Es Salaam (UDSM) go for practical training every year. The capacity to accommodate the students is also limited as on average it was estimated around 120 industries per year host the students. All the engineering schools and students compete for placements in the limited existing industries. In Rwanda, industrial attachments take 10 weeks in organizations of students' specialty just after the completion of the third year. In Kenya, students in industrial attachments have logbooks on which they are expected to record daily assignments, and universities ensure that students report to their respective attachment places through an assessment form.

B. Engineering education and employability: numbers and trends

Tanzania leads in terms of registered engineers in the region. 63% of the registered engineers in the EAC are from Tanzania [22, p.41]. However, benchmarking in the Southern African Development Community (SADC) shows that Tanzania has about 60 engineers practitioners per 100,000 persons, which is actually low in the region [25]. In Uganda, a tracer study conducted between 2008 and 2012 on "Ugandan engineering graduates" shows that civil engineering graduates lead in proportion (25.7%), followed by telecommunication (17.6%), mechanical (17.2%), electrical (14.1%) and agricultural (5.4%) engineering. Despite having a good record of employment shortly after graduation, according to the tracer study, the majority of Ugandan engineering graduates (91.7%) were not formally registered due to, among many other reasons, lack of minimum requirements for registration. Like Tanzania, Uganda has a small per capita ratio of engineers per population (one engineer per 53,000 people versus a desired global average of 1:770. In Rwanda, although no aggregated data were provided, the 2014 tracer study of graduates from higher learning institutions (HLIs) revealed that engineering graduates lead compared to other disciplines. Between 1996 and 2013, the report shows that 6180 students graduated with engineering degree as compared to 2286 from medicine and 3739 from ICT. According to the World Economic Forum Executive opinion survey, Rwanda ranked 74th (out of 148) in the world in terms of availability of scientists and engineers, and 125th in objective measurements of enrollment in tertiary education [21]. The UNESCO Go- Spin report on Rwanda concludes that the fields of medicine, ICT and engineering experience critical skills gaps. In addition, Rwanda has a 15% unemployment rate, which is explained by challenges in synergy and partnerships between public and private employers with HLIs. A 2017 UNCTAD report on Rwanda says that "each year, 1400 engineering students successfully graduate. In the last promotion [2016], 300 had found a job in government structures and 200 in the private sector, while the others are searching for a job, and this in spite of an unresolved skills gap." [20, p21]

C. Main policies and institutions that Influence the engineering ecosystem

EAC member states have in place institutions and policy framework that play an important role in influencing the engineering ecosystem in the region. Academic institutions are mostly at the centre of the system, and the synergy among the actors is influenced by the nature and quality of the policy and institutions in place. For example, the EAC treaty (article 104) allows free movement of persons, labour, services and right of establishment and residence. The Mutual Recognition Agreement (MRA) for engineering professionals signed on the 7th of December 2012 enables recognition of professionals (registered) of one member state in other member states [22, p.41]. Engineering Registration Boards (ERB) exists in each country with a similar mandate: to make sure that licensed engineers are competent enough to lead projects and missions of engineering nature and that they are capable and aware of safety and quality standards.

At the national level, for example, in Rwanda, the achievements observed in engineering education in terms of enrollment and the level of performance as revealed by different reports indicate serious trends toward change in the national policy of workplace learning [26]. Although the existing policy is designed for technical and vocational training, rather than tertiary, it reflects a general approach toward bridging skill gaps in STEM by using workplace training (internships) and industrial secondments.

In Tanzania, on the other hand, the Higher Education Students' Loans Boards (HELSB) is a funding mechanism that offering loans to students and plays an important role in the engineering ecosystem through having a say in terms of access to education and time the students are required to finish their studies and pay back loans. In addition, there exists the Structural Engineering Apprenticeship Program (SEAP) - a program established under ERB that funds engagement of fresh engineering graduates to qualify for registration as professional engineers.

Kenya has in place a new body called the National Industrial Training Authority (NITA) that engages in sponsoring students' placements in industries. In addition, organizations such as Linking Industries with Academia (LIWA) provide training and linkages between industries and academia through, for example, facilitating students' placements at industries.

D. Observation and Potentials relevant to Engineering Ecosystem

General observations and potentials relevant to engineering ecosystem in the region show the existence of functioning frameworks. In Tanzania for example, frameworks have mostly built upon early establishments from the post-independence period, and they seem to work at the minimum capacity level since few changes take place or divert from what is established, calling for political will to take advantage of the stability to move gears to adjust or transform the enabling environment.

Uganda has many cases of engineering expatriates who come with foreign companies contracting projects in the country. Also, certified engineers from other countries in EA come and work in Uganda, while few Ugandan engineering practitioners are licensed/registered engineers. Under such conditions there is little 'know-how transfer' between foreign and local engineering practitioners, a situation that begs to be addressed.

In Rwanda, taking advantage of the smallness of the country, national policies go with strong coordination, and plans are enforced once approved. In fact, such a situation may sound good or bad depending on the type of policies and implementing institutions. Sound policies – evidence- based or strategy-informed – trigger real opportunities of improvement, while unsound policies bring unintended consequences.

The experience with linkages in Kenya between academia and industry is manifested through the students' assessment forms designed by universities and filled in by industries. Universities rely on those forms to understand students' performance.

Furthermore, the study recorded similar challenges across countries, voiced by student, faculties and industries alike. For example, all four countries reported insufficiency of supervision, placement and financing for students in industrial attachments or practical training programs. The insufficiency in the level of supervision was explained by the number of engineering students that keeps increasing compared to the number of industries in operation in each country.

IV. PRELIMINARY DISCUSSIONS

Weak documentation of the history and present of SIS programs (or industrial training/attachment programs) was one major challenge faced by the study team. Most stakeholders that the study team met could not offer more than verbal information, although the team requested that any relevant documentation be shared. The unavailability of, or weak access to, such records makes it a challenge to have a rigorous investigation –for this study team or for universities and industries in general – to make informed decisions that could improve the status quo.

However, the systems approach that was chosen for the study still came in handy. Engineering ecosystems are broad and interlinked. Elements (nodes) and connections (relations) are diverse and influence each other in various ways. Considerable evidence exists for the existing of systems phenomena, such as:

- reinforcing feedback loops (e.g. less competent engineers graduate, less employed, less new students join engineering schools, less pressure to improve engineering curricula);
- system delays (changes in curricula, or training of instructors in PBL, can only show outcome in years after implementation); and
- possible leverage points (e.g. changes in structure and financing mechanisms of SIS programs). This particular part is the main focus of this study, and it will require clearer documentation and investigation of data (analysis and synthesis) to draw an abstract, broad picture of the engineering ecosystem. Diagram 1 provides a preliminary visualization of the main elements and connections of the engineering ecosystem if new engineers (i.e. senior undergraduates or recent graduates) are taken as the center of attention.

More information also is needed– through the pilot phase (currently ongoing) and second round of stakeholder consultation, after more information and conceptual/theoretical framework (or system mapping) is constructed – to either concretize or challenge the preliminary findings and theoretical argumentation.

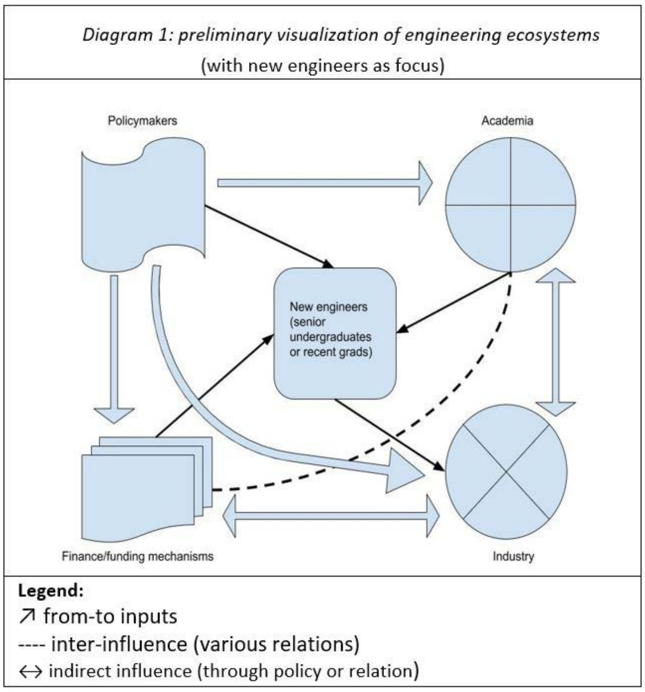

***FIGURE 1** Preliminary visualization of engineering ecosystems (with new engineers as focus).*

V. CONCLUSIONS

From Phase I of the study, general characteristics and patterns already appear. The four East African countries share many similarities, in history and current challenges and interlinkages, making them a good example of a regional 'engineering ecosystem' that exists along national ecosystems as well.

A system's approach points towards a need for recognizing feedback loops and delays in the engineering ecosystems as they respond to a twofold problem: the relative shortage of engineering practitioners and the limitations to employability for the existing practitioners. Pedagogical approaches that aim for strong academia- industry linking, such as SIS and PBL, have the potential of resolving such dissonance (i.e. they could be leverage points in the ecosystems). They deserve a chance.

REFERENCES

[1] N. Ibrahim, C. Luo and M. Metcalfe, "Developing Africa's future city engineers." In Infrastructure and sustainable development-impact of regulatory and institutional framework, 460. The development and investment in infrastructure (DII) Conference Series. Livingstone, Zambia, 2017.

[2] UNESCO, Engineering: issues, challenges and opportunities for development. UNESCO, 2010.

[3] Royal Academy of Engineering, Global engineering capability review. Royal academy of engineering, 2020.

[4] G. Sheikheldin, and B. Nyichomba, "Engineering education, development and growth in Africa" Scientific African, vol. 6, October, 2019.

[5] A. Despres-Bedward, N. Ibrahim and K. Newfield, "Engineering education for sustainable cities in Africa". A conference paper, 2015.

[6] A. Kumar, A. Ochieng, and m. Onyango, "Engineering education in African Universities: A case for internationalization" Journal of studies in international education, vol. 8, pp. 377-89, December 2004.

[7] G. Nganga, "Survey finds most East Africa graduates 'half-baked'. University World News, Global Edition, no. 321, 2014.

[8] J. Case, D. Fraser, A. kumar, and A. Itika, "The significance of context for curriculum development in engineering education: A case study across three African countries". European journal of Engineering education, vol. 41, pp. 1-14, June 2015.

[9] M. Klassen,, and M. Wallace. "Engineering Ecosystems: A Conceptual Framework for Research and Training in Sub-Saharan Africa." University of Lagos, Nigeria. 2019.

[10] C. Beaudry, j. Mouton, and H. Prozesky, (eds) The Next generation of scienctists in Africa. Cape Town: African minds, 2018.

[11] Royal Academy of Engineering, "Engineering for Africa: Identifying engineering capacity needs in Sub-Saharan Africa. Summary report". October 2012.

[12] B. Burt, D. Carpenter, C. Finelli, T. Harding, j. Sutkus, M. Holsapple, R. Bielby, and E. Ra, "Outcomes of engaging engineering undergraduates in co-curricular experiences", 2011 http://deepblue.lib.umich.edu/handle/2027.42/86117.

[13] R. Hackett, G.R. Martin and D.P. Rosselli, "Factors related to performance ratings on engineering students in cooperative education placements". Journal of engineering education, vol. 87, no. 4, pp. 455-58, 1998.

[14] T. Friel, "Engineering cooperative education: A statistical analysis of employer benefits. Journal of engineering education, vol. 84, no. 1, pp. 25-30, 1995.

[15] D. Kotys-Schwartz, M. Besterfield-Sacre, and L. Shuman, "Informal learning in engineering education: where we are – Where we need to go". Proceedings – Frontiers in Education conference, October, 2011.

[16] Aalborg University, "Problem based learning – Brochure". Aalborg University, Denmark. PBL.AAU.DK, 2015.

[17] University of Dar Es Salaam, "Practical training in industry: regulations and guidelines". College of Engineering and Technology, 2018.

[18] Makerere University, "Guidelines for field attachment", n.d.

[19] Republic of Rwanda, "A tracer study of graduates from Higher learning institutions (HLIs) and employers' satisfaction of graduates' competences". Submitted by LG Consuslt LTd (Powered by Rwanda association of Local government Authorities (RALGA), 2015a.

[20] UNCTAD (United Nations Conference on Trade and Development", "Science, technology and innovation policy review: Rwanda." UNCTAD/DTL/STICT/2017/8. UNCTAD, 2017.

[21] UNESCO, "Mapping research and innovation in the Republic of Rwanda". Edited by G.A Lemarchand and A. Tash. vol. 4, 2015

[22] I. Barugahara and S. Sebbale, Tracer study of engineering graduates in Uganda: an expedition from University to work. Uganda National Council for Science and Technology (UNCST), 2016.

[23] G. Mohamedbhai, "Improving the quality of engineering education in Sub-Saharan Africa. Report for the global engineering deans council".
February 2014

[24] STIPRO (Science, Technology and Innovation policy Research Organisation), "Industrialization and energy in Tanzania: Challenges and opportunities". Concept note presented at the roundtable on industrialisation and energy in Tanzania, Dar Es Salaam , 2018

[25] SADC, "Engineering numbers and needs in the SADC region". Gaberone: The southern African Development Community (SADC) Secretariat, 2019

[26] Republic of Rwanda, "National policy on workplace learning to prepare Rwandan youth for employment (Workplace learning policy)", 2015b.

[27] B.A., Lundvall, ed, National innovation systems: toward a theory of innovation and interactive learning. London: Printer, 1992.

[28] R. Maharajh, M. Scerri, and M. Sibanda, "A review of the national innovation system of the United Republic of Tanzania". External review report, 2013.

[29] D.H. Meadows, "Leverage points: places to intervene in a system". The Solutions Journal, vol 1, no.1, pp. 41-49, 2010.

Technical Papers

Multi-party collaborative education: A new way to train high-quality engineering talents in China

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***Abstract*—Proficient engineering problem-solving skills are indispensable for engineers, but the limited engineering practice experience provided by universities cannot meet the future work requirements and career development needs of engineering graduates. To give full play to the role of university external resources in training engineering talents, China has proposed and implemented a multi-party collaborative education(MPCE) model in which universities, enterprises, scientific research institutions, industry organizations, and governments have cooperated in-depth. Different from previous engineering education reform policies, MPCE is the first important engineering education reform made by China from the level of national development planning since entering the 21st century. This model aims to carry out the cooperation with various stakeholders outside the university in a larger scope and deeper degree, to train all kinds of engineering talents to better match industry requirements and adapt to the current and future development of economic society. To provide some inputs and rationales to engineering education policymakers in other national contexts, this paper systematically sets out China's MPCE model, and analyzes the MPCE conceptual framework and the roles of universities, enterprises, research institutes, governments, and industry organizations in MPCE. It is concluded that the systematicness, synergy, and integrity of policies are crucial to the formation and development of the university-industry interaction.**

Keywords—industry-university cooperation, multi-party collaborative education, internship problem-solving skills training, engineering education

I. INTRODUCTION

Talent is the core resource of current economic and social development and innovation activities, so the effectiveness of talent training has been widely concerned. The new stage in China's economic and social development of talent demand and the trend of the future new technology revolution puts forward new requirements to the talent training, namely economic growth must shift from relying on a large number of lower-level technical persons to relying on high-quality innovative talents. The practice is the essence of engineering and the foundation of innovation, and the engineering practice education system is the basic platform for the cultivation of innovation ability of outstanding engineering science and technology talents.[1] Having students with 'work-based' skills is a means of guaranteeing economic development in a new technology revolution round. [2] Developing students' skills to move into industrial roles is now viewed as fundamental for graduate readiness to work and is linked to engineering problem-solving skills.[3] In order to equip undergraduates with job-oriented job skills, engineering education must extend beyond the classroom to the industrial sector[4]. The new trend of economic development is gradually blurring the boundaries of higher education system. It has gradually become a reality for governments at all levels, industrial enterprises, research institutes, and industrial organizations to participate in personnel training. The participation of all parties outside the university in the personnel training has been gradually strengthened, and the personnel training system has been expanded and endowed with richer connotations.

Actually, increasing interaction of university, industry, government, and other parties outside the higher education system is always a crucial research topic. Etzkowitz and Leydesdorff built the 'triple helix' (government-industry- university) theory to explain and enhance the interaction between university and industry.[5] However, The 'triple helix' theory stresses innovation, instead of engineering talents training. Even though the 'triple helix' theory had a heavy influence on China's government-industry-university collaboration of R&D, the industry participation of engineering education still lacks dynamics. To give full play to the role of university external resources in training engineering talents, China has proposed multi-party collaborative education(MPCE) model in which universities, enterprises, research institutes, industry organizations, and governments have cooperated in-depth. The MPCE is a new initiative that advocates multi-party participation and focuses on engineering talent training, which different from former initiatives. Chinese State Council issued the document of *Several Opinions of the General Office of the State Council on Deepening Integration of Industries into Education* on December 19, 2017, and on July 24, 2019, the ninth meeting of the Central Committee for Deepening Overall Reform reviewed and adopted *A Plan on Promoting A National Pilot Program for the Integration Between Industry and Education*, which issued on September 25, 2019, by the National Development and Reform Commission, the Ministry of Education, Ministry of Industry and Information Technology, Ministry of Finance, the Ministry of Human Resources and Social Security, and State-owned Assets Supervision and Administration Commission. MPCE has risen to the level of the national development plan, which reflects the great significance of the integration of industry and engineering education for the future economic and social development.

The paper focuses on the conceptual framework of MPCE and what actions China has taken to reinforce the collaboration among university, industry, government, and industry organization to cultivate engineering talents. Especially, the paper addresses the mechanism for MPCE and explains the different initiatives and actions which China has taken. The main difference China has done is that the MPCE becomes a national plan and action. Moreover, China stresses on the integrity of the MPCE parties and makes the

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industry organization play the role of bridging the gaps among governments, universities, enterprises, research institutes, and other parties.

II. METHODOLOGY

The article builds on a series of policy documents that were published during the recent five years. The policy documents describe institutional approaches and policy measures that are related to MPCE in China. The paper constructs a conceptual analysis framework based on Text Mining, and then uses the conceptual framework to analyze how the policies were initiated and developed, and the mechanism for implementation.

The policy documents are from the website of the Ministry of Education of the People's Republic of China. Following completion the policy documents were synthesized by the author. The analytic process was done manually to assure that they can be considered comparable and refer to the same overarching theme. The analysis compares the qualitative studies with the aim to depict common features and approaches in the respective thematic field.

III. CONCEPTUAL FRAMEWORK OF MPCE

A. Connotation and extension of MPCE

MPCE is a kind of talent training mode, which refers to multiple participants such as universities or colleges, governments, enterprises, and scientific research institutes, according to the principles of resource sharing and complementary advantages, and based on their own interest claims, while satisfying each other 's interest claims to form a collaborative system in which all stakeholders participate together to achieve synergistic effects and jointly cultivate a talent training model with practical and innovative capabilities. MPCE promotes the in-depth cooperation among governments, universities or colleges, enterprises, scientific research institutes, industry associations, and international higher education institutions through a collaborative mechanism to achieve effective integration of scientific research and teaching resources, to form different types of personnel training vehicles, and improve the quality of talent training, the technical level and core competitiveness of enterprises, and the scientific research capabilities of universities and institutes.[6]

As the importance of MPCE for improving the quality of engineering talent cultivation has been highlighted, it has triggered the transformation of the entire education system and the development of the entire industry system with a focus on engineering education, which has become a national industrial structure transformation and upgrading, educational reform and talent development of an organic part of the overall system design. In the continuous evolution, MPCE has been given multiple historical missions: it is not only a new mode of promoting engineering education innovation to lead economic development but also a new mode of realizing "demographic dividend" to "engineer dividend" in China's economic development. Furthermore, it is also a key force for China to reserve talents to cope with future global competition, the new round of scientific and technological revolution and industrial transformation MPCE has gone from the early stage of school-enterprise cooperation and collaborative education to the stage of transformation, upgrading and deepening of the implementation of action, and then to achieve its mission.

B. Roles of joining parties in MPCE

The main participants of MPCE include universities or colleges, enterprises, governments, research institutes, and industry organizations. The main goal of MPCE is talent training, but talent training is not the only goal. The goals of MPCE also includes all subjects collaboration in the cultivation of innovative talents, scientific research, technology research and development, the transformation of scientific research achievements, innovation and entrepreneurship, and industry incubation. The participants and functions of MPCE are shown in Figure 1.

FIGURE 1 *Participants and functions of MPCE*

Participants in MPCE need to play their own roles and take into account each other's needs to achieve win-win cooperation. Universities or colleges mainly provide students, faculties, resources, and environment, which possess all kinds of innovative talents, multi-disciplinary scientific research teams, and excellent education and research environments to help industrial enterprises to develop and win the market competition, governments at all levels to achieve development goals and implement policies and measures, and scientific research institutes to obtain innovative results.

The important role of industry or enterprise in the training of engineering talents mainly lies in the following conditions that the university or college does not have: 1) accurately grasp the social demand for engineering talents; 2) has the most advanced production equipment and manufacturing technology; 3) has a group of experienced engineering and technical personnel; 4) provides real engineering practice and innovation environments; 5) owns a learning atmosphere with a complete advanced corporate culture. The cooperation between universities or colleges and industries or enterprises in cooperative education is precisely to take these advantages of enterprises.

The government mainly provides systems and policies support for MPCE. The central government and local governments influence the national and local industrial development layout, direction, structure, speed, and scale through policies. Therefore, the systems and policies made by the government play important roles in all parties' cooperation. Besides, the government can provide information and build platforms for the collaboration.

There are two ways for universities and governments to promote the MPCE: the first one is to support the implementation of government industrial policies and measures by cultivating engineering talents that industry needed to promote the development of the industry; the second one is to influence the formulation of industrial policies and measures of the government through the construction of engineering disciplines and the direction of industrial development in the future [7].

China has a large number of research institutes, which mainly engaged in frontier basic research and applied research. The research content is closely related to current or future industrial development and corporate needs. And it aims to promote the progress and development of the entire industry by technology as scientific research. Research institutes can provide cutting-edge technical support for MPCE, including advanced experimental conditions and high- level technical guidance.

Industry organizations also play a vital role in MPCE, mainly as a bridge of coordination and communication between stakeholders to promote the realization of MPCE goals. Firstly, industry associations can deepen mutual understanding and complementary advantages between enterprises and universities through information communication and exchange, and deepen sustainable and in-depth cooperation between the two parties. Secondly, industry organizations can coordinate the relationship between the government and the market, which is conducive to giving full play to enterprises. The role of market regulation and government guidance in the development process to promote the development of enterprises and increase the enthusiasm and initiative of participating in multi-party collaborative education. Thirdly, industry organizations can provide the current and future information and necessary technical guidance for all parties involved.

IV. THE IMPLEMENTATION PATH OF MPCE

The fact that China's higher education system is dominated by public universities and colleges determines that the reform of higher education model must be led by the government. The government plays a crucial role in this reform, and the central government and its ministries, local governments and departments in charge of education administration are participating in this important reform.

A. Overall designing the national industry-education system integration mechanism

The policy called Several Opinions of the General Office of the State Council on Deepening Integration of Industries into Education, which issued by the Chinese State Council in 2017, systematically planned the future integrated development of industry system and engineering education system. In 2019, the national development and reform commission, the Ministry of Education, and other ministries and commissions jointly issued the document of *promoting a national pilot program for the integration between industry and education.* Subsequently, the national development and reform commission and the ministry of education jointly issued the document of *implementation measures for the integration of industry and education enterprises (trial)* in 2019. All of these policies emphasize the top institution design of MPCE and build a quaternity structure by giving full play to the role of supply and demand in coordinating government planning, important enterprises, the reform of talent training in colleges and universities, and social organizations. MPCE extends the integration of industry and education from vocational education to the whole education system with the focus on vocational education and higher education, and promotes the integration of industry and education from the development concept to the system supply.

To strengthen the integration between the engineering education system and the industrial system, the Chinese government coordinates the integration of the entire education system and the industrial system from the level of the national development plan, so as to form an integrated technology research and development transformation mechanism and MPCE mechanism, integrate the advantages of academic training in higher education with the practical skills training in the industry, and promote the concept of MPCE into the operational phase. As MPCE can not be completed by the Ministry of Education alone, to further break the boundary between the industrial system and the education system, multiple departments of the State Council work together to promote the integration process of the industrial system and the education system. This changed the model that was mainly promoted by the education sector in the past and assisted by a few other departments in the past. Instead, the new model is jointly promoted by relevant departments including the Ministry of Education, the National Development and Reform Commission, the Ministry of Industry and Information Technology and the Ministry of Finance, and the provincial government. The State Council will make an overall arrangement for relevant sectors to participate to ensure the horizontal coordination of departments. At the level of specific operating mechanisms, the government leads or guides, taking universities and enterprises as the main body, organically combining various government sectors, industries, enterprises, research institutes, financial institutes, universities or colleges, and other institutes to form an integrated innovation of industrial system including real economy, science and technology innovation, modern finance, human resource elements.

B. Promoting MPCE by gradient

To form an atmosphere of deep integration of the industrial system and the engineering education system in the whole society, the government is committed to building regions to a cluster, cities to carry, industries to aggregate and enterprises to domain with deep integration of industry and education. A new path and mechanism of reform focusing on the center, cities as nodes, industries as the fulcrum, and enterprises as the focus.

It is an important content to realize regional integration and an important force to accelerate regional integration to promote the integration of the regional industrial system and education system and cultivate high-quality talents. Therefore, the government plans to choose some cities with near geographical locations and close connections to carry out MPCE and build distinctive MPCE areas.

Cities are important carriers for deepening the industry- education integration, and are the main nodes for the implementation of reform policies. The goal of sinking various reform tasks into cities is to solve the problem of the 'last one mile' of policy implementation, and to build a city that integrates industry and education.

At least 3-5 industries will be selected in industry- education integration cities and the provinces to carry out pilot projects. Provincial governments, on the basis of promoting the comprehensive deepening of industry-education integration reform in pilot cities, rely on regionally dominant leading industries or characteristic industry clusters, promote key industries and key areas to deepen industry-education integration, carry out MPCE, and form industry-specific MPCE mode. At the same time, industry administration sectors and organizations play the role of coordination and public service in MPCE reform, so as to create a number of benchmark industries leading the reform.

Enterprise is the main part of MPCE, so the government is actively constructing a number of industry-education integrity enterprises that play important roles in participating in MPCE, universities or colleges reform, and promoting entrepreneurship and innovation skills talent training. The government plans to build and cultivate about 100 enterprises integrating industry and education in each pilot city carrying out MPCE, and encourage the construction and cultivation of more than 5,000 enterprises in other areas.

C. Upgrading the higher education personnel training system to support MPCE

To improve students' ability to innovate and solve complex engineering problems based on practical ability, the higher education system will establish a classified cultivation system for academic talents and applied talents, and increase the proportion of applied talents. At the same time, the government will promote high-level universities to strengthen the cultivation of innovative and entrepreneurial talents, provide students with diversified growth paths, give universities more autonomy, support the construction of applied undergraduates and industry-specific universities, and closely focus on industry needs and strengthen practical teaching to improve the training system focusing on applied talents. The government will reform the professional graduate training mode that combines enterprise and university to enhance the ability to cultivate interdisciplinary talents. As is known to all, evaluation orientation plays an important role in urging the enthusiasm and initiative of colleges and universities to participate in MPCE. The government is actively exploring the establishment of an education evaluation system embodying the MPCE orientation to better stimulate the enthusiasm of various types of universities to participate in MPCE.

D. MPCE platform construction

MPCE needs to achieve a comprehensive and substantial integration of resources, people, technology, management, culture, and other aspects, which requires the establishment and optimization of several platform carrier support in physical space. Universities and colleges, governments and enterprises will jointly build MPCE platforms that carry out the cultivation of technical talents, scientific and technological innovation and the construction of disciplines and specialties, and this situation will open up the chain of basic research, application development, achievement transfer and industrialization. In 2018, the National Development and Reform Commission, the Ministry of Education, Human Resources and Social Security Ministry, and the National Development Bank jointly issued the document of on strengthening the implementation plan of investment and financing support for the construction of training base, which put forward the construction of three kinds of MPCE training base: dominated by colleges and universities, enterprises, and governments. The MPCE training base dominated by colleges and universities mainly serves for students' professional and technical practice and provides various forms of continuing education to the whole society. The MPCE training base dominated by enterprise mainly serves for its own staff training, as well as the productive practice and specialized training of students in vocational schools and universities or colleges. The MPCE training base dominated by the government provides all kinds of workers, vocational schools, vocational training institutions, enterprises and universities or colleges with skills training, skills competition, skills identification, business incubation, teacher training, curriculum research and development, and other public vocational skills training. Besides MPCE training bases, the government also supports universities, local governments, and enterprises to build innovative industry-education integrity platforms. Since the 13th five-year plan, the National Development and Reform Commission has allocated 17.705 billion yuan from the central budget to support the construction of 743 industry-education training bases. The central government budget invests in supporting pilot cities to independently build MPCE training and innovation platforms. The investment further promotes the cross-penetration and mutual integration of innovation factors in higher education and industrial development.

E. Encourage and support enterprises to participate in MPCE measures

MPCE is a kind of market economy behavior, and enterprises are the most vital part. Therefore, it is particularly important to reasonably divide the boundaries of Administrative intervention and market. The promotion of MPCE does not rely on administrative imperative, but gives full play to the role of the market and uses market rules to allocate resources. The government's policy measures focus on the use of market rules, mobilize the enthusiasm of all parties to participate.

Encourage and attract enterprises to participate in the reform of MPCE measures as following: first, the government is focusing on implementing incentive policies such as portfolio investment and financing. Through various channels, the government will support the construction of major MPCE projects. Pilot enterprises can set up a qualified investment in vocational education, 30% of the investment can be used to offset the additional education fees and local additional education fees payable in the current year. All provinces fully implement the preferential policies applicable to education organized by social forces, and make a list of them available to the whole society. For enterprises that have been selected and certified as industry-education integrated enterprises, a combined incentive of "finance + banking + estate + credit" will be given. Second, strengthen the traction of industrial and educational policies.

Encouraging manufacturing enterprises to build training facilities for new production capacity and technical upgrading projects, and supporting qualified enterprises, schools, and enterprises to recruit and jointly train graduate students with professional degrees. Third, support the integration of enterprise demand into talent cultivation, from the "supply-demand" one-way chain of talents to the "supply-demand-supply" closed-loop feedback, and promote the all-round integration of enterprise demand and education supply factors. Carrying out the reform of introducing enterprises into education, improving the system for students to practice in enterprises, and encouraging enterprises to participate in running schools in various forms.

F. New ways for universities to participate in MPCE

Universities will be gradually guided by the government to establish a talent cultivation model to satisfy the needs of industries. First, gradually increase the degree of participation of industrial enterprises in running schools, improve the diversified running system, comprehensively implement multi-party collaborative education, and solve the major structural contradiction between the supply of talent education and industrial demand, to enhance the contribution of higher education to economic development and industrial upgrading. Second, the faculty is the basic guarantee for the quality of engineering education reform, so the university needs to strengthen faculty team construction. Accelerating the mobility of college or university and enterprise, supporting enterprise technology and management talents to teach in university or college, encourage qualified places to explore special job plans for industrial teachers(tutors).

V. DISCUSSIONS

The 'optimal' shape of the university-industry collaboration is likely to vary across countries, regions, and institutions but this article has identified some common principles for national policies, higher education, and institutions. Some of these will also apply to other countries, regions, and institutions. MPCE is a new initiative that China is working on, and its system design is a complex and systematic project. This new model will have a significant influence on engineering education, especially to the undergraduates' work-based ability, because more enterprises will provide more practice opportunities in the MPCE model. From the MPCE model in China, some common principles that can be concluded.

Designing a comprehensive and systematic mechanism for university-industry collaborative education is an essential condition to make the mechanism effective. As the model of MPCE involves the national development planning, the coordination of administrative forces and the role of the market in the formation process, it will be very difficult to complete this difficult reform task without a comprehensive and systematic mechanism design. The design of the system is affected by the supporting systems, and the systems should be coupled with each other. Otherwise, frictions and conflicts between various systems can be easily caused, thereby damaging the overall efficiency of the system.

Attaching importance to the synergy of university- industry collaborative policies must be considered in policymaking, and the policy design should be consistent with the principles of incentive compatibility and harmony. In other words, policies should be coupled with each other to avoid policy weaknesses, conflicts, distortions, and imbalances. Now many MPCE policies and measures have been promulgated on multi-party collaborative education in China. However, these policies are currently fragmented, lacking integration and even the policy objectives inconsistent with policy tools. That indicates some policies do not consider the pre-policy during the formulation process and the impact of policies on the subsequent policies, which leads to the insufficient policy synergy.

Providing incentives for institutions and funding for researchers to engage in MPCE; using appropriate metrics to measure engineering education interactions between university and industry. It is necessary to establish different types of incentive policies as MPCE education policies and project-based financial incentives to encourage universities to change their development strategies and build discipline and professional clusters that are closely connected to the industrial and engineering education chains.

Still many governments, universities, and research institutes are lagging behind in implementation due to internal leadership and management gaps or conflicting policy signals and incentives. university-industry engineering education collaboration will only be productive if it is embedded in a well-functioning entrepreneurial ecosystem. This means that multi-level governance arrangements between ministries, universities or colleges, local and regional governments must define the respective roles of stakeholders while enabling them to be held accountable. Finally, effective governance for the university-industry engineering education collaboration necessitates the input of regional business leaders with a long term commitment to the region.

VI. CONCLUSIONS AND FUTURE RESEARCH

This study analyzes the background of MPCE in China, and then explains its connotation and extension, and the role of each participant in MPCE. Besides it also analyzes a variety of measures taken by the government to promote the MPCE overall mechanism design by gradients and categories, to attract enterprises to participate in by various preferential measures, build a practice platform, and put forward policy recommendations. China aims to promote the in-depth integration of the industrial system and the education system to enhance MPCE to the level of the national development plan. If the plan can be successfully implemented, it is foreseeable that this model will significantly improve the quality of engineering personnel training.

The article studies the MPCE model from the perspective of policy. Future research into the actual physical institute or platform of MPCE would be helpful. That is, although we know that China is actively promoting the implementation of the MPCE and the main actions that governments are taking, we lack systematic knowledge about how MPCE generates physical institute of the platform to provide practice opportunity for engineering undergraduates, how university, government, research institute, and industry collaborate and what specific role they play in a specific physical institute or platform. This would be a worthwhile research direction.

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REFERENCES

[1] J. Lin, "The Construction of China's New Engineering Disciplines for the Future," Tsinghua Journal of Education. Beijing, vol. 38, No. 2, pp. 26–35, March 2017.

[2] Andrews, J., and H. Higson. 2014. "Is Bologna Working? Employer and Graduate Reflections of the Quality, Value and Relevance of Business and Management Education in Four European Union Countries." Higher Education Quarterly 68 (3): 267–87.

[3] Jackson, D. "Employability Skill Development in Work-Integrated Learning: Barriers and Best Practice." Studies in Higher Education 40 (2): 350–67. 2015.

[4] Cranmer, S. 2006. "Enhancing Graduate Employability: Best Intentions and Mixed Outcomes." Studies in Higher Education 31 (2): 169–84.

[5] Etzkowitz H, Leydesdorff L. The dynamics of innovation: from national systems and 'mode 2' to a triple helix of university–industry–government relations[J]. Research Policy, 2000, 29(2): 109–123.

[6] J. Lin, Lele Geng, "Research on the Government Action and Typical Models of the United States and Britain's Multi-Party Cooperative Education," Research in Higher Education of Engineering, Wuhan, No. 4, pp. 52–65, July 2019.

[7] J. Lin, "New Engineering Disciplines Construction: A Updated Version of 'the Plan for Educating and Training Outstanding Engineering' with a Strong Effort," Research in Higher Education of Engineering, Wuhan, No. 3, pp. 7–14, May 2017.

Technical Papers

Engineering graduates at a South African university and their prospective employers – expectations and reality

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***Abstract*—Since the dawn of democracy in South Africa in 1994, numerous changes have occurred at tertiary institutions to enable greater access for people of all backgrounds and increased graduate throughput to fulfil the needs of the labor market for engineers. Widespread changes in the size and composition of successive undergraduate engineering cohorts have occurred. Simultaneously, the needs of industry have undergone significant changes due to the information age, globalization, the rapid increase in technological advances and access. This study attempted to assess the alignment between the expectations of engineering graduates, the expectations of engineering employers and reality. A mixed methods research was developed. The study firstly surveyed engineering graduates at a South African University using a questionnaire developed for quantitative analysis. Convenience sampling and a positivist approach were used. Graduates' needs, study approaches, employment and workplace expectations were determined, analyzed and interpreted through the lens of two frameworks, namely Biggs' study motives and strategies and Bloom's taxonomy. Secondly, the study conducted semi-structured interviews with all engineering discipline academic leaders at the University, within an interpretivist paradigm using deductive thematic semantic analysis. Academic leaders were used as a proxy for industry opinion and questioned on a number of themes including graduate and employer expectations, positive or negative trends, graduate training programs, further training and postgraduate study, exit- level outcomes (ELOs) and graduate attributes, the reality of mis- alignment and what the University can do to limit it. Responses were collated and compared quantitatively and qualitatively where appropriate. A number of issues and mis-alignments were identified together with their causes. Mis-alignment was identified in salary, growth and guidance expectations, confidence, software and niche proficiencies and innovation expectations. Key causes included language barriers, lack of engineering hobbyist backgrounds, workload and study strategies, assessment changes and personal responsibility. Findings were discussed within the theoretical frameworks mentioned above and summarized in light of the objectives of this study. Recommendations for the University in mitigating many of the issues and mis-alignment were provided, along with recommendations for any possible future research in this area.**

Keywords—Engineering education, graduates, employers, South Africa

I. INTRODUCTION

Poor scholarly habits, a high drop-out rate and a high failure rate in certain core modules have resulted in sustained low student performance in many South African University Engineering Programmes credited by the Engineering Council of South Africa (ECSA). The increasing number of students repeating modules often require five years or more to complete the four- year BSc.Eng. degree. The average time for an engineering student to complete a four-year programme is now approximately 5.5 years with an average throughput rate of 60% of engineering graduates[1].

Local companies in Durban, South Africa, have also expressed deep concern regarding graduate readiness for the workplace, graduate awareness and sense of responsibility, graduate confidence, and independent learning ability [2].

Mis-alignments between new graduate expectations, employer expectations and reality have various potentially negative implications for corporations and the economy in general. These include misguided delegation of duties, workplace tension between new recruits and managers, workplace dissatisfaction among graduates and managers, decline in new recruit interest and productivity, high corporate investments in unproductive operations such as employee training with no guarantee of a return and ultimately the decline in innovation and competitiveness of organizations[3,4].

Employers of engineers have sought to mitigate any shortcomings of new graduates in their employ by facilitating mentorships and engineer-in-training (EIT) programmes to develop skills that are often specific to the tasks required by the firm. Programmes are often time-consuming and costly to the company with no guaranteed return on investment [3].

This study thus focused on assessing the alignment of the expectations of new engineering graduates regarding the workplace and that of employers' expectations regarding newly-employed engineering graduates. Key research questions include: What are the employment and daily-work expectations of engineering graduates?; What expectations and hopes do current engineering employers have for today's engineering graduates?; Are there any trends, positive or negative, that have occurred in engineering graduates as observed by employers?; and How can the university assist in bridging the gap between graduate and employer expectations to ensure enhanced productivity? An assessment of this alignment may contribute to updating curricula and improving teaching and learning in order to better align graduate perceptions to what's required in the workplace.

II. REVIEW OF LITERATURE

Engineering ranks among the most difficult of careers to pursue. Key attributes to the success of an engineer is an enquiring mind,

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creativity, innovativeness, self-motivation and an overall drive for excellence [5]. One of the legacies of Apartheid in South Africa was the denial of certain race groups from raising a cohort in the fields of science, engineering, medicine. The advent of democracy allowed access for all race groups to pursue engineering as a career. However, many candidates from previously disadvantaged race groups pursued the career with a lack of family social capital who could provide good practical career advice to current hopefuls [6].

Although candidates may have the technical abilities required of engineers and graduate with an engineering degree at university, many graduates find great difficulty coping, growing and succeeding in an engineering career. Large industries have stepped in by providing two-year EIT programmes for their new graduate employees [7,8]. These EIT programmes are often specific to the industry in which an engineer works and costly, requiring much investment on the part of companies. Substandard performance in EIT programmes typically threatens candidates' job security [8].

This study utilized two theoretical frameworks. In order to analyse the pedagogy of engineering education, it is important that concepts of learning ability and educational goals be clearly defined. A thorough classification was conducted by Bloom, Engelhart, Furst, Hill and Krathwohl (1956) [9], which came to be known as "Bloom's taxonomy". Educational goals are classified into six categories listed from the simplest to the most complex, including Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation. The framework has been adapted and modified in a variety of ways to categorise various education goals [9]. While Bloom's taxonomy is sufficient in categorising the various goals and tiers of education, it does not provide an indication of how the tiers of education are affected by the relationship between students and teachers and the personal motives of students.

Biggs (1987) [10] developed a novel Study Process Questionnaire (SPQ) containing 42 questions which categorize students' motives and strategies for study into Surface, Deep and Achieving. Extent of depth in approaches were categorized as moderate to exclusive. Motives such as gainful employment, the need to simply pass assessments, obtain a degree and general short-term planning were categorized as Surface motives. Associated with Surface motives, Surface strategies for learning included rote learning, lack of questioning and sticking only to necessary material. Deep motives were defined as inherent motives to gain an excellent and deep understanding of the pursued career with an intention to add value to the career. Deep strategies include a high degree of questioning, a good pursuit of study material outside of what educators stipulate and strong independent learning. Motives associated with seeking a degree for the prestige of the degree and doing well for the pride of obtaining good grades were considered to be achieving motives. Achieving strategies included excessive studying of past papers, student competitiveness and opposition to group effort. [11]

The Biggs framework is not perfect. Previous studies [12] found that Biggs' (1987) original set of questions was too long and cumbersome. Participants became impatient and eager to finish the questionnaire and often ended up answering flippantly rather than honestly. The categorization process was also too detailed, undermining meaningful categorization. It is also challenging to survey students over an entire degree, since students' motives and strategies can change based on the type of module they are studying. Some modules are energy intensive and encourage rote learning especially in a pressured environment, while other modules require report writing and practical assessments that encourage deep approaches. This study utilizes the condensed version of the questionnaire [11].

Minimal research has been conducted on graduate readiness and employer expectations of engineering students. Respondents of a survey [2] indicated that employers maintain confidence in engineering degrees that are accredited by ECSA. However, despite this, it was revealed that the unemployment of engineers in South Africa was a structural issue with relatively few companies prepared to take on new graduates, while there exists a high demand for experienced engineers with five or more years' experience and preferably registered as professional engineers with ECSA [12]. Expensive EIT programmes and short courses have been normalised in that many employers accept graduate shortcomings as a norm and accept the responsibility of training graduates further [4].

III. RESEARCH METHODOLOGY

Bearing in mind the two different types of audiences (engineering graduates and academic leaders), it was determined that a mixed methods approach was appropriate. Assessing graduate opinions and expectations required the participation of a high number of graduates in order for the findings to be credible. Graduate biographical information, general opinions, and motives for pursuing an engineering career and graduate learning strategies were collated using a positivist approach.

The aim was to survey 120 graduates out of a population of 393 graduates present at the 3rd April 2019 Engineering Graduation Ceremony [13]. The method of sampling these 120 graduates was one of stratified probability sampling, with the aim of surveying at least 20 graduates from each engineering discipline as a subset to get a representative sample of all types of engineering graduates at the university [14]. However, when considering the 20 questionnaires handed out to each discipline, random probability sampling was observed.

Section A of the questionnaire formed a biographical section and contained 13 multiple-choice questions pertaining to graduates' backgrounds. Questions concerning their age group, race, gender, home and second language and field of engineering were asked. Questions concerning whether graduates worked and ran their own household while studying, graduates' current employment status, as well as the most and least relevant factors that contribute to them accepting a job offer were asked.

Section A of the questionnaire aimed to ascertain any background factors which might account for how the graduate approached studying towards their career. Section B of the questionnaire contained a set of 23 questions, 20 of which are from the condensed version of the Biggs (1987) questionnaire [11].

The questions attempted to cross-examine graduate's motives and strategies for studying their engineering degree. The extent of deep or surface learning was gauged, as well as the extent of deep or surface strategies. The final section, Section C, contained a written component where graduates were asked open-ended questions about aspects such as what the best parts of their degree were, why they chose a degree in engineering, short and long term career goals, employment prospects and options and general attitude towards entering the workplace.

Regarding surveying of academic leaders, the sample was highly specific. Academic leaders in charge of each engineering discipline were interviewed due to their close relationship with industry partners, thereby providing a credible proxy for industry insight. While there are seven disciplines of engineering at the particular university of study, there were only four academic leaders since some oversaw multiple disciplines. In addition to better efficiency, the surveying of academic leaders gave the study access to the insights of at least thirty-two different employers, and were thus more representative of a collated, validated and well-rounded industry opinion, since actual responses from individual companies often provide recommendations that suit their niche enterprise. Academic leader insights thus provided a highly credible proxy for overall industry insight. The interview schedule consisted of 17 questions developed to probe respondents on the themes of graduate expectations of the workplace, employer expectations of graduates, trends in new graduate employees, mentorships and EIT programmes, ECSA exit-level outcomes (ELOs), the extent of industry participation in academia, external workshops and courses for continuous professional development. The interviews were semi-structured, including follow-up questions depending on respondents' responses and taking redundancy into account.

Secondary data in the form of the University Quality Promotion and Assurance (QPA) Graduate Opinion Survey, conducted annually during all graduation ceremonies, was also utilized in this study for comparison and triangulation of information [13]. This is a standard survey including questions related mainly to the quality of the campus facilities, lecturer ability and other aspects relating to the university experience. A few background and future prospect questions are also posed to graduates. It was developed and is administered wholly by QPA.

Analysis of results obtained from the questionnaire developed in this study was conducted using MS Excel, with QPA results being used merely for comparison and further discussion. Interviews were recorded and transcribed using Amberscript software and MS Word. Academic leader interview responses were qualitative in nature and analyzed thematically.

A gatekeeper letter was obtained and ethical clearance approval granted by the University Research Office. Informed consent forms were issued, assuring participants of confidentiality and anonymity. Procedures relating to validity, reliability, credibility and trustworthiness were adhered to.

IV. RESULTS AND DISCUSSION

The graduate survey achieved a response rate of 42%. Likely reasons for the low response rate may be the length of the questionnaire, as well as the concurrent running of the QPA survey [13]. Moreover, as the respondents were graduates attending their own graduation, it is possible that participation in the written segment was seen as time consuming as graduates were excited and keen to be attentive to the actual event and not be distracted with providing lengthy answers. Despite the above concerns, the response rate was not abnormally low for this particular survey setting. By comparison, the University QPA questionnaire [13] achieved a response rate of 56.2%. This convenience sampling method offered the advantage of surveying graduates from all engineering disciplines at one sitting, thereby achieving stratified probabilistic sampling. The academic leader survey had a response rate of 100% and proved to serve as beneficial proxies for industry opinion.

Interviewees revealed that there is an industry perception that most graduates simply expect or want to have a job and be employed. Under the Biggs framework, this attitude translates into a surface motive. The graduate survey on the other hand indicated 68% of graduates had moderately to exclusively deep approaches to their engineering career. Sixty-four percent wanted growth opportunities in the company they are employed in as first or second priority. Sixty-one percent of respondents indicated intrinsic interest in science. It is possible that employers are underestimating the mature and prudent drive of new graduates to grow in their career and these assumptions may negatively impact on how new graduates are treated, thereby stifling innovation and new ideas. Interview respondents expressed that employers prefer graduates with broad necessary skills in order to condition them into their particular enterprise which is often a maintenance-driven, and this conflict between employer and graduate aspirations may impact negatively on their long-term drive, innovativeness and productivity.

Twenty seven percent of graduates indicated that they desired strong alignment to their field of study. Low interest (6%) in universally applicable modules was expressed, 19% were interested in very specific modules and 23% of respondents had very specific job goals. This finding agreed with literature [4]. Academic leader responses however, have suggested that this has become an increasingly unrealistic desire for graduates of a Bachelor of Science in engineering due to the versatility required by growing companies in the 4th industrial revolution. Interviewees pointed to the large number of engineers who find employment in banks and insurance companies. In the graduate survey itself, of those who have indicated that they are already employed, 16% indicated that they are not doing engineering work.

On the positive side, graduates implicitly displayed a spark of interest. For 68% of respondents, it was either 'always' or 'frequently true' that any topic could be interesting once they get into it. This is a highly positive indication as it reveals that graduates were not simply interested in a few topics of their degree while shunning the rest, but rather possessed an appreciation for all aspects of their degree in general. However, only 44% of respondents spent significant time trying to find out more on relevant topics. While interest was clearly indicated, fewer respondents put effort into pursuing such interests. Numerous graduate responses to Section B of the questionnaire substantiated a recurring theme of expression of interest, yet lack of action towards that interest.

The Graduate Opinion Survey [13] found that only 53% of engineering graduates felt that there was sufficient time to understand content and only 54.5% indicated that the workload was manageable, the lowest statistics in the entire college. While deep motivations were present, the sheer workload of undergraduate engineering degrees often resulted in an embrace of surface strategies, where students were studying the bare minimum to keep afloat and pass their modules. There is little room to nurture deep motives into deep action and it has impacted their capacity as graduates for mature expectations of the workplace. When probed concerning graduates' expectations of the workplace, the question was interpreted by 44% of respondents to concern workloads. Nineteen percent of respondents expect a lower workload and less stress at the workplace. Collectively 25% expected the opposite. A further 19% expected less guidance and stricter deadlines.

According to academic leader responses, workloads and stress will increase in many companies. They indicated that some companies can require outputs as often as once a week and smaller firms typically have higher expectations than larger firms. The expectation of some graduates of less workload and stress can unfortunately be an invalid one. The Graduate Opinion survey [13] survey also revealed polarised opinion regarding the manageability of the workload. Literature indicates that workload considerations also result in certain technical modules being more emphasised while others concerning soft skills are neglected, at least in undergraduates' minds, to their own detriment [15]. The survey also revealed that 39% of graduates worked hard only around exam time. Lack of planning and consistency risks graduates entering the workplace without such habits, impacting workplace success.

Nineteen percent of respondents expected less emphasis on theory and more application in the workplace, in agreement with literature [16]. This is concerning as it is not the case with many companies, according to academic leader responses. Many companies expect their employees to tackle new and unique problems by starting from first principles and formulating a solution. Significant time re-learning relevant theory associated with one's work, leads to workplace inefficiency and possibly necessitate wasteful investment in further basic training.

Sixty-one percent of respondents indicated they expect guidance and training from their employer, towards their goal of registering as professional engineers (Pr.Eng.) with ECSA. This guidance is expected to include a structured EIT programme for new graduates. While not necessary for initial employment, a Pr.Eng. certification is a highly coveted title among engineers, as it is often required for promotion into high-level positions and dramatically increases an engineer's employment attractiveness, thereby commanding considerably higher salaries.

Unfortunately, as revealed by academic leaders, the presence of a structured EIT programme prevails in only a handful of large industrial companies. These companies are also declining in their intake of new graduates as economic conditions worsen and it is increasingly smaller firms that many new graduates find employment in. There is thus possibly a high mis-alignment between what new engineering graduates expect and what employers offer in this regard. This issue seems to be compounded by ignorance over ECSA policy and guidelines [17]. Only one interviewee indicated awareness of ECSA guidelines for EIT and mentorship programmes which were followed by large engineering employers.

Graduates indicated high salary expectations for their new employment, in agreement with literature that many degrees are chosen or avoided based on the perception of the salary they command [16]. Discussions with academic leaders revealed a general feeling that new graduate salary expectations are too high, especially considering that most new posts are offered by smaller companies. Numerous other reasons have been given for graduates' pursuit of an engineering degree. Collectively, 61% possessed a high interest in science, which is an encouraging find. There is some mis-alignment with industry expectations as interviewees indicated that many companies perceived their university programme to overemphasise mathematics. However, interviewees expressed that this overemphasis was beneficial in giving graduates necessary skills to thrive in industries such as banking and insurance.

While Section B of the graduate questionnaire revealed deep motives in respondents in their pursuit of their engineering degree, the written section indicates that these deep motives are still often inward for many respondents, possibly self-serving and devoid of a sense of citizenry and social responsibility. Interviewees confirmed that socio-economic and environmental awareness have to be more emphasized in new graduates. Literature has corroborated this finding [18, 19]. Another consideration however is South Africa's current economic climate. Twenty-four percent of graduate respondents needed to work and/or run their own household while studying. Even for those who have been fortunate enough to make it to the level of attending tertiary education, life is a daily struggle and the aim of overcoming one's own personal poverty and increasing one's own quality of life often takes precedence.

Sixteen percent of respondents indicated their desire to have a stable income, something which interviewees indicated may be more common. Literature indicates that technical modules were concentrated on by undergraduates who simply had that aim of getting a good starting salary, while soft skills were under-emphasised. Graduates with higher aspirations and mature plans left nothing underemphasised and possessed the soft skills required to excel in the workplace [15]. Interviewees indicated that a key complaint from industry was related to poor technical report writing skill, with smaller firms being much more vocal and less forgiving about this issue since they are focused on growth and efficiency. Report writing also serves as evidence of built-up engineering experience over years, which may be used towards Pr.Eng. application and registration.

While postgraduate enrolments in engineering at the University are low, 27.6% of respondents of the Graduate Opinion Survey[13] indicated interest to study further at some point in the future. Interviewees indicated that remuneration for full-time engineering postgraduate research is comparatively much lower than what a job in industry offers, and also does not guarantee higher pay. Of primary recognition in industry is the possession of Pr.Eng. registration, indicating high engineering experience. The absence of tangible encouragement of research from industry ultimately reduces interest in postgraduate enrolment and risks market stagnation in innovation [19]. Low interest in postgraduate study is accompanied by a low interest in business creation. Interviewees indicated that low interest in postgraduate studies and low stimulation from non-innovative firms could paint a bleak picture for engineering innovation and entrepreneurship in South Africa.

Twenty-two percent of graduates in the study did not speak English as their first language and the Graduate Opinion Survey [13] revealed that 63% of the universities graduates were English second-language speakers. Academic leaders attested to the effects of this at the workplace, with poor report-writing skills and communication barriers between engineers and other workmen. Smaller firms also expect graduates to have more knowledge of their niche industry. Large employers have however accepted that their new intakes lack experience and accept the responsibility of training them further.

Graduate confidence in tackling unfamiliar problems, planning of work and sourcing and using quality information was reportedly high, according to the majority of the graduate respondents surveyed. Forty-five percent of respondents also wrote that they are generally excited and confident to join the workforce. This confidence at graduation is not reflected by industry. Academic leaders, have declared that industry often reports a lack of confidence in new recruits.

This mis-alignment and complete contrast could be symptomatic of unrealistic expectations imposed on new employees by their employers. As academic leaders have mentioned, there are a few companies who have unrealistic expectations that their graduates should be highly suited to their particular enterprise. Interviewees reported niche subject matter demands that certain employers want but there is no way to accommodate them in the curriculum. While many of these unreasonable expectations are dismissed by academic leaders, it is possible that new graduate employees bear the brunt of these demands and find themselves lacking in certain proficiencies, thereby reducing their confidence.

The key theme identified by the interviewees to resolve the gap between graduate and employer expectations centred on undergraduate participation and vacation work in industry. Some advised a more standardized approach to facilitating and monitoring industrial advisory board participation. Others recommended closer links between university staff and industry partners to achieve a high overlap and structured availability of industrial vocational training. These efforts will greatly assist in improving graduate readiness, providing graduates with a realistic view of the workplace and also provide industry with realistic expectations of graduate capabilities.

In light of the frameworks used in this work, academic leader interview responses indicated that at the very least, employers require new graduates to be competent or proficient in at least the first three of Bloom's categories of education, namely: knowledge/ remembering; comprehension/ understanding; and application. Other categories may be developed as their career progresses and learning occurs. Under the Biggs framework [11], the study found significant deep thinking present in graduates, while their strategies actions resembled more surface approaches, due to the inherently high workload of engineering curricula and other personal challenges outside of tertiary study.

V. CONCLUSIONS AND RECOMMENDATIONS

This research examined the alignment of expectations of new engineering graduates regarding the workplace and that of employers' expectations. Academic leaders were used as proxies for industry insight due to time constraints. Employment and daily work expectations of engineering graduates and employers have been ascertained. The main misalignments concern differing emphasis on soft skills, theory, reporting and presentation between graduates and employers. Misalignments in graduate expectations with reality stemmed from surface strategies in coping with the high workload in engineering degrees, while misalignments in employers often stemmed from a natural desire for graduates to be more educated to suite their particular niche industry. The reality of maintenance-driven industries misaligning with graduate expectations of design and growth was identified as a key factor stifling innovation and entrepreneurship in new engineering graduates.

The main recommendations derived from the study was closer and more structured ties between the university and industry to promote guidance, opportunities for vacation work, and industry-driven postgraduate projects to encourage innovation and entrepreneurship in early-career engineers. Future in-depth research may pursue employer insight directly for increased certainty in results.

VI. REFERENCES

[1] J. Pocock, "Leaving Rates And Reasons For Leaving In An Engineering Faculty In South Africa: A Case Study," S. Afr. J. Sci., vol. 108, pp. 1-8, 2012.

[2] P. Naidoo and K. Osman, "Insight Into The Graduate Development / Engineer-In-Training Programmes In South Africa," South African Society for Engineering Education Conference 2015, South Africa, 2015.

[3] G. Tejedor, J. Segalàs, M. Rosas, "Transdisciplinarity In Higher Education For Sustainability: How Discourses Are Approached In Engineering Education," J. Clean. Prod., vol. 175, pp. 29-37, 2018.

[4] C. Onar, A. Ustundag, C. Kadaifci and B. Oztaysi, "The Changing Role of Engineering Education in Industry 4.0, Era," Adv. Manuf., vol. 1, pp. 137-151, 2018.

[5] Engineering Council of South Africa (ECSA), "Annual Report 2017/2018," Engineering Council of South Africa, Pretoria, 2019.

[6] N. Badsha, "Reflections of South African University Leaders, 1981 to 2014". 1st Edition, African Minds, Cape Town, pp. 37-45, 2016.

[7] M. Mtshali, "Ensuring The Expertise To Grow South Africa: Qualification Standard For Bachelor Of Science In Engineering (Bsc(Eng))/ Bachelors Of Engineering (Beng): Nqf Level 8," Engineering Council of South Africa, Pretoria, 2019.

[8] K. Mulder, "Strategic Competences For Concrete Action Towards Sustainability: An Oxymoron? Engineering Education For A Sustainable Future," Ren. Sust. Energy Rev., vol. 68, no. 2, pp. 1106-1111, 2017.

[9] N. Adams, "Bloom's taxonomy of cognitive learning objectives," J. Med. Lib. Assoc., vol. 103, 152-153, 2015.

[10] J. Biggs, "Study Process Questionnaire Manual," Melbourne: Australian Council for Educational Research, 1987.

[11] J. Biggs, D. Kember and D. Leung, " The Revised Two Factor Study Process Questionnaire: R-SPQ-2F," Br. J. Educ. Psychol., vol. 71, pp. 133-149, 2001.

[12] K. Osman, "Exploring Social And Economic Factors That Affect Scholarly Performance In Chemical Engineering Students," 10th Annual Teaching and Learning in Higher Education Conference, Durban, South Africa, p. 1-13, 2016.

[13] Quality Promotions and Assurance (QPA), "Graduate Opinion Survey Report On The Quality Of University Education 2019," College of Agriculture, Engineering and Science. University of KwaZulu-Natal, South Africa, 2019.

[14] A. Bhat, "Probability Sampling: Definition, Methods and Examples," Chicago: Question Pro Sales and Marketing, 2019.

[15] M. Itani and I. Srour, "Engineering Students' Perceptions of Soft Skills, Industry Expectations, and Career Aspirations," J. Prof Iss. Eng. Ed. Pr., vol. 142, pp. 4-15, 2016.

[16] F. Townsend, "Challenges for Geotechnical Engineering Graduate Education," J. Prof Iss. Eng. Ed. Pr., vol. 1, pp. 163-167, 2005.

[17] Engineering Council of South Africa (ECSA), "Discipline Specific Guidelines: Civil Engineering," Engineering Council of South Africa, Pretoria, South Africa, 2013.

[18] V. Tretko, and Y. Vashkurak, "Globalization Of Nanoengineers' Professional Training:Foreign Experience," Comp. Prof Pedag., vol. 7, pp. 25-31, 2017.

[19] B. Martinez, M. Alonso, A. Valenzuela, A. Marmol and A. Funes, "Results, Difficulties and Improvements in the Model of Personal and Social Responsibility". Phys. Ed., vol. 1, pp. 62-82, 2017.

Technical Papers

Disruptive engineering and education in emerging economies: challenges and prospects

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Abstract—**A plethora of literature have existed on disruptive technologies revealing its relevance in academia and application in the field of engineering education. The directions of possible problems of the application in the field of engineering education however are still obscured despite the abundant available literature with different opinions and inconsistent results which necessitates a review to harmonize the challenges and prospects to ensure continuity of study during this COVID-19 health crisis in emerging economies. In this work, disruptive engineering education in emerging economies is thus investigated and reviewed, and the challenges and prospects are examined and presented. The work also presents the emerging trends in disruptive engineering, proposes some solutions to overcome the key challenges by giving some novel recommendations on technical requirements and potential enablers.**

Keywords—Disruptive technologies, engineering education, challenges and prospects, COVID-19, emerging economies, economic development, Industry 4.0

I. INTRODUCTION

Engineering education plays a key role in the social and economic development of a country. All over the world, science and engineering education is viewed as the foundation of technological innovation and economic growth. With the recent pace of disruption of the existing status quo by emerging technologies in the field of engineering such as Internet of Things (IoT), 5G, 3D printing, artificial intelligence (AI) etc. amidst global challenges such as COVID-19 pandemic, the significance of disruptive engineering education which is becoming increasingly relevant cannot be over emphasized as it captures the idea of the confluence of new technologies and their cumulative impacts on our world. The sudden outbreak of a deadly disease called Covid-19 caused by a Corona Virus (SARS-CoV-2) shook the entire world. This situation has challenged the education system and has forced educators across the world to call for the use of disruptive technologies for online mode of teaching [1].

The term disruptive technology as coined by Clayton Christensen [2] is a new technology that disrupts the existing technology. Usage may start with few number of users and then grow overtime to replace the traditional practices or prominent technology [3]. The disruptive technologies have the tendency to transform social, economic and political systems penetrating every aspect of life such as education, health, security etc. It has been suggested that the traditional education models need change because students get bored in the traditional classrooms and sometimes cannot understand the lectures especially when the content being taught is out of context. Thus, implementation of such stimuli in the classroom with the help of disruptive technologies can help in improving student engagement, motivation and retention of knowledge [4]. As such, developing countries and emerging economies need to strategically position themselves for the profound impacts.

However, meeting this need presents some challenges to engineering faculties and colleges at universities in developing countries as well as for policy makers and other stakeholders. Nonetheless, it also comes with prospects.

What is the current trend of disruptive technologies in engineering education? What are prospects of disruptive technologies in engineering education? What are challenges to the use of disruptive technology in engineering education? These questions are thus addressed in this study. The study aims to review the prospects and challenges faced by developing countries in applying some commonly used disruptive innovation practices in engineering education context.

The methodological approach for conducting the study involves reviewing previously published and contemporary articles related to disruptive technologies in engineering education with respect to its prospects and challenges in emerging economies. These articles were searched using keywords such as “disruptive technology”, “emerging economies and prospect of disruptive technologies”, “emerging economies and prospect of disruptive technologies” in databases such as Science Direct, IEEE Xplore, Scopus, and Google search. The searched articles were evaluated to establish their relevance to the study. Of the total articles reviewed, those containing related components found to be critical to our review were selected, while obsolete articles were further removed.

While Section One introduces the topic titled Disruptive Engineering and Education in Emerging Economies: Challenges and Prospects, Section Two discusses disruption in engineering education. In Section Three, the prospects of disruption in engineering education are presented. The challenges of emerging economies to disruption in technology are given in Section Four and conclusion is drawn in Section Five with some recommendations.

II. DISRUPTIONS IN ENGINEERING EDUCATION

A. Introduction

Several waves of emerging technological changes hit engineering institutions across the world whereby engineering education schools have to disrupt the traditional process. The institutions have to be innovative in exploring the prospective advantages and benefits of the emerging technologies [5]. Industry 4.0 also known as fourth industrial revolution (4IR) is a new industrial

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stage with several emerging or disruptive technologies. Two of such disruptions are Engineering Education 4.0 and Education 4.0 which are most relevant to the field of engineering education [6]. Some of the convergence technologies of Engineering Education 4.0 and Education 4.0 include: The Internet of Things, Artificial Intelligence, Big Data, 3D printing, Cloud computing and 5G. However, this list of disruptive technologies is by no means exhaustive or complete but rather the area of focus in this paper.

B. Engineering Education 4.0

The conflicting demand of engineering industry using Industry 4.0 for engineers and the drive to increase teaching quality for excellent teaching and learning in engineering science education students is at the center of developing new technology called Engineering Education 4.0. Few of the disruptive engineering education technologies have been developed and experimented to have great impact in higher engineering education learning. They include Augmented Reality (AR) and Virtual Reality (VR) technologies. VR is an interactive computer simulation which transfers sensory information to a user who perceives it as substituted while AR is a system that combines real content (observed through IP cameras and displays) and virtual computer-generated content, adequately superimposed on the real content [7]. These emerging technologies are novel tools to help promote the way students are educated in the field of engineering education [7-8].

C. Education 4.0

Education 4.0 is an advanced creativity-focused technology of education in the age of Industry 4.0. It as a networked ecosystem capable of developing skills and building competences for the new era of engineering education. Some of the proven effects is to improve students' independence, activeness, innovation and self-directed learning style. Primary roles for teachers and Profs are to monitor and observe learning. Teachers and Profs sourcing for content through technology-based dynamic and 3D materials. Roles in institutional arrangement are creativity, skillful innovative and dynamic activities. Technology use as e-learning, high-speed internet, mobile technology, social media platforms, virtual reality etc. Location of institution include globally networked human body; anytime, anywhere, any device and any platform [8].

D. The Internet of Thing (IoT)

The Internet of Things has opened up a whole new world of possibilities in higher education. The increased connectivity between devices and "everyday things" means better data tracking and analytics, and improved communication between student, Prof, and institution, often without ever saying a word. IoT is making it easier for students to learn when, how, and where they want, while providing Profs support to create a more flexible and connected learning environment. With the help of IoT technologies, predictive analytics can provide additional insight into how students are doing and performing both in the classroom and on campus. With the right infrastructure in place, universities will be able to respond to early indicators of an "at-risk" student at the critical moment before that student's performance begins to suffer [9-10].

E. Artificial Intelligence (AI)

Artificial Intelligence (AI) technology can be used in engineering education to design curriculum and defining the expected outcome of education program as required to meet the specified role [11].

F. Big Data

Big data is high-volume, velocity, and variety information assets that demand cost-effective, innovative forms of information processing for enhanced insight and decision making [12]. Big Data has penetrated the education industry today and is a dominant driving force behind the success of education sector in developed countries. Leveraging and application of Big Data is disrupting in education and can contribute to improve students result, reduce dropout, customize programs and targeted international recruiting [13].

G. 3D Printing

3D printing, or additive manufacturing is the construction of a three-dimensional object from a CAD model or a digital 3D model. The term "3D printing" can refer to a variety of processes in which material is deposited, joined or solidified under computer control to create a three-dimensional object, with material being added together (such as liquid molecules or powder grains being fused together), typically layer by layer. Studies have shown that application of 3D printing in schools, universities, libraries and special education settings have been supportive in teaching technology, production of artefacts that aid learning, and creating assistive technologies [14].

H. Cloud Computing

Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction [15]. The advantages of cloud services for education are: reduced costs for hardware and software, payment for actual consumption and provision of many free services. Among the most popular cloud services that are successfully implemented in education are cloud- based office suites and storage services (cloud storage) [15].

I. 5G

The 5th generation technology is a high resolution and bi-directional large bandwidth shaping that offers a wide range of features, which are beneficial for all group of people including students, professionals (doctors, engineers, teachers, governing bodies, administrative bodies, etc.) and even for a common man. Beyond just wireless, 5G incorporates computing and cloud technologies to make everything smart and connected.

III. PROSPECTS OF DISRUPTION IN ENGINEERING EDUCATION

The sudden outbreak of a deadly disease called COVID- 19 and the spread of the pandemic is no longer a news all over the world. Part of the strategies to curtail the spread by several countries include temporary closure of tertiary institutions. For these institutions to continue a smooth education program, education sector needs disruptive innovation. This study hence argues that disruption of technologies should be the most sought after in education as it offers a lot of advantages to help reduce the spread of diseases and smooth running of education curriculum. Deployment of disruptive technologies for online learning, Remote Working, and e-collaborations etc. for example can have a profound impact on the education sector during this outbreak of Corona Virus crisis [16].

The academic institutions and engineering education schools in emerging economies therefore need to grab the opportunity of disruptive technologies by making their lecturers, teachers and Profs teach and students learn. The low income countries in particular need to leverage on the use of disruptive technologies as it offers low procurement and maintenance costs for effective facilitation of educational processes in difficult times like this COVID-19 pandemic era.

The use of disruptive technologies will enable teachers and students to frequently engage in the meaningful use of gadgets for teaching and learning. It will offer teachers better access to relevant articles and teaching and learning materials [17]. The arrival of 5G is expected to provide high internet connectivity thereby providing Smart Learning and efficient use of disruptive technologies in engineering education. 5G will hopefully enter the classroom and bring new ways of learning to students. For instance, Augmented Reality, Virtual Reality and Virtual Presence will mean that students will be immersed in a more visual and interactive learning experience where students and teachers may not necessarily be in the same location [18].

Specifically, disruptive technologies if connected by 5G network will provide:

- Availability and access - Expected increased availability and access to learning and teaching materials due to high-quality, affordable internet options that enable distance learning and providing equal opportunity to education [19].
- Distance learning – Evolution of distance learning will enabling a more immersive experience for educators and students in disparate locations [1].
- Absence reduction – Virtual presence technology combined with robotics could allow students away from class (e.g., sick students, those with household obligations) to continue to attend classes. Improved access to high-speed, low-latency broadband at home may expand educational opportunities for students and potential students that were previously unable to access education, such as in less-developed countries, less-affluent communities, and individuals—often women and girls—with household obligations that prevented regular attendance at school [4, 20].
- Increased safety - May expand access to high-quality education and expert educators (e.g., distance-learning offerings from universities, native language speakers, and subject matter experts), including both academic and workplace education scenarios. Day-to-day safety may be enhanced by broadband-enabled first responder communications, as well as new and improved tools to provide first responders with the data or support needed to address situations most effectively (e.g., patient data in ambulances, aerial footage from drones).
- Disaster protection – Disruptive technology may enable enhanced disaster responses, including communications in situations without adequate network infrastructure and use of remote devices to assist with rescue or emergency situations that are otherwise too difficult or dangerous

IV. CHALLENGES OF EMERGING ECONOMIES TO DISRUPTION IN TECHNOLOGY

Many universities and colleges of education in developing countries are likely not to disrupt their traditional processes in engineering education for innovative technologies even after the ease of COVID-19 in universities reopening. Some of their challenges may include:

- Disruptive technologies though are cheaper but the advent of the novel Coronavirus pandemic in Africa and other developing countries has induced recession resulting to loss of jobs and income of students' parents and guidance from where they mainly sourced for money to purchase innovative solutions through products and services. On the part of the government, there is inappropriate policy for education and in the present case of COVID-19, funding are mostly in favour of health care sector and palliative programs at the expense of other important sectors such as education [21].
- There exists little or no infrastructure backbone in most universities to disrupt. Relatively poor technology infrastructure is the fundamental problems for developing countries. One of the worst cases is the supply of electricity [21-24].
- Many institutions offering engineering programs have tried to implement disruptions but fail because of lack of understanding about disruption and the associated processes, the required finances, human resources and more importantly the innovation capabilities. Some have no innovation in teaching-learning for decades and in the process are not in a position to achieve any disruption that augurs desired changes [25].
- Most education systems in low- and middle-income countries were grossly underfinanced even before the coronavirus crisis. A report has estimated that spending on education in low- and middle-income countries must be more than double between 2015 and 2030, from approximately $1.25 trillion per year to nearly $3 trillion [25].
- Another problem is corruption. The misuse of government funds which could have been used to develop the education sector like the new technology in education is channeled to other directions i.e. few people benefit from those funds through siphoning into personal bank accounts. This kind of scenario is very common in developing countries where corruption has found a remarkably safe space to proliferate.
- According to Dhawan [1] some of the challenges facing developing countries to adapt to disruptive technologies in higher institution are unequal distribution of Information and Communication Technology (ICT) infrastructure, quality of education, digital illiteracy, digital divide, technology cost and obsolescence. Dhawan added that point of weakness of developing countries are technical difficulties, learner's capability and confidence level, time management, distractions, frustration, anxiety and confusion, lack of personal and physical attention.

V. SUMMARY, CONCLUSION AND RECOMMENDATIONS

Disruptive technologies are growing at a very fast pace in the field of engineering education. The critical trending disruption of technologies are The Internet of Things (IoT), Artificial Intelligence (AI), Big Data, 3D printing (3DP), Cloud Computing and 5G. The technologies bring substantial benefits to the field engineering education in emerging economies as its offers low procurement and maintenance costs for effective facilitation of educational processes, smooth running of education curriculum, reduce the spread of diseases, better access to relevant articles and teaching/learning materials, enhance distance learning and reduce students' absenteeism. As the disruptive technologies continues to gain popularity in engineering education, emerging economies are faced with barriers such as lack of infrastructure, lack of understanding about disruption and corruption among others.

To a great extent, disruptive technologies has the potential to improve the educational system and to ensure continuity of courses including engineering education during this COVID- 19 health crisis but developing countries are far from making use of the opportunities because of barriers. Infrastructure deficits of equipment expected to be used in the education industry are some of the difficult challenges identified. We find, in this work, potentials for global competitiveness, industrial development, and solutions to complex problems - such as diseases, unemployment and climate change - besetting most emerging economies as exciting prospects of disruptive engineering and its education.

The coronavirus crisis is a deep and sudden shock, but it is unlikely to be the last. Hence governments in developing countries should find ways through policy framework to strengthen engineering education such as creating new engineering schools and strengthening the existing ones through hands-on oriented training activities and provision of cutting-edge equipment. Governments should not lose sight of the existing problems of education sector before the COVID- 19 health crisis and ensure engineering school systems are adequately financed, make smart use of technologies while both the students and teachers are in good health.

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REFERENCES

[1] S. Dhawan, "Online Learning: A Panacea in the Time of COVID-19 Crisis," Journal of Educational Technology Systems, Vol. 49, pp. 5-22, 2020.
[2] C. Christensen, "The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail" Harvard Business Review Press; 1st edition, 1997.
[3] I. S. Jacobs and C. P. Bean, "Fine particles, thin films and exchange anisotropy," in Magnetism, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.
[4] J. Martin-Gutierrez, "Editorial: Learning Strategies in Engineering Education Using Virtual and Augmented Reality Technologies." EURASIA J. Math., Sci Tech. Ed, vol. 13, no. 2, pp. 297–300, 2017.
[5] J. Sandra, R. Geetha, "Disruptions in the Process of Engineering Education - A Curriculum Design Perspective," Procedia Computer Science, Vol. 172, pp. 277–282, 2020.
[6] O. Bongomin, A. Yemane, B. Kembabazi, C. Malanda, M.C. Mwape, Mpofu N.S. & Tigalana D. (2020). The Hype and Disruptive Technologies of Industry 4.0 in Major Industrial Sectors: A State of the Art. Preprints. Preprint · June 2020. DOI: 10.20944/preprints202006.0007.v144/preprin.
[7] J. Grodotzki, T. R. Ortelt, A. E. Tekkaya, "Remote and Virtual Labs for Engineering Education 4.0," Procedia Manufacturing, vol. 26, pp. 1349–1360, 2018.
[8] J. M. Huang, S. K. Ong, A. Y. C. Nee, "Visualization and interaction of finite element analysis in augmented reality" Computer Aided Design, 2017.
[9] P. Ozoh, O. Ibidapo-Obe, In A.O.F. Williams, A. O. Ogunbayo, and O. Abass (Eds). Developments in Biotechnology, Systems, Control and Education: Festerchrift in Honor of Prof Rahamon Adisa Bello, (2018), University of Lagos Press, Lagos.
[10] B. J. Faritha, R. Revathi, M. Suganya, N. R. Gladiss-Merlin, "IoT based Cloud Integrated Smart Classroom for smart and a sustainable Campus," Procedia Computer Science, Vol. 172, pp.77–81. 2020.
[11] M. Somasundarama, P. Lathab, S. A. Saravana Pandian, "Curriculum Design Using Artificial Intelligence (AI) Back Propagation Method," Procedia Computer Science, Vol. 172, pp. 134–138, 2020.
[12] Gartner, (2013). Gartner's Big Data Definition Consists of Three Parts, Not to Be Confused with Three "V"s. by By Svetlana Sicular. https://www.forbes.com/sites/gartnergroup/2013/03/27/gartners-big- data-definition-consists-of-three-parts-not-to-be-confused-with-three- vs/#23a192e042f6
[13] F. Kalota, "Applications of Big Data in Education,". World Academy of Science, Engineering and Technology International Journal of Educational and Pedagogical Sciences. Vol. 9, pp. 1607-1612, 2015.
[14] S. Ford, T. Minshall, "Invited Review Article: Where and how 3D printing is used in teaching and education," Additive Manufacturing (2018), https://doi.org/10.1016/j.addma.2018.10.028.
[15] G. Kiryakova, "Application Of Cloud Services In Education," Trakia Journal of Sciences, Vol. 15, pp. 277-284, 2017.
[16] T. Favale, F. Soro, M. Trevisan, I. Drago, M. Mellia, "Campus traffic and e-Learning during COVID-19 pandemic," Computer Networks, Vol. 176, 107290, 2020.
[17] W. Lidia, S. Mark, C. Thomas, and H. Thomas, "The impact of ICT and games based learning on content and language integrated learning," in Proceedings of International Conference ICT for Language Learning, 4th Edition, pp. 1–7, Florence Italy, 2018.
[18] Intel, Importance of 5G for Developing Countries. ITU Regional Forum on New Technologies Cairo-Egypt, 23-24 November 2016. https://www.itu.int/en/ITU-D/Regional- Presence/ArabStates/Documents/events/2016/NTD/Presentations/Sess ion1/Intel-ITU%20Forum-5G-Intel.pdf
[19] S.Gejendhiran, S. Arokia Anicia, S.Vignesh, M. Kalaimani, "Disruptive Technologies - A promising key for Sustainable Future Education," Procedia Computer Science, Vol. 172, pp. 843–847, 2020.
[20] M. D. Fabio, A. S. Guimaraes, B. R. Carvalho, J. P. P. Martins, "Virtual and Augmented Reality game-based applications to Civil Engineering Education" IEEE Global Engineering Education Conference, 978-1-5090-5467- 1/17, 2017.
[21] A. A. Barakabitze, A. W. Lazaro, N. Ainea, M. H. Mkwizu, H. Maziku, A. X. Matofali, A. Iddi, C. Sanga, "Transforming African Education Systems in Science, Technology, Engineering, and Mathematics (STEM) Using ICTs: Challenges and Opportunities. Hindawi Education Research International Vol. 2019, pp. 1-29, 2019.
[22] S. Patti, M. W. Esther, "Tanzania ICT in education: situation and needs analysis," 2018, http://www.youthmetro.org/uploads/4/7/6/5/47654969/tanzania_ict_in _education.pdf.
[23] O. Emmanuel, J. W. Arakpoguna, and R. Wanjirua, "Impediments to the implementation of universal service funds in Africa: a cross-country comparative analysis," Telecommunications Policy, vol. 41, no. 7-8, pp. 617–630, 2017.
[24] J. M. Huang, S. K. Ong, A.Y.C. Nee, Visualization and interaction of finite element analysis in augmented reality, Computer Aided Design, 2017.
[25] R. S. Chandu, S. G. S. Chandu, "Understanding and Extrapolation Of Disruption For Engineering Education-Principles And Problems," Procedia Computer Science 172 (2020) 1066–1076. 2020.

Technical Papers

Industry 4.0 Competence Maturity Model design requirements: A systematic mapping review

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***Abstract*—The impact of Industry 4.0 (I4.0) on the manufacturing industry's systems and processes extends to employees' competency requirements. This consequently requires a response in the preparation of graduates who will be rseady to practice engineering with professional level technical know-how and soft skills in I4.0. The study focused on developing a conceptual I4.0 competency maturity model (I4.0CMM) and illustrating it using industrial engineering capability functions. Using the systematic mapping review approach, a gap analysis was conducted of design requirements for I4.0 competency models and frameworks in the literature as measured against predefined design requirements of an I4.0CMM. A total of 303 relevant research papers from Scopus, Web of Science online databases, and grey literature were retrieved. Twenty-five papers and documents were included in the study. The results of the review indicated that the predefined design requirements for an I4.0CMM were not all satisfied in literature. Thus, a conceptual I4.0CMM that is aligned to industrial engineering capability functions was developed and is illustrated. The I4.0CMM could be a solution in providing a comprehensive competency assessment framework for industrial engineering practice and education.**

Keywords—Industry 4.0, competency, maturity model, systematic mapping review, industrial engineering

I. BACKGROUND TO THE STUDY

Workforce competencies significantly influence the successful adoption of Industry 4.0 (I4.0) in organizations [1]. The background of I4.0 and its application in the manufacturing industry [2, 3] require that engineers considerably drive its successful adoption. Accordingly, the engineering education role of "preparing the graduates to practice engineering with competent technical know-how and soft skills at professional level" [4] becomes particularly important.

Industry 4.0 demands higher competency levels and requires employees with substantial skills and qualifications [1, 5, 6]. Thus, the alignment of engineering education in producing graduate attributes that meet I4.0 competency requirements cannot be avoided [5].

A study by Acerbi et al. [7] pointed out that there was a lack of comprehensive I4.0 competency assessment models and tools in literature. To assess this gap in literature, design requirements for a conceptual Industry 4.0 competency maturity model (I4.0CCM) were generated while guided by literature [8, 9]. This was followed by a systematic mapping review to identify I4.0 competency models and frameworks existing in literature. A design requirements gap analysis measured against the predefined design requirements for an I4.0CMM was then conducted.

A conceptual I4.0CMM that aligns with the industrial engineering domain was developed and is presented in this paper. As I4.0 has the potential to significantly impact on the knowledge and skills of industrial engineers [10], the conceptual I4.0CMM is illustrated using industrial engineering capability functions.

II. STUDY PURPOSE

The purpose of this study was to develop a conceptual I4.0CMM and illustrate it by using industrial engineering capability functions. The study was guided by three research questions:

1) *Which I4.0 competency models and frameworks exist in literature?*
2) *Do the existing I4.0 competency models and frameworks satisfy all the predefined design requirements for an I4.0CMM?*
3) *What are the domains and dimensions that could be used to formulate the conceptual I4.0CMM?*

III. INDUSTRY 4.0 COMPETENCY MATURITY MODEL (I4.0CMM) DESIGN REQUIREMENTS

The People Capability Maturity Model (PCMM) [11, 12] was developed to assist organizations in enhancing their workforce capabilities. Application of PCMM enables organizations to mature their "capability for attracting, developing, and retaining the talent" [11] needed.

Management of employees' competencies from graduate level to professional level is crucial for organizations' success [13]. Thus, continuous alignment of employees' competencies with "business objectives, performance and changing needs" [11] is essential for business success.

Maturity models can serve a descriptive purpose if they are applied for assessing the "as-is" capability by comparing the "capabilities of the entity under investigation with respect to given criteria" [8, 9, 14]. On the other hand, maturity models can serve a prescriptive purpose when it is used to show how to find a desirable maturity level and stipulate guidelines to achieve a better state [8, 9, 14].

The design requirements for an I4.0CMM were generated based on serving both descriptive and prescriptive purposes. Table I presents I4.0CMM design requirements which were generated guided by the maturity model design principles framework of Pöppelbuß and Röglinger [8] and as applied by Van Dyk [9].

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TABLE I *I4.0CMM conceptual design requirements*

Category	Design requirements (DR)
Application domain	DR1: The I4.0CMM must outline engineering profession competency requirements for the manufacturing industry that must also be adaptable to other engineering industries.
Purpose of use	DR2: The I4.0CMM must provide a set of knowledge, technical and soft skills required to perform specific engineering capability functions. DR3: The I4.0CMM must support and guide engineering professionals' practice and continuous professional development. DR4: The I4.0CMM must provide competence reference standards for engineering education and quality assessment of engineering processionals along the career continuum. DR5: The I4.0CMM must be useful to assess employees' competency measured against the industrial revolutions and future requirements.
Target group	DR6: The I4.0CMM must be easily understood and useful for researchers, academics in engineering education, manufacturing professionals, and human resources practitioners.
Class of entities under investigation	DR7: The I4.0CMM must be adaptive and flexible in identifying skills for the future and must not only be confined to I4.0 applications and technologies.
Maturity and dimensions of maturity	DR8: The I4.0CMM must include a competency domain, a capability functions domain, and a distinct maturity levels domain. DR9: The I4.0CMM competency statements must be clearly defined and easy to interpret.
Maturity levels and maturation paths	DR10: The competency statements must clearly differentiate between maturity levels.

IV. METHODOLOGY

According to Grant and Booth [15], systematic mapping review is among the fourteen reviews that have been used in a significant number of studies to identify research gaps in existing literature [16-22]. Peters and Wood [16] attest that systematic mapping review is "a review method of choice when a focused area of inquiry is in early scientific development" [16].

To accomplish the purpose of this study, both peer reviewed research papers and grey literature [23] were considered in the systematic mapping review [18].

The systematic mapping review was defined and accomplished in three steps [16, 17]: gathering data using a predefined search procedure, selecting the relevant data using predefined inclusion and exclusion procedures, and extracting relevant information from the literature.

A. Search Procedure

A predefined search strategy was developed to minimize bias during the search for relevant literature to be used in this study. The study used three key search terms: I4.0, competencies, and model. The systematic mapping research method utilized a Boolean search string [24] with the following alternative search words: fourth industrial revolution, skills, and framework. The literature search was conducted on Scopus and Web of Science online databases and included searching grey literature on key consulting organization websites and expanding the data source by a dedicated search of reference lists [18].

B. Inclusion and Exclusion Criteria

Iterative inclusion and exclusion criteria [18, 24] were used to select relevant studies published between 2011 and 2020. This was because the I4.0 concept was coined in 2011 [2]. Studies that focused on I4.0 competency models or frameworks were included. Five iterative steps for excluding studies were followed: exclusion by duplication; exclusion by language compatibility; exclusion by full paper text not accessible; exclusion by paper using the terms competencies and skills loosely in relation to I4.0 competency models; and exclusion by inadequate evidence of a model or framework.

C. Data Analysis

The data analysis focused on identifying design requirement gaps in the included systematic mapping review literature as measured against the predefined design requirements for an I4.0CMM presented in Table I.

V. RESULTS

This section presents the systematic mapping review results and the gap analysis results.

A. Systematic Mapping Review Results

Twenty-five papers were included in the systematic mapping review (Figure 1). A significant number of papers used the search terms casually and hence were excluded from further analysis.

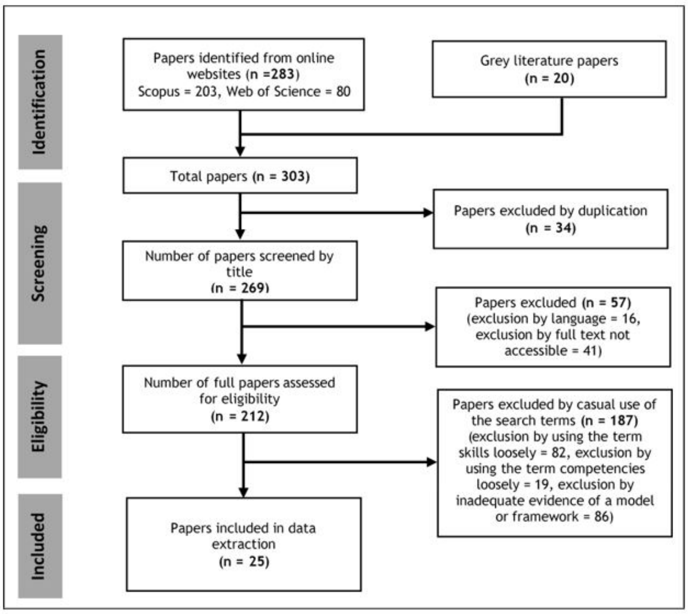

FIGURE 1 *Systematic mapping review results*

B. Gap Analysis Results

Table II maps the gaps between design requirements for the I4.0 competency models and frameworks in literature and the predefined design requirements for an I4.0CMM. The analysis revealed that I4.0 competency models and frameworks in literature satisfied some but not all of the predefined design requirements for an I4.0CMM.

DR1, DR3 and DR4 were fully satisfied by a significant number of studies which provided sufficient information on I4.0 skills and knowledge that could guide the engineering profession's skills development and practice.

Some studies partially satisfied DR2, for example Sakuneka et al. [25] focused on the skills and knowledge of a control engineer. Only Accenture Consulting [26] fully satisfied DR2 by presenting a set of skills and knowledge required for various engineering roles in I4.0.

None of the reviewed studies satisfied DR5, DR7 and DR8 in any way. All studies were confined to I4.0 competency with no flexibility in looking beyond I4.0 requirements.

DR9 was partially satisfied by a few studies, such as the study of Acerbi et al. [7] that provided general competency statements for different maturity levels. Only Accenture Consulting [26] fully satisfied DR9 by presenting capability statements for various skills in different engineering roles.

The work of Acerbi et al. [7] satisfied DR10 by suggesting five distinct competency maturity levels: basic level, aware level, practiced level, competent level, and proficient level.

TABLE II *gap analysis results*

No	*Paper Title and Reference*	*DR1*	*DR2*	*DR3*	*DR4*	*DR5*	*DR6*	*DR7*	*DR8*	*DR9*	*DR10*
1	A methodology to assess the skills for an Industry 4.0 factory [7]	✓	×	✓	×	×	✓	×	×	×	✓
2	Estimating Industry 4.0 impact on job profiles and skills using text mining [27]	×	×	×	✓	×	✓	×	×	×	×
3	Emerging learning environments in engineering education [28]	✓	×	✓	×	×	✓	×	×	×	×
4	Skills in European higher education mobility programs: Outlining a conceptual framework [29]	×	×	✓	✓	×	✓	×	×	×	×
5	A summary of adapting Industry 4.0 vision into engineering education in Azerbaijan [30]	✓	×	×	×	×	✓	×	×	×	×
6	An investigation of Industry 4.0 skills requirements [24]	✓	×	✓	✓	×	✓	×	×	×	×
7	Industry 4.0 competencies for a control systems engineer [25]	✓	×	✓	✓	×	✓	×	×	×	×
8	Smart Education in the context of Industry 4.0 [31]	×	×	✓	✓	×	✓	×	×	×	×
9	Challenges and requirements for employee qualification in the context of human-robot-collaboration [32]	✓	×	✓	✓	×	✓	×	×	×	×
10	Smart industry and the pathways to HRM 4.0: Implications for SCM [33]	✓	×	×	✓	×	✓	×	×	×	×
11	Conceptual framework for the development of 4IR skills for engineering graduates [34]	✓	×	✓	✓	×	✓	×	×	×	×
12	Analyzing Workforce 4.0 in the Fourth Industrial Revolution and proposing a road map from operations management perspective with fuzzy DEMATEL [35]	✓	×	✓	✓	×	✓	×	×	×	×
13	Model of competency management in the network of production enterprises in Industry 4.0: Assumptions [36]	✓	×	✓	✓	×	✓	×	×	×	×
14	Toward a data driven competency management platform for Industry 4.0 [37]	✓	×	×	✓	×	✓	×	×	×	×
15	Tangible Industry 4.0: A scenario-based approach to learning for the future of production [38]	✓	×	✓	✓	×	✓	×	×	×	×
16	Conceptual key competency model for smart factories in production processes [39]	✓	×	✓	✓	×	✓	×	×	×	×
17	Text mining of Industry 4.0 job advertisements [40]	✓	×	✓	✓	×	✓	×	×	×	×
18	Makerspace for skills development in the Industry 4.0 era [41]	✓	×	✓	✓	×	✓	×	×	×	×
19	The Industry 4.0 induced agility and new skills in clusters [42]	✓	×	×	✓	×	✓	×	×	×	×
20	Integration of 3D printing and Industry 4.0 into engineering teaching [43]	✓	×	×	✓	×	✓	×	×	×	×
21	Skill development for Industry 4.0 [44]	✓	×	✓	✓	×	✓	×	×	×	×
22	A competency model for "Industrie 4.0" employees [45]	✓	×	✓	✓	×	✓	×	×	×	×
23	Preparing tomorrow's workforce for the Fourth Industrial Revolution for business: A framework for action [46]	✓	×	✓	✓	×	✓	×	×	×	×
24	Preparing for Industry 4.0: Will digital skills be enough? [47]	✓	×	✓	✓	×	✓	×	×	×	×
25	Manning the mission for Advanced Manufacturing [26]	✓	✓	✓	✓	×	✓	×	×	✓	×

Key:

✓ - Fully satisfied the relevant design requirement

× - Did not satisfy the relevant design requirement or only partially satisfied it

VI. DISCUSSION

A significant number of I4.0 competency models and frameworks reviewed in this study focused on skills requirements in I4.0. There is a lack of comprehensive I4.0 competency assessment tools that address the skills and knowledge requirements for specific capability functions in engineering.

The reviewed models seldomly provided a comparative scale to gauge employees' competency with reference to the industrial revolutions. A model that could assist in assessing employees' current competency levels and point out higher level requirements could be of significance to decision makers.

There is a noticeable shortage of studies that predicted skills requirements beyond I4.0. Development of an I4.0 competency assessment tool that presents competency requirements for specific capability functions in engineering is therefore necessary.

VII. A CONCEPTUAL INDUSTRY 4.0 COMPETENCY MATURITY MODEL

A. I4.0CMM structure

The conceptual I4.0CMM is illustrated in Figure 2 using the industrial engineering domain. The proposed I4.0CMM conceptual model comprises three domains: a competency domain, a capability functions domain, and a maturity levels domain.The competency domain has two dimensions: skills (technical and soft) and knowledge requirements.

The capability functions domain has ten dimensions related to industrial engineering [10, 48]. Though these are not exhaustive, the capability functions that were adopted are aligned with industrial engineering roles' requirements. The proposed I4.0CMM conceptual model assumes the five maturity levels to be in line with industrial revolutions: level 1 (1st industrial revolution), level 2 (2nd industrial revolution), level 3 (3rd industrial revolution), level 4 (4th industrial revolution), and level 5 (Future requirements).

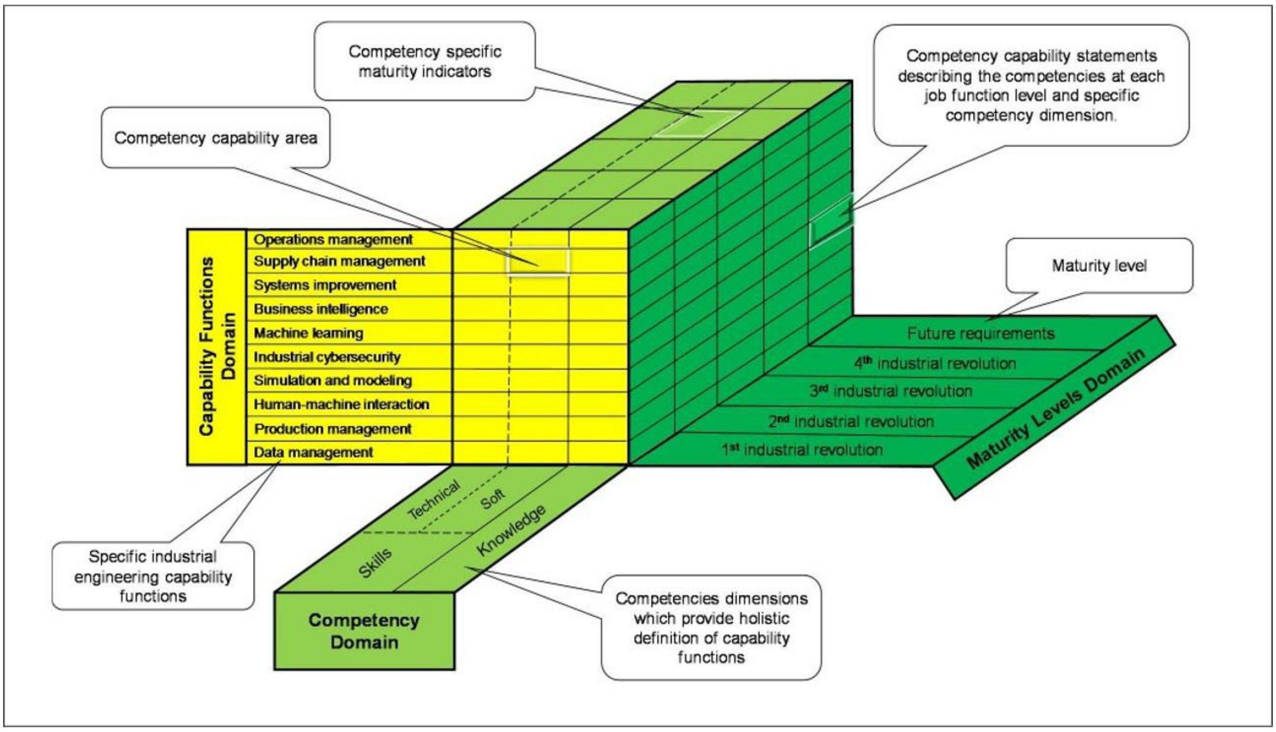

FIGURE 2 *I4.0CMM conceptual model*

B. I4.0CMM Illustration

The I4.0CMM will be used to assess employees' current competency in terms of skills (technical and soft) and knowledge requirements to satisfy a specific industrial engineering capability function. Table III and Table IV illustrate the assessment of the data management and human-machine interaction capability functions, respectively. Technical skills, soft skills and knowledge capability statements at each maturity level are presented.

The upskilling requirements depend on the currently determined level of the employee. For example, if the data analysis capability matches level 3 (3rd industrial revolution) requirements, then the industrial engineer needs to upskill to level 4 (4th industrial revolution) requirements. The capability statements presented in Table III and Table IV are not exhaustive and are only used for the purpose of illustrating how the I4.0CMM model would work in practice. Further development is required in this respect.

TABLE III *Illustration on how to use i4.0cmm – data management capability function*

CAPABILITY FUNCTION	*Data management – collection, handling, and analysis of data*		
	COMPETENCY DOMAIN		
	Technical Skills	**Soft Skills**	**Knowledge**
Future requirements	Using algorithms and statistical programming languages to analyze real-time data. Handling, analyzing, and interpreting complex digital data.	Proactive learning, future thinking, innovation, and creativity.	Data analytics technologies, real data science development.

CAPABILITY FUNCTION	*Data management – collection, handling, and analysis of data*		
	COMPETENCY DOMAIN		
	Technical Skills	**Soft Skills**	**Knowledge**
4th Industrial Revolution	Identifying patterns and extracting actionable insights and information from data. Corroborating data from multiple sources; accessing data on mobile devices and computers; identifying trends in data and detecting problems; visualizing data; data cleaning [26].	Critical thinking, agile problem identification and problem solving, open minded thinking, communication skills.	Programming knowledge in Scala, Python, R and PySpark. Data optimization, coding, big data analytics
3rd Industrial Revolution	Retrieving, handling and querying data using Structured Query Language (SQL) and NoSQL from rational and irrational databases [49, 50]. Analyzing numeric data using tools such as advanced Microsoft Excel.	Communications skills (verbal and written), analytical mind, attention to details.	Statistical knowledge, SQL knowledge, strong Microsoft Excel skills, advanced mathematical knowledge
2nd Industrial Revolution	Recording data on punch cards using keypunches and systematically processing the data using a tabulating machine and its improved versions [49].	Persistent mind, attention to details, communication skills.	Mathematical knowledge, statistics knowledge.
1st Industrial Revolution	Manually collecting, preparing, and analyzing data using statistics and mathematics [49].	Accuracy, communications skills.	Mathematical knowledge, statistics knowledge.

TABLE IV *Illustration on how to use i4.0cmm – human-machine interaction capability function*

CAPABILITY FUNCTION:	*Human-machine interaction*		
	COMPETENCY DOMAIN		
	Technical Skills	**Soft Skills**	**Knowledge**
Future requirements	Interacting and sharing workload with cognitive and automous robots and machines.. Executing desision and moitoring processes for a multitude of different production complexes on-site, and off-site [51].	Ability to collaborate and not compete with autonomous robots. Emotional intelligence.	Autonomous robots, artificial intelligence, human factors modeling, and human-machine interaction.
4th Industrial Revolution	Performing multimodal interaction with machines - touchscreen, dialogue-driven voice control and gesture recognition {51, 52}. Interacting with cognitive and autonomous and self-organizing machines. Using augmented reality and virual reality a mediating interface in Cyber-physical systems. {52}	Ability to collaborate with machines. Emotiona intelligence and agile adaptability to a quick changing environment.	Cyber-physical systems, application of virtual reality and augmented reality, Internet of Things, Smart manufacturing, emotional intelligence
3rd Industrial Revolution	Humans as machine supervisors - monitoring machines as they perform automated tasks [52]. Interacting with machines in unimodal interactions, i.e. commanding machines through mechanical input, such as a keyboard [51].	Flexibility and ability to interact with machines.	Cyber-physical systems, application of virtual reality and augmented reality, Internet of Things, Smart manufacturing, emotional intelligence
2nd Industrial Revolution	Humans as controllers of machine - controlling machines in a mass production environment [52].	Multi-skilling, paying attention to details.	Controlling systems and machine display interfaces.
1st Industrial Revolution	Routine, more-physical-effort tasks to operate the machine - ability to use the machine and making machine adjustments.	Physical ability and individual attitude.	Operation of steam engines, mechanical machines.

VIII. CONCLUSION

This study presents a gap analysis of design requirements for I4.0 competency models and frameworks in literature measured against predefined I4.0CMM design requirements. The analysis points out that the predefined design requirements for an I4.0CMM have seldomly been satisfied in literature. A conceptual I4.0CMM was developed and illustrated in this study using industrial engineering capability functions. The fully developed I4.0CMM, in line with the recommendations (section IX), could close the competency assessment framework gap in the literature. The I4.0CMM has the potential of adding value in assessing and aligning workforce competency requirements in I4.0 and beyond within the manufacturing industry. The I4.0CMM could provide a framework that aligns industrial engineering competency development to industry competency demand. The I4.0CMM will guide engineering education in developing graduate attributes that will meaningfully contribute to the adoption of I4.0 in the manufacturing industry.

IX. RECOMMANDATIONS

This study provides a foundation for further development of an I4.0CMM as a competency assessment tool in the manufacturing industry. The I4.0CMM model was illustrated using industrial engineering capability functions. The recommended next step in this work is to refine the presented I4.0CMM conceptual model by performing an iterative design process to ascertain the validity of model domains and dimensions. This will be followed by the development of capability statements for the specific capability functions. The capability statements should include all the competency dimensions at each maturity level. A structured interview with manufacturing industry representatives and engineering education academics will be conducted to test the validity and functioning of the I4.0CMM.

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REFERENCES

[1] A. Benešová, and J. Tupa, "Requirements for education and qualification of people in Industry 4.0," Procedia Manuf., vol. 11, pp. 2195-2202, 2017.
[2] C. J. Bartodziej, The Concept Industry 4.0: An Empirical Analysis of Technologies and Applications in Production Logistics. Wiesbaden: Springer, 2016.
[3] Plattform Industrie 4.0, What is Industrie 4.0?, 2019 [Online] Available: https://www.plattform-i40.de/PI40/Navigation/EN/Industrie40/WhatIsIndustrie40/what-is-industrie40.html [Accessed May 23, 2019].
[4] IGI Global, What is Engineering Education, 2020 [Online] Available: https://www.igi-global.com/dictionary/engineering-education/33646 [Accessed May 8, 2020].
[5] A. Benešová, M. Hirman, F. Steiner, and J. Tupa, "Requirements for Education 4.0 and study programs within Industry 4.0," presented at the 2019 International Conference on Industrial Engineering and Operations Management. [Online]. Available: http://ieomsociety.org/pilsen2019/papers/358.pdf [Accessed April 8, 2020].
[6] M. Maria, F. Shahbodin, and N.C. Pee, "Malaysian higher education system towards industry 4.0: Current trends overview," AIP Conference Proceedings. 2018. [Online]. doi: https://doi.org/10.1063/1.5055483 [Accessed May 23, 2019].
[7] F. Acerbi, S. Assiani, and M. Taisch, "A methodology to assess the skills for an Industry 4.0 factory," in Advances in Production Management Systems: Towards Smart Production Management Systems, F. Ameri, K. E. Stecke, G. von Cleminski, and D. Kiritsis, Eds. New York: Springer, 2019, ch. 2, pp. 520-527.
[8] J. Pöppelbuß, and M. Röglinger, "What makes a useful maturity model? A framework of general design principles for maturity models and its demonstration in business process management," presented at the 2011 European Conference on Information Systems (ECIS).[Online]. Available: https://www.researchgate.net/publication/221409904_What_makes_a_useful_maturity_model_A_framework_of_general_design_prin ciples_for_maturity_models_and_its_demonstration_in_business_process_management [Accessed May 23, 2019].
[9] L. van Dyk, "The development of a telemedicine service maturity model," Ph.D. dissertation, Department of Industrial Engineering, Stellenbosch University, 2013. [Online]. Available: https://scholar.sun.ac.za/bitstream/handle/10019.1/85787/vandyk_development_2013.pdf?sequence=1&isAllowed=y [Accessed May 23, 2019].
[10] S. M. Sackey, and A. Bester, "Industrial engineering curriculum in Industry 4.0 in a South African context," S. Afr. J. Ind. Eng., vol. 27, no. 4, pp. 101-114, 2016.
[11] B. Curtis, B. Hefley, and S. Miller, People capability maturity model (P-CMM) version 2.0, second edition. Pittsburgh: Carnegie-Mellon University,2009.[ebook].Available: https://resources.sei.cmu.edu/asset_files/TechnicalReport/2009_00 5_001_15095.pdf [Accessed May 23, 2019].
[12] B. Curtis, W.E. Hefley, and S. Miller, Overview of the people capability maturity modelSM. Pittsburgh: Carnegie-Mellon University,1995. [ebook]. Available: https://resources.sei.cmu.edu/asset_files/MaturityModule/1995_00 8_001_16349.pdf [Accessed May 23, 2019].
[13] H. El-Baz, and I. A. Zualkernan, "Employee competency maturity model and its application in global software outsourcing," Int. J. Comput. Appl., vol. 40, no. 3, pp. 170-180, 2011. [Online]. Available: https://www.inderscienceonline.com/doi/pdf/ 10.1504/IJCAT.2011.039138 [Accessed May 23, 2019].
[14] J. Becker, R. Knackstedt, and J. Pöppelbuß, "Developing maturity models for IT management," Bus. Inf. Syst. Eng., vol. 1, no. 3, pp. 213-222, 2009.
[15] M. J. Grant, and A. Booth, "A typology of reviews: an analysis of 14 review types and associated methodologies," Health Inf. Lib. J., vol. 26, no. 2, pp. 91-108, 2009.
[16] B. C. M. Peters, and W. Wood, "Autism and equine-assisted interventions: A systematic mapping review," J. Autism Dev. Disord., vol. 47, no. 10, pp. 3220-3242, 2017.
[17] A. Fernandez et al., "Flooding and mental health: A systematic mapping review," PLoS One, vol. 10, no. 4, p. e0119929, 2015.
[18] S. Lukersmith, M. Millington, and L. Salvador-Carulla, "What is case management? A scoping and mapping review," Int. J. Integr. Care, vol. 16, no.4, pp. 1-13, 2016.
[19] M. J. Booker, A. R. Shaw, and S. Purdy, "Why do patients with 'primary care sensitive' problems access ambulance services? A systematic mapping review of the literature," BMJ Open, vol. 5, no. 5, p. e007726, 2015.
[20] A. L. Gordon et al., "A systematic mapping review of Randomized Controlled Trials (RCTs) in care homes," BMC Geriatrics, vol. 12, no. 1, p. 31, 2012.
[21] A. O'Cathain, K. J. Thomas, S. J. Drabble, A. Rudolph, and J. Hewison, "What can qualitative research do for randomised controlled trials? A systematic mapping review," BMJ Open, vol. 3, no. 6, p. e002889, 2013.
[22] J. Brett, S. Staniszewska, M. Newburn, N. Jones, and L. Taylor, "A systematic mapping review of effective interventions for communicating with, supporting and providing information to parents of preterm infants," BMJ Open, vol. 1, no. 1, p. e000023, 2011.
[23] The New York Academy of Medicine, What is Grey Literature? 2016 [Online]. Available: http://www.greylit.org/about [Accessed Apr. 2, 2020].
[24] W. Maisiri, H. Darwish, and L. van Dyk, "An investigation of Industry 4.0 skills requirements", S. Afr. J. Ind. Eng., vol. 30, no. 3, pp. 90-105, 2019.
[25] T. Sakuneka, A. Marnewick, and J. -H. Pretorius, "Industry 4.0 competencies for a control systems engineer," in Proceedings of the IEEE Technology & Engineering Management Conference (TEMSCON), Atlanta, GA, USA, 12-14 June 2019, New York: IEEE, 2019, ch. 5, pp. 24-29.
[26] Accenture Consulting, Manning the mission for Advanced Manufacturing, 2017. [ebook]. Available: https://www.accenture.com/t20170421T010107Z w /sg- en/_acnmedia/PDF-50/Accenture-Manning-Mission-Advanced- Manfacturing.pdf [Accessed May 23, 2019].
[27] S. Fareri, G. Fantoni, F. Chiarello, E. Coli, and A. Binda, "Estimating Industry 4.0 impact on job profiles and skills using text mining," Comput. Ind., vol. 118, p. 103222, June 2020.
[28] R. G. Hadgraft, and A. Kolmos, "Emerging learning environments in engineering education," Australas. J. Eng. Educ., January 2020. [Online]. https://doi.org/10.1080/22054952.2020.1713522 [Accessed May 23, 2019].
[29] S. Garcia-Esteban, and S. Jahnke, "Skills in European higher education mobility programmes: Outlining a conceptual framework," Higher Educ. Skills Work-based Learn., vol. 10, no. 1, pp. 33-55, 2020.
[30] A. Ahadov, E. S. Asgarov, and I. El-Thalji. "A summary of adapting Industry 4.0 vision into engineering education in Azerbaijan," in IOP Conference Series: Materials Science and Engineering. IOP Publishing, 2019, pp. 1-6.
[31] D. Assante, A. Caforio, M. Flamini, and E. Romano, "Smart Education in the context of Industry 4.0," in Proceedings of the 2019 IEEE Global Engineering Education Conference (EDUCON), Dubai, 8-11 April 2019, IEEE, 2019, pp. 1140-1145.
[32] L. M. Daling, S. Schröder, M. Haberstroh, and F. Hees, "Challenges and requirements for employee qualification in the context of human-robot-collaboration," in Proceedings of the 2018 IEEE Workshop on Advanced Robotics and its Social Impacts (ARSO), IEEE, 2018, pp. 85-90.
[33] L. B. Liboni, L. O. Cezarino, C. J. C. Jabbour, B. G. Oliveira, and N. O. Stefanelli, "Smart industry and the pathways to HRM 4.0: Implications for SCM," Supply Chain Manag., vol. 42, no. 1, pp. 124-146, 2019.
[34] F. M. Kamaruzaman, R. Hamid, A. A. Mutalib, and M. S. Rasul, "Conceptual framework for the development of 4IR skills for engineering graduates," Glob. J. Eng. Educ., vol. 21, no. 1, pp. 54- 61, 2019.

[35] Y. Kazancoglu, and Y. D. Ozkan-Ozen, "Analyzing Workforce 4.0 in the Fourth Industrial Revolution and proposing a road map from operations management perspective with fuzzy DEMATEL," J. Enterp. Inf. Manag, vol. 31, no. 6, pp. 891-907, 2018.

[36] M. Graczyk-Kucharska, M. Szafrański, M. Goliński, and M. Spychała, "Model of competency management in the network of production enterprises in Industry 4.0: Assumptions," in Advances in Manufacturing, A. Hamrol, O. Ciszak, S. Legutko, and M. Jurczyk, Eds. New York: Springer, 2018, ch. 19, pp. 195-204.

[37] K. Kusmin, T. Ley, and P. Normak, "Towards a data driven competency management platform for Industry 4.0," in Proceedings of an i-Know Workshop, Graz, Austria. 2018.

[38] S. Erol, A. Jäger, P. Hold, K. Ott, and W. Sihn, "Tangible Industry 4.0: A scenario-based approach to learning for the future of production," Procedia CIRP, vol. 54, pp. 13-18, 2016.

[39] A. Jerman, A. Bertoncelj, G. Dominici, M. Pejić Bach, and A. Trnavčević, "Conceptual key competency model for smart factories in production processes," Organizacija, vol. 53, no. 1, pp. 68-79, 2020.

[40] M. Pejić-Bach, T. Bertoncel, M. Meško, and Ž. Krstić, "Text mining of industry 4.0 job advertisements," Int. J. Inf. Manag., vol. 50, pp. 416-431, 2020.

[41] E. F. dos Santos, and P. Benneworth, "Makerspace for skills development in the Industry 4.0 era," Braz. J. Oper. Prod. Manag., vol. 16, no. 2, pp. 303-315, 2019.

[42] M. Götz, "The Industry 4.0 induced agility and new skills in clusters," Foresight and STI Governance, vol. 13, no. 2, pp. 72-83, 2019.

[43] S. Chong, G. -T. Pan, J. Chin, P. L. Show, T. C. K. Yang, and C. - M. Huang, "Integration of 3D printing and Industry 4.0 into engineering teaching," Sustainability, vol. 10, no. 11, p. 3960, 2018.

[44] BRICS Skill Development Working Group, "Skill development for Industry 4.0," India: BRICS Business Council, 2016.

[45] L. Prifti, M. Knigge, H. Kienegger, and H. Krcmar, "A competency model for 'Industrie 4.0' employees," presented at the 13th International Conference on Wirtschaftsinformatik, 12-15 February, 2017, St. Gallen, Switzerland. [Online]. Available: https://www.wi2017.ch/images/wi2017-0262.pdf [Accessed May 23, 2019].

[46] Deloitte and Global Business Coalition for Education, "Preparing tomorrow's workforce for the Fourth Industrial Revolution for business: A framework for action", Pretoria: Deloitte, 2018.

[47] IBSA Innovation & Business Skills Australia, "Preparing for Industry 4.0: Will digital skills be enough?" East Melbourne, Victoria: IBSA, 2018, pp. 1-31.

[48] D. S. Sink, D.F.Poirier, and G.L. Smith, "Full potential utilization of industrial and systems engineering in organizations," in Handbook of Industrial Engineering: Technology and Operations Management, G. Salvendy, Ed. Hoboken, NJ: John Wiley & Sons, 2001, ch. 1, pp. 1-26.

[49] Build My Forms, "The evolution of data analysis: A brief history," 2017. [Online]. Available from: http://www.buildmyforms.com/blog/The-Evolution-of-Data- Analysis-A-Brief-History [Accessed July 10, 2020].

[50] Dataquest, "Why do you need to learn SQL?" 2019. [Online]. Available: https://www.dataquest.io/blog/why-sql-is-the-most-important-language-to-learn/ [Accessed July 13, 2020].

[51] D. Gorecky, M. Schmitt, M. Loskyll, and D. Zühlke, "Human- machine-interaction in the Industry 4.0 era," presented at the 2014 12th IEEE International Conference on Industrial Informatics (INDIN). [Online]. Available: https://www.researchgate.net/ publication/286571545_Human-machine- interaction_in_the_industry_40_era [Accessed May 23, 2019].

[52] M. D. Nardo, D. Forino, and T. Murino, "The evolution of man–machine interaction: The role of human in Industry 4.0 paradigm," Production & Manufacturing Research, vol. 8, no. 1, pp. 20-34, 2020.

Technical Papers

Preparing 5.0 engineering students for an unpredictable post-COVID world

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***Abstract*—In 2020, Higher Education and industry across the globe were immersed in extreme, unpredictable environments. Given the devastating impacts and disruptions observed since the appearance of COVID-19, the question to ask Higher Education is how it can better prepare students who are capable of being agile and proactive, and who demonstrate effective decision-making capabilities in complex situations. This paper therefore seeks to explore how educational engineering programs can better prepare 5.0 engineering students for their future workplace. It draws on the authors' involvement in two European Union projects, to provide insights and recommendations, which suggest that the focus be on: revisiting the curriculum; developing transversal skills and V-shape Engineer workspaces; work-based learning; graduate employability; and strengthening ties between academia and industry. We are also increasingly moving towards a 5.0 era where the emphasis is on developing human- centred IT soft-skills. This paper presents educational engineering-program leaders and managers, with suggestions for how to be responsible and proactive in ensuring that 5.0 engineering students have not only a qualification, but the requisite skills to make a more meaningful impact in their future workplace.**

Keywords — engineering education, COVID-19, transversal skills, industry relations, workplace.

I. INTODUCTION

In the job market, specific and extraordinary demands are anticipated. Cedefop's skills forecast in 2018 already highlighted that in Europe, work environments in the near future are expected to feature more autonomy, less routine, more use of Information and Communications Technology, reduced physical effort and increased social and intellectual tasks [1]. The European labour market is challenged by changes in the demographic composition of the labour force and by increasing work complexity and processes.

Most countries across the globe have been severely affected by COVID-19, with most workplaces in 2020 also experiencing the effects. Educational and professional practice in 2020 has been clearly characterized by high levels of Volatility, Uncertainty, Complexity, and Ambiguity (VUCA) [2]. Such impacts are predicted to continue beyond 2020, in light of the severe consequences wrought by the COVID-19 pandemic in several sectors.

The future of work, along with graduate students' employability and careers, needs to be re-examined for the post-COVID era. A recent analysis carried out by *Société des Ingénieurs et Scientifiques de France* (www.iesf.fr) on competence assessment, illustrates that "the academic knowledge and the professional competence of French Alumni, holders of an Engineer's degree, are of utmost importance in the present days, in order to actively contribute to the challenges of the post-COVID-19 era, tomorrow and thereafter" [3]. Engineers and scientists will have to actively contribute to new societal challenges. The younger generation of students and new graduates need to be adequately prepared for a range of possible world crises (e.g. economic, natural disasters, terrorism, biological warfare, pandemic, climate, etc.).

This paper explores how Higher Engineering Education (HEE) program leaders and managers can best prepare 5.0 engineering students for future changes in workplaces and a post-COVID-19 VUCA world. It is critical that HEE program leaders and curriculum designers learn from the 2020 pandemic in order to proactively adapt and realign educational offerings and services, to ensure that new transversal and versatile 5.0 skills are developed and reinforced in engineering students. Engineering graduates, who are to be workplace ready, should be able to effectively deal with complex issues and make decisions instantly in professional situations characterised by higher levels of risks, uncertainty, and complexity.

II. STUDY BACKGROUND AND APPROACH

New curriculum guidelines were recently proposed, e.g. for Industry 4.0 [4], as well as numerous recommendations to University management that have to anticipate changes and make choices on how to adapt [5].

The paper draws on two Erasmus projects (DAhoy and EASTEM) to address the main question under investigation, namely, identifying ways in which HEEs can ensure that engineering students are appropriately trained to meet future challenges in the workplace. DAhoy is a strategic partnership focused on developing the decision-making skills of engineering and Science, Technology, Engineering and Mathematics (STEM) students. DAhoy is founded on an understanding of academia and industry's perceptions and expectations of students, and is fully aligned with the strategic VUCA challenges to accelerate pedagogical innovations and revise their educational systems with transversal skills. The second project, EASTEM, is a capacity-building project within South-East

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Asia, facilitating a competency approach and University Business Industry Collaboration models (UBICs) within STEM education programs in Europe and eastern Asia.

Both projects have sought to transform Engineering students into technological-change-leaders and decision makers, specifically for a VUCA world. Student-centred learning approaches are employed.

EASTEM enhanced STEM students' employability in an unpredictable future by facilitating the exploration of multiple realities, in different cultural settings and contexts, at an international level. The broader context also highlighted how important it is that students, while still at HEEs, spend time in industry to be exposed the working world. Another important aspect to consider is that HEEs and other institutions should take responsibility in developing the entrepreneurial skills of students and where possibly, assist with small start-ups / incubators.

The rationale is that students are not only developed to be mere employees who will be working for a boss or company. It is important to also bear in mind that a shift was made in some institutions to be entrepreneurial universities, whereby academics help students in this respect, rather than only be pure research universities.

A major outcome of DAhoy is that seven decision- making skills were identified as transversal skills (formerly known as transferable skills) and introduced to facilitate VUCA training. Key outcomes from the project include defined and evaluated innovative teaching and learning (T&L) activities to be integrated in educational frameworks at a systemic level; quality assurance and recommendations. DAhoy's European partnerships resulted in positive and sustained effects in the participating organisations and their staff and students' transversal skills integration, which is also now evident in other regional, national and European Institutions.

Given their focus on VUCA and career preparation, these two projects – although emanating primarily from a European perspective – provide insights into how HEE managers and program leaders could better prepare 5.0 engineering students for the future workplace and a post- COVID-19 unpredictable world. This enhances academia's capacity to be responsible and proactive in ensuring that 5.0 engineering students have the requisite skills, as well as qualification, to make a more meaningful impact in the workplace.

III. REVISITING CURRICULA FOR NEW CONTEXTS

Through a 3-year design-based research, including qualitative and quantitative iterative analysis, DAhoy conceptualized and analyzed seven decision-making-skills statements [6], shared several constructively aligned T&L courses and investigated their mapping in some national qualification frameworks. Results offer some recommendations for adapting curricula in the short term, to incorporate greater emphasis on transversal skills, including V-shape perspectives.

A. Transversal Skills

New graduates are potential leaders and managers of the future and they should have the necessary skills and competencies to face the current, as well as future VUCA situations. HEE has to ensure that engineering graduates have effective transversal skills to more comfortably face VUCA-like situations while working in the new post-COVID-19 VUCA world and also, along with professionals and graduates, to take advantage of the new landscape of career opportunities for a 5.0 future. Engineers need to develop 5.0 soft skills, such as Information Technology (IT) communication skills (working more online and less face-to- face), adaptation to change, and empathy – some of the 24 generic skills as highlighted in the work of Abdulwahed et al. [7].

As an illustration of the need for transversal skills, the COVID-19 crisis of 2020 has demonstrated that it is now critical to have effective judgment and decision-making capabilities. In 2005, the European Qualification Framework[8] indicated the importance of students at Bachelor level 6, being able to:

> *"[take] responsibility for decision-making in unpredictable work or study contexts" and, at Master level 7, to "manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches; take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams".*

In 2015, the European Network for Accreditation of Engineering Education, which sets program outcomes for engineering education accreditation in the EU, prioritized decision-making and judgement abilities among its ten outcomes [9]. In Europe it is expected that the learning process should enable Masters' degree graduates to demonstrate the:

- ability to manage complex technical or professional activities or projects that can require new strategic approaches, taking responsibility for decision-making;
- ability to integrate knowledge and handle complexity, to formulate judgements with incomplete or limited information, that include reflecting on social and ethical responsibilities linked to the application of their knowledge and judgement.

The needs of the economy have changed in 2020 as a result of COVID-19, with new workforce requirements and revised economic-growth strategies. Graduate attributes and core learning outcomes need to change so that they include transversal skills, such as decision-making, as conceptualized and analysed by DAhoy.

Now, soon after the initial COVID-19 crisis, HEE programs should be realigned without waiting until the periodic quality evaluation processes or revised engineering program outcomes are formalized in qualification frameworks. The conventional periodic review and evaluation of engineering programs, often at four or five-year intervals (as with the US ABET or with CTI in France) [10], may need to be examined in light of 2020's exceptional changing context and needs.

B. V-shape 5.0 Engineers

In 2018, Robin Karvo, Human Resources Consultant at Nokia France, indicated that, "today's business world is changing more quickly than ever before: rapidly evolving markets, regulations, and technologies make it hard to see very far into the future" [11]. Before the crisis, technological universities were mainly focused on producing a 2020 STEM graduate, with 'T-shape' skills [12]. T-shaped scientists [13] are those who have good depth of knowledge and skill in one discipline, and a reasonable breadth of knowledge and skill across multiple disciplines, e.g. management, so have transferable skills for judgement and decision-making

(T- shaped were an evolution of 'I-shaped' graduates, who have developed good depth of knowledge and skill in a single discipline only).

As the VUCA context is now prevalent in most sectors, engineering graduates should ideally be more 'V-shaped' [14], a quality reinforced as a result of a versatility-oriented curriculum. V-shaped individuals grow in knowledge and skill, and also in spiral fashion, both horizontally and vertically. A V-shaped graduate is neither a specialist nor a generalist [15]. V-shaped graduates have balanced knowledge and skills and can learn a new domain of skills easily; this is why in software engineering programs, ACM- IEEE curricula recommendations include additional requirements about domain-specific knowledge [15]. More and more, it is evident that an engineer 5.0 era prevails [14], with human-centred IT soft-skills, and empathy requirements being at the forefront of the skills required. Society 5.0 encompasses a combination of cyberspace and physical space and is "a human-centred society that balances economic advancement with the resolution of social problems by a system that highly integrates cyberspace and physical space" [16].

For the post COVID-19 period in HEEs, transversal skills are required, and this context provides an opportunity for HEEs to revise program outcomes and aim for V-shaped perspectives for their graduates. V-shaped individuals are the kind of people needed post-COVID-19, with a focus on careers and competency development, both across and up, to grow tomorrow's workforce. STEM graduates will need to implement decisions, knowledge and skills in order to be able to actively contribute to the post-COVID-19 era, to replicate the success of spontaneous and ongoing mission-driven engagement. This engineer needs to embody the traits of a leader: decisive, bold yet humble, courageous, resilient, open to change and continuous learning, and able to be adaptable in various contexts.

C. *Flexible Curricula in the Digital Era*

The 2020 crisis is changing the nature of work, of workers, and of workplaces. Professional workplaces and communication technologies will need to change business practices, and companies will also need to adapt their approaches and processes [4]. The value of online learning platforms and video-conferencing procedures were reinforced all around the world in 2020, as they were for the HEE sector with the sudden, rapid shift to remote education. The new generation of STEM students (digital native) is open to distance education, e.g. Massive Open Online Courses and Small Private Online Courses. Most STEM students, especially engineering students, are already aware of 'learning to learn' in 2020 and are fairly independent.

This new generation is therefore fertile ground for this VUCA-like environment of learning, but the monitoring of the learning process remains a concern for all. In 2020, society is in the midst of a cultural change, and is experiencing a transition towards a new generation of universities where technology-enhanced learning is becoming the norm, including diversity of learning paths.
Nevertheless, as highlighted by Kamp [5], it is far easier to educate students for our past than for their future. The chaotic VUCA situation is not a predictable linear extension of the present. Long-term forecasts of discrete scenarios lead to billowing plumes of uncertainty. University leaders and HEE program managers need to revise their curricula to better prepare their students for an uncertain future. For the post-COVID-19 period, traditional recognition of learning and competence development will have to be revisited.

D. *Workspaces*

In 2020, the risk of virus transmission, resulting in COVID-19 infections, was greatest in places where large numbers of individuals congregate, such as universities. While it became apparent at the outset of the COVID-19 crisis that ensuring continuity of study and work was made possible by enabling rapid external engagements, which relied in turn on supportive workspaces, managing the crisis required that the ideal workspace was balanced by mitigating the risk of unsafe crowding in university environments.

Workspaces in universities need to be rethought, due to constraints pertaining to physical proximity. Innovative solutions to confined spaces, through the design of more space-driven intersection and student-working meeting places with industry were required for Vocational Education and Training education. Lots of campuses in 2020 were closed, semesters abroad have been cancelled, internships have been interrupted, and the European Schengen area will probably remain closed for a while until COVID-19 is perceived to be more manageable.

Multiple and diverse impacts will be observed in the long run as a result of the COVID-19 period. On the one hand, HEEIs will have to consider various factors, such as international status, quality and certification, teachers' confidence, students' confidence, and financial reserves. On the other hand, students are more concerned with employability, quality of education and training, having a well-recognized diploma and social connection with peers.

IV. PREPARING ENGINEERS FOR THE WORKPLACE

EASTEM, with 13 technological universities, conceptualized eight UBICs via literature reviews and semi- structured interviews [17]. Its analysis lay the foundation for a structured relationship model for STEM universities to be expanded later by shared good practices among partners thanks to a 3-days collaborative international and virtual meeting in October 2020, including industrial stakeholders. Requirements and maturity levels in UBIC models differ greatly between countries and institutions and are part of the international diversity of culture, educational and industry history, and national economic growth. One objective is that STEM programs will be more sustainable once partner institutions are better equipped to interact with corporate partners in the development of their STEM-university education. The results could echo strategic plans and policies of HEE and, in the short term, suggest some recommendations to reinforce cooperation with industry and companies.

A. *Work-based Learning Tensions and Recognition of Learning*

In 2020, professional work activities integrated into the engineering curricula were under pressure, mostly in countries where internships and apprenticeship models are in place for engineering education [18]. As a result of COVID- 19, many interns had to immediately leave their companies as some organizations were forced to close in some countries or sectors.

For the post-COVID-19 period, recognition of student learning and competence development in companies will have to be revisited. Student engagements devised to practically assist society could perhaps include grading of portfolios of experiences, a process which may be applicable also as a means for universities to recognize accomplishments by informal dynamic learners, as well as their prior learning processes for VET.

B. Graduate employability and professional needs

Graduate employment and employability analysis protocols in HEE will need to change. The recruitment market, nationally and internationally, will not be the same as before COVID-19. There is for example already change in how industry is being relocated in Europe, with some countries bring more adaptable than others. However, some sectors, currently under skills pressure, will offer growth opportunities, such as IT and telecommunications, some Industry 4.0 pillars, health, science and biomedical Research and Development, logistics and supply chains, or start-ups.

For the post-COVID-19 period, the employment indicators will have to be revised alongside territorial, regional and national priorities. Institutions will need to organize and implement new actions and adapt processes to the VUCA situation. Students always need to be exposed more quickly to new career perspectives, so that they can navigate their career path with less anxiety in the short term. For the post COVID- 19 period, universities, along with industry, should provide more support to their students by setting personal, national and regional goals in preparation for their future careers. Students should reinforce their capabilities to analyze and judge the situation for career decision-making, in order to organize and implement actions to better prepare for the end of their studies in readiness for their first job [19]. Moreover, they may need to re-orient themselves in their chosen career path and personally take on that responsibility, for themselves and for the broader society. It is time to identify and motivate new role models, e.g. as future entrepreneurs, via high-potential recruitment programs.

C. Strengthen ties between academia and industry

Engagement with industry has always been a crucial requirement for technological universities to support economic development since the 1st Industrial Revolution [20]. During the COVID-19 crisis, some university-industry engagement experiences around the world have shown the capacity of HEEI, and their students, to engage rapidly and flexibly. Ongoing collaboration will be critical to ensuring the recovery phases of both HEE and the economy. The magnitude of the 2020 economic crisis, at national and global levels, will require that HEE institutions rise above systemic passive inertia and reactively engage in the constant work of creating new forms of collaboration, models and processes.

Cooperation between academia and industry will be critical for both parties during and after COVID-19. Academia can improve its curriculum and knowledge delivery whilst industry takes advantage of subjects developed by academia. Some universities have been slow to acknowledge the academia-industry divide. Reimers and Schleicher [21] proposed a checklist in their Organisation for Economic Co-operation and Development (OECD) report, aimed at supporting education decision-making to develop and implement effective educational responses to the COVID-19 global pandemic. The first task is to establish a task force or steering committee that will have the responsibility to develop and implement an educational response. It must be ensured that, where possible, those in the task force represent different constituents, including representatives of industry when relevant.

Support structures are essential for enabling rapid external engagement; transdisciplinary, multi-sector strategies are necessary when seeking to solve complex problems that threaten global public health and safety [22]. Other tasks include exploring partnerships with the private sector and the community in securing the necessary resources to provide devices and connectivity. These issues are largely in the hands of HEEs. We need to have shared strategies with governments (national and regional), industry and business sectors, universities and their students. Students, as future professionals, need to assist in the short term with economic recovery, in order to have a more resilient future.

V. DISCUSSION AND RECOMMENDATIONS

The 2020 crisis has demonstrated just how fragile many systems actually are. Strategic leadership is required to create crisis-recovery groups, incorporating both analysts and skilled VUCA decision makers, to prepare for any future crises that may echo in STEM and engineering education. It is important to put plans (short, medium and long-term) in place but HEEs leaders will need to be responsive-ready and agile, should another crisis appear.
HEEs structures, processes and policies need to be revisited on a regular basis, and the institutional culture has to be conducive to embracing change, rather than characterized by extreme bureaucracy and hierarchy, and the upholding of traditions. This is particularly relevant as the world struggles to pick up the pieces after being battered by the pandemic. It is important for HEEs transitioning to the new normal to be able to integrate social and societal aspects, even natural fundamentals and values which are far too neglected, and to encompass the concrete experiences learned from each crisis, to ensure development as reflective practitioners [23].

This analysis may guide university leaders and managers to enhance and accelerate university-industry engagement alongside a V-shaped and more flexible curriculum. It is, however, important to avoid a mismatch in expectations [24]. Collaboration between these two sectors needs to be reinforced [8] but it is likely that there will be inhibiting factors which will remain – "Industry and academia have different cultures, different values, different needs and different expectations (Morell 2014: 2) [25]… the biggest barrier that may exist is the failure to recognize that each sector has different needs" (Morell 2014: 3) [25].

In 2020, the future is uncertain, and we have no clear directions as to how societies, economies, and the very way of life will be impacted. We also find ourselves in the midst of a human-centred society 5.0, which involves integrating cyberspace and physical spaces. Despite not having any certainties, HEE have a moral responsibility to ensure that graduates are not ill equipped for a VUCA future with a 5.0 perspective. It is thus imperative that, without further delay, students are taught how to meaningfully contribute to a human-centred society that balances economic advancement with collaboration, nature and the resolution of social and societal problems.

VI. CONCLUSION

This paper sought to explore how HEE managers and educational program leaders can best prepare 5.0 engineering students for the workplace and a post-COVID VUCA world. Through analysis conducted in two EU projects, the first with four European universities and the second with thirteen technological universities, the authors recommend that HEE leaders focus on: revisiting the curriculum, emphasising transversal skills and V-shape Engineers' workspaces, work- based learning, graduate employability, and strengthening collaborations between academia and industry. To reinforce the adoption of transversal skills, a framework originating from DAhoy highlighted six Reference Models intended to guide university leaders in implementing the learning environment for decision-making skills in VUCA situations. The eight UBICs emanating from EASTEM form a foundation on which to foster collaborations with Industry, including several shared good practices per UBIC.

With a society 5.0 vision in their curricula, HEE must now be ready to adapt themselves into learning spaces for V- shaped students, to prepare their students to become flexible lifelong students, capable of facing VUCA post-COVID once they enter the workforce. The engineer 5.0 era involves a human-centred society which takes into account both the economic and the social, with human-centred IT soft-skills and empathy requirements being at the core. There is a clear shift towards realizing just how important traits and characteristics are, and not only technological know-how. Engineering educational leaders should lead the way in shaping Engineering graduates to thrive in VUCA situations.

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REFERENCES

[1] Cedefop, "Skills forecast trends and challenges to 2030," European Centre for the Development of Vocational Training, Retrieved from https://www.cedefop.europa.eu/, 2020.

[2] N. Bennett and J. Lemoine, "What VUCA Really Means for You," Harv. Bus. Rev., vol. 92(1/2), 27, 2014.

[3] M. Ventre, "COVID-19: IESF Press release," Ingénieurs et Scientifiques de France (IESF), 8 April 2020. Retrieved from https://www.iesf.fr/offres/doc_inline_src/752/1- CommuniquePresident-IESF-Covid19.pdf, 2020.

[4] PwC, "Skills for Industry Curriculum Guidelines 4.0: Future-proof education and training for manufacturing in Europe," EASME Dpt. A - COSME, H2020 SME and EMF. Final Report, January 2020.

[5] A. Kamp, "Navigating the landscape of higher engineering education: Coping with decades of accelerating change ahead," Delft University of Technology Edition. 4TU. Centre for Engineering Education. Delft, Netherlands, April 2020.

[6] S. Rouvrais, S. Gaultier Le Bris, and M. Stewart, Engineering Students Ready for a VUCA World? A Design-based Research on Decisionship. In Proceedings of the 14th International CDIO Conference, pages 872–881, KIT, Kanazawa, Japan, June-July 2018.

[7] M. Abdulwahed, W.Balid, M. O. Hasna, and S. Pokharel, "Skills of Engineers in Knowledge Based Economies: A Comprehensive Literature Review, and Model Development," In Proc. of the 2013 IEEE International Conference on Teaching, Assessment and Learning for Engineering, 759-765. Bali, Indonesia, August 2013.

[8] European Commission, "Descriptors defining levels in the European Qualifications Framework (EQF). Learning Opportunities and Qualifications in Europe," Retrieved 19 April 2020 from https://ec.europa.eu/ploteus/en/content/descriptors-page, 2005.

[9] ENAEE, "The EUR-ACE Framework Standards and Guidelines (EAFSG)," The European Network for Accreditation of Engineering Education, 2017.

[10] CTI, "Conséquences Episode Coronavirus". Communique by French 'Commission des Titres d'Ingénieur', 26 March, Retrieved from https://www.cti-commission.fr/consequences-episode-coronavirus-2, 2020.

[11] R. Karvo, "Career Decision Making", Retrieved from https://youtu.be/LC0GRvD9ALg, 2018.

[12] I. Liem, Y. Asnar, S. Akbar, A. Mulyanto, and Y. Widyani, Y. Reshaping software engineering education towards 2020 engineers. In 27th Conference on Software Engineering Education and Training (CSEE&T), 171-174. IEEE Klagenfurt, 23-25 April 2014.

[13] D. L. Johnston, "Scientists Become Managers-The "T"-Shaped Man," IEEE Eng. Manag. Rev., vol. 6(3), pp. 67–68, 1978.

[14] B. Hinton, "V Shaped Engineers: The evolution of T-shaped," Blog post of May 4, Retrieved at http://hintonbr.wordpress.com, 2016

[15] A. Koohang, L. Riley, T. Smith, and K. Floyd, "Design of an Information Technology Undergraduate Program to Produce IT Versatilists," J. Inf. Technol. Educ., vol. 9(1): pp. 99-113, 2010.

[16] Japanese Cabinet Office, "Society 5.0," Japanese Council for Science, Technology and Innovation, Science and Technology Policy. Retrieved from https://www8.cao.go.jp/cstp/english/society5_0/index.html, 2020.

[17] S. Rouvrais, G. Jacovetti, P. Chantawannakul, N. Suree, and S. Bangchokdee. University-Industry collaboration themes in STEM higher education: An Euro-ASEAN perspective. In Proceedings of the 16th International CDIO Conference, hosted online by Chalmers University of Technology, Gothenburg, Sweden, 9-11 June 2020.

[18] S. Rouvrais, B. Remaud, and M. Saveuze, "Work-based Learning Models in French Engineering Curricula: Insight from the French experience", Eur. J. Eng. Educ., Special Issue, vol. 45(1), pp. 89-102, 2018.

[19] C. Gerwel Proches, N. Chelin, and S. Rouvrais, « Think first job! Preferences and expectations of engineering students in a French Grande Ecole," Eur. J. Eng. Educ., vol. 43(2), pp. 309-325, 2018.

[20] B. Kloot and S. Rouvrais, "The South African Engineering Education Model with a European Perspective: History, Analogies, Transformations, and Challenges," Eur. J. Eng. Educ., vol. 42(2), pp. 188-202, 2017.

[21] F. M. Reimers and A. Schleicher, "A framework to guide an education response to the COVID-19 Pandemic of 2020," Published under the responsibility of the Secretary General of the OECD, April 2020.

[22] K. H. Jacobsen, A. A. Aguirre, C. L. Bailey, A. V. Baranova, A. T. Crooks, A. Croitoru, P. L. Delamater, J. Gupta, K. Kehn-Hall, A. Narayanan, and M. Pierobon, "Lessons from the Ebola outbreak: action items for emerging infectious disease preparedness and response," EcoHealth, vol. 13(1), pp. 200-212, 2016.

[23] D. A. Schön and V. DeSanctis, V., "The Reflective Practitioner: How Professionals Think in Action", J. Cont. High. Educ., vol. 34(3), pp. 29-30, 1986.

[24] A. C. Bickley and D. H. Nash, "Building a Long Term Strategic University-Industry Partnership". In Proceedings of the 2018 University-Industry Interaction Conference: Challenges and Solutions for Fostering Entrepreneurial Universities and Collaborative Innovation. Pp. 146–154. London, UK, 20-22 June 2018.

[25] L. Morell, "Scaffold to Build and Sustain Industry-University Partnerships," J. Eng. Educ. Trans., vol. 27(4), pp. 2349-2473, 2014.

Technical Papers

Practical approaches to implement graduate attributes in engineering faculties

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***Abstract*—The International Engineering Alliance has developed graduate attributes to improve the employability of engineering graduates and to reduce the gap between academic work and practice. The three main accords that form part of this international alliance are the Washington Accord, the Sydney Accord, and the Dublin Accord. All countries that belong to these accords have developed graduate attributes for accreditation purposes. Embedding graduate attributes into the curriculum can be complex and would depend on academic staff involvement. Hence, the necessity to determine how best graduate attributes can be developed and give clarity about assessment strategies. Engineering faculties need to consider developing clear processes that clarify the programme outcomes assessment in the context of graduate attributes. This paper provides an overview of some practical approaches that could be used for the development of graduate attribute assessments.**

Keywords—Graduate attributes indicators, graduate attribute descriptors, graduate attribute assessment

I. INTRODUCTION

Institutions of higher education aimed at preparing graduates for the world of work. The only constant in life is change and this is true for workplace requirements as well. According to the report of the World Economic Forum, the majority of children, entering primary school after 2016 will be employed in jobs that do not exist at present [1]. As the world becomes more and more dependent on technology, the field of engineering is becoming crucial. It is vital for the engineering profession to remain relevant and to meet the constantly changing needs of industry and society. The International Engineering Alliance plays a critical role to ensure the continued relevance of the profession.

A. Educational quality and mobility within the engineering profession

The International Engineering Alliance (IEA) ensures countries cooperate with regard to educational quality and enhanced mobility. The three main accords that form part of this international alliance are the Washington Accord, the Sydney Accord, and the Dublin Accord. The Washington Accord is an agreement between accreditation bodies of engineering degree programmes. The Sydney Accord is an agreement between the accreditation bodies of engineering technology programmes and lastly, the Dublin Accord is an agreement between the accreditation bodies of engineering technicians [2]. The International Engineering Alliance has classified engineering activities as complex, broadly-defined, and well-defined to distinguish between the categories of engineer, technologist, and technician [3]. The international engineering alliance has developed a set of attributes that each of the three groups, should have once they graduate [3]. Internationally, the respective accreditation bodies that form part of the various accords have developed outcomes-based criteria for academic programmes. Table 1 provides a small snapshot of a typical range statement describing the problem-solving attributes. It illustrates that the graduate attributes are similar but are at different levels for the three groups. These graduate attributes are generic and applicable to all fields of engineering [3].

TABLE 1 *Snapshot of part of the range statement of problem-solving as defined by IEA [3]*

Attribute	Complex engineering problems	Broadly defined engineering problems	Well defined engineering problems
Range of conflicting requirements	Involve wide- ranging or conflicting technical, engineering, and other issues	Involve a variety of factors which may impose conflicting constraints	Involve several issues but with few of these exerting conflicting constraints
Depth of analysis	Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models	Can be solved by the application of well-proven analysis techniques	Can be solved in standardised ways
Familiarity of issues	Involve infrequently encountered issues	Belong to families of familiar problems which are solved in well-accepted ways	Are frequently encountered thus familiar to most practitioners in the practice area

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B. Development and implementation of graduate attributes assessment at a South African university

The Engineering Council of South Africa (ECSA) is the body responsible for the accreditation of all engineering programmes. ECSA has developed eleven graduate attributes that graduating engineers [4], [5] need to meet, and ten graduate attributes that technologists [6] and technicians [7] need to meet. Universities in South Africa must show how graduate attributes are linked to learning objectives and assessments [8]. Universities and different programmes vary significantly in how they link graduate attributes to learning outcomes and assessments. Currently, there are no prescriptions, that guide the assessment of graduate attributes. Often final year projects are used to assess many, if not all, of the graduate attributes [9]. Trained registered professionals from industry and academia form part of the committees that peer review the various academic programmes. Programme evaluation auditors would generally want to check for the graduate attributes assessed and the corresponding learning outcomes that support them, the various indicators used to assess these graduate attributes, the descriptors used to define acceptable levels, and the feedback mechanism in place.

The typical process followed in universities is to understand the required graduate attributes. This is achieved by closely working with ECSA and providing training to all lecturers and academic personnel in the Engineering Faculty. Each department then decides how/where the respective graduate attribute would be developed and assessed. Rubrics are developed to ensure all aspects of the graduate attribute have been met. This process is based on academic staff's beliefs on teaching and assessing graduate attributes as indicated in the literature [10]. This approach is mainly teacher-centred. ECSA is not prescriptive in its approach and the institution does not provide a common approach for the development and implementation of graduate attributes. It is left to the lecturer to design a suitable mode of assessment and implementation of these graduate attributes. This opens the doors for multiple interpretations.

II. OBJECTIVE

The objective of this paper was to discuss potential practical approaches that can enable the development of graduate attribute assessments that are in line with international and national requirements. It is believed that the development of practical approaches would create more consensus regarding acceptable graduate assessments and implementation. Although various academic institutions should have the autonomy to develop graduate attribute assessments, approaches based on best practices would provide a solid foundation. In addition, some studies have pointed out the fact that graduates' attributes cannot be assessed directly. Hence, it is necessary to develop a measurable and pre-determined standard to evaluate learning. These descriptors can be used to clarify what students must do to be considered competent in the attribute.

III. METHODOLOGY

The research conducted in this paper focused on existing studies that describe the development and implementation of graduate attributes descriptors in engineering faculties. It contributes to the effort to integrate graduate attributes effectively across curricula within South African universities, particularly in engineering faculties as supported by De la Harpe and David [11]. To get an overview of existing publications, keywords that include the exact phrase "graduate attributes descriptors", and "graduate attribute indicators" were used within the web search engine Google Scholar. No other search criteria were defined.

To avoid bias, all the articles that met the requirements of the search were analysed qualitatively. The content of the papers listed in the reference section provides valuable insights relating to graduate attribute development and implementation. Fig 1 is a pictorial representation of the number of existing publications on graduate attributes indicators or descriptors. From a total of 45 search results using the keywords "graduate attribute indicators" and "graduate attribute descriptors", 87% were obtained using the first keywords, and 13 % were obtained using the second one. This shows that most researchers use the identifier "graduate attribute indicators" in their studies.

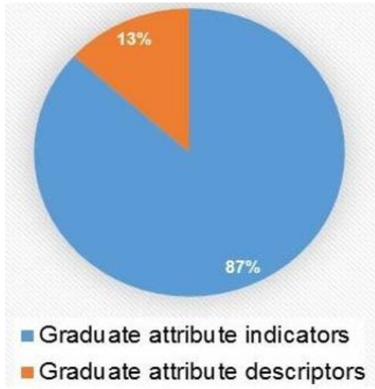

FIGURE 1 *Proportion of search results using the proposed two keywords*

IV. FINDINGS

A. Importance of graduate attributes

There is a clear link between graduate attributes and employability [12]. After their studies, each engineering graduate must demonstrate competence as per the graduate attributes assessed during the Programme. It has been proven that developing the graduate attributes from early on in a student's academic career leads to the entrenchment of these attributes [13].

Effective teaching and assessment of graduate attributes have been linked to the confidence and willingness of academic staff [12]. It is interesting to note that confidence and willingness to teach and assess graduate attributes have been linked to academics experience in industry and teaching qualifications. These two attributes are vital and engineering lecturers are willing to teach and assess the graduate attributes as it is critical for accreditation. However, some may be less confident than others. Outcomes-based education offers engineering educators more freedom about content as the application of knowledge gained more importance [14].

Some have criticised the use of graduate attributes and argued that it is difficult to implement graduate attributes as there is not a shared understanding of academic freedom and should be abandoned and replaced with "Powerful Knowledge" [15]. Academic freedom can be defined as the freedom of academics to teach in their field of expertise without external interference [16]. The question has been asked whether teaching and assessing graduate attributes are the best way to ensure employability. Nagarajan and Edwards suggested that additional frameworks may be required to fully prepare students for work [17]. However, engineers need to have certain skills, knowledge, and attitudes to be employable and therefore graduate attributes play a critical role.

Embedding graduate attributes into the curriculum is complex and depends highly on academic staff involvement either directly or indirectly. Ratloff et al. [10] pointed out that the belief of academic staff plays a significant role in the teaching and assessment of the graduate attributes. Though most academic staff have expertise in their field, their training generally has not focused on teaching and evaluating students. Hence, the assessment of graduate attributes can be reduced to teachers' beliefs about learning and teaching. Students will generally focus on what will be assessed while academic staffs focus on content. The mode of assessment, therefore, sends a strong signal to the student about what is important to learn. Some academics are convinced that students' perceived lack of knowledge and skills is their responsibility which is described as a teacher-centered approach. Radloff et al. argue that the most effective way to embed graduate attributes is a student-centered, learning-oriented approach that focuses on developing knowledge and skills, including graduate attributes [10].

Changes in beliefs are fundamental to embed graduate attributes.

B. Possible standardised approach: CDIO Syllabus

In 2001 Massachusetts Institute of Technology (MIT) published a generic syllabus that could be customised to any engineering programme [18]. The objective of this syllabus was to set clear goals for engineering education. It summarises the skills, knowledge and attitudes that industry, alumni and academia would like future engineers to have. CDIO stands for Conceive, Design, Implement and Operate, which is the context within which engineering fundamentals are framed in this syllabus [19]. The researchers followed a rigorous process to ensure that all the skills, knowledge and attitudes required of the future engineer were included. The CDIO Syllabus v1 has been used as a reference in over 100 programmes worldwide for setting goals, planning curricula and assessing outcomes [20]. This syllabus was translated into Swedish, French, Spanish, Vietnamese, and Chinese. This CDIO version 2 was published in 2011 [20].

This syllabus emphasises that deep knowledge of engineering fundamentals should be the main aim of any undergraduate engineering programme [20]. The four high-level categories covered in this syllabus are a) Technical Knowledge and Reasoning, b) Personal and Professional Skills and attributes c) Interpersonal skills: Teamwork and communication, and d) Conceiving, Designing Implementing, and Operating Systems in the enterprise and societal context [20]. Technical knowledge and reasoning is the part that is unique to engineering programmes. Personal and interpersonal skills should be the same for all engineering professionals [18].

This syllabus also enabled the development of rigorous outcomes-based assessments [12]. This was done by establishing the levels of proficiency required for identified topics. Specific learning objectives and possible assessments of these objectives by using Bloom's taxonomy, to ensure that the levels of required proficiency are met, are established. Bloom's taxonomy defines six levels of learning from the lowest to the highest [21]. Each of these levels has specific verbs that are associated with assessment at that level. MIT used these verbs to create generic statements for assessments of attributes e.g. Evaluate "data and symptoms" [18].

C. Comparing graduate attributes.

A comparison was done of the graduate attributes of the 17 signatories of the Washington accord [14]. Four countries used the International Engineering Alliance graduate attributes as is (India, Malaysia, New Zealand, and Sri Lanka). Five main themes were found and each of these themes was broken down into 21 categories [14] as can be seen in Fig 2. These countries also compared how often the 21 categories appeared and classified them as always appeared (17 times), almost always appeared (16 times), and then frequently appeared (12-15 times)

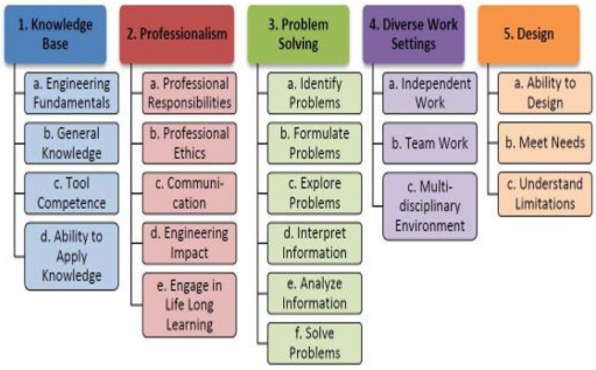

FIGURE 2 *Themes and categories identified from 17 countries accreditation bodies [22]*

In a comparison between the CDIO syllabus and the Canadian Engineering Accreditation (CEAB) requirements, it was found that the CDIO requirements exceeded the CEAB requirements [23]. This is also true for a comparison of the CDIO syllabus with the Accreditation Board for Engineering and Technology (ABET) [20]. It could be true of most of the accreditation body requirements as they are reasonably close to each other and all satisfy the IEA requirements, although further research is required to confirm this.

D. Development and implementation of graduate attributes assessment

A graphic representation of a generic assessment process adopted in many institutions can be seen in Fig 3. A faculty could develop common indicators associated with each attribute. Examples of graduate attribute indicator rubrics related to knowledge-based engineering, and developed by the faculty of engineering of Manitoba and McGill Universities, are shown in Fig 4. The various indicators defined to assess the 12 CEAB graduate attributes namely knowledge-based engineering, problem analysis, investigation, design, use of engineering tools, individual and teamwork, communication skills, professionalism, the impact of engineering on society and environment, ethics and equity, economics and project management and life-long learning are described in reference [24] and [25].

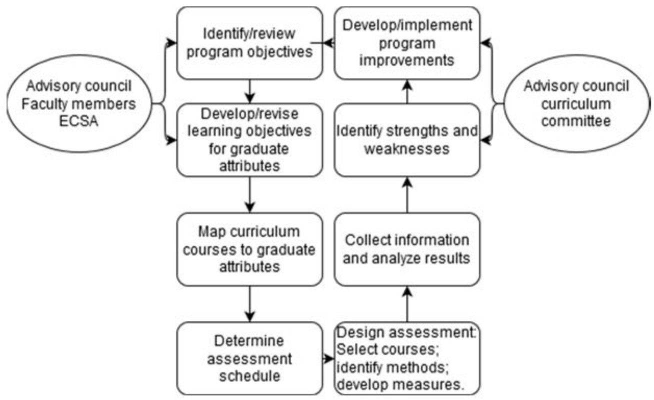

FIGURE 3 *Typical graduate attribute assessment process*

Practically, two methods (tools) are proposed for the assessment of graduate attributes [26]. The first method is called a direct assessment. In this mode of assessment, each attribute is broken down into a level of competencies such as below expectations, marginal, meets expectations, and exceeds expectations (Figure 4a) or strong, competent, developing, and needs work (Figure 4b). Typical means of assessment used for this method of assessment are test questions, assignment, capstone or design project, laboratory report, etc. [26]. The second tool is the indirect assessment. It consists of rating opinions that indicate students' abilities using alumni surveys, exit interviews, and records to get a sense of students' educational experience. This feedback could be used for continual improvement as pointed out in Fig 3. Halibas et al. [27] recommended that direct assessments must be complemented by indirect assessment for continuous improvement. This is not the case in many South African universities currently.

The challenge associated with the assessment of graduate attributes in large classes was studied in reference [28]. A multiple-choice question was developed to assess graduate attributes. Though the approach is restricted to the assessment of lifelong learning and professionalism only, it is useful to identify indicators that need improvement. This approach makes graduate attributes more meaningful and reinforces good academic practice.

Knowledge Base for Engineering (KB)

Indicators	Below expectations <55% (D and F)	Marginal 55-64% (C^+ and C)	Meets expectations 65-79% (B^+, B and B^-)	Exceed expectations 80-100% (A and A^-)
KB.1 - Recalls and defines information and concepts in mathematics	• Unable to recall previously learned information and concepts in mathematics	• Recalls some of the previously learned information and concepts in mathematics	• States most principles and theories and identifies most rules and methodologies in mathematics	• Explains specifics, principles, theories, rules, and methodologies in mathematics

(a)

INDICATORS	Level 4 *Strong*	Level 3 *Competent*	Level 2 *Developing*	Level 1 *Needs Work*
Mathematical and Scientific Terms: *Ability to interpret (understand and apply) mathematical and scientific terms.*	Demonstrates a skillful ability to interpret mathematical and scientific terms correctly.	Demonstrates an ability to interpret most mathematical and scientific terms correctly.	Demonstrates some ability to interpret mathematical and scientific terms correctly.	Demonstrates minimal or no ability to interpret mathematical and scientific terms correctly.

(b)

FIGURE 4 *Illustration of graduate attribute rubrics from (a) McGill and (b) Manitoba University*

Rather than being considered as a set of additional statements to the course description, graduate attributes may be used, as a tool, for reflection on teaching and assessment approaches, and curricular review and design. While reviewing programs and their constituent modules, the learning outcomes and contents would provide clarity about where/how attributes are explicitly and specifically addressed. Evidence showing how teaching methods and learners' tasks are enacted in practice to enhance the achievement of attributes could be reviewed Assessment of students' attainment of minimum requirement could be reviewed as well. This can be summarized as shown in Figure 5. Such an approach can be implemented at the modules and Programme level. Halibas et al. propose a framework made of three-levels for the assessment of graduate attributes and learning outcomes: institutional level, Programme level, and module-level [27]. This framework is illustrated in Figure 6. This framework proposes that the enhancement of institutional quality and effectiveness be conducted at an institutional level using an indirect method of assessment. The attributes achieved by students can be assessed upon graduation using indirect assessment while learning outcomes are assessed at the module level with a direct assessment.

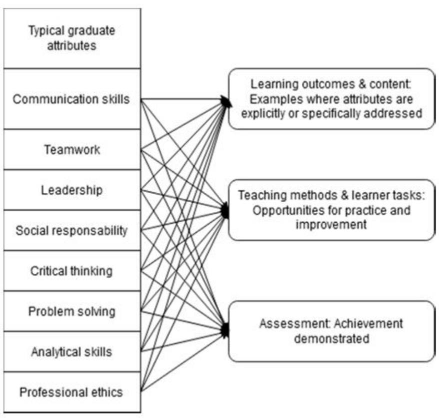

FIGURE 5 *Graduate attribute for assessment of module and program*

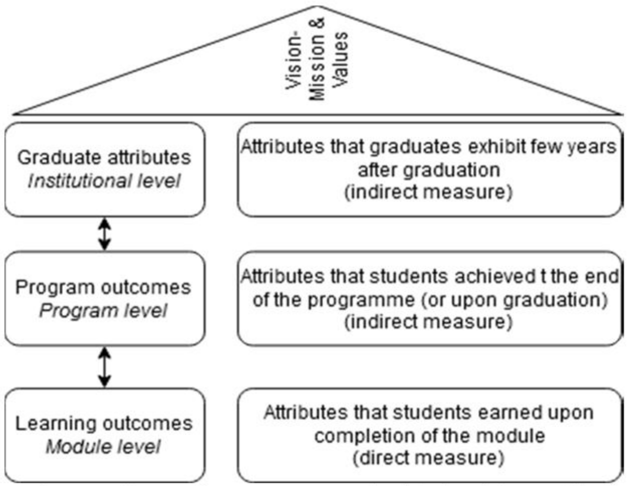

FIGURE 6 *Graduate attribute assessment per level (Adapted from Ref. [27])*

V. CONCLUSION

Some studies indicated that graduates' attributes cannot be assessed directly. Hence, it is necessary to develop measurable and pre-determined standards to evaluate learning. Graduate attributes are complex to develop but it is possible and beneficial to create a generic framework to assess graduate attributes in South Africa. The CDIO syllabus demonstrates how this is possible. The process of establishing generic graduate attributes has been clearly described.

In this paper, some existing practical approaches that could potentially contribute to addressing issues related to the implementation of graduate attribute assessment in the faculty of engineering in South African universities have been described. Through graduate attributes, students are meant to acquire and demonstrate several skills in addition to subject knowledge. The following summarises the conclusions of this study:

1. Graduate attribute assessment in most South African universities focuses on modules and programme levels leaving out the institutional level assessment. Indirect assessment of graduate attributes should also take place at the university level for continuous improvement of programmes and graduates. This could be achieved by surveys that target graduates and stakeholders;
2. Currently, the assessment of graduate attributes depends on the academic staff in charge of the specific modules. It mainly focuses on satisfying ECSA requirements. This study pointed out that irrespective of academics expertise in their field and ECSA's statements describing modules and learning outcomes, the current assessment approach is not free from subjectivity and has rooms for improvement. This study advocated for a shift from a teacher-oriented approach to a student-centered, learning-oriented approach that focuses on developing knowledge and skills, including graduate attributes. It is necessary to embed graduate attributes in the curriculum and make use of it for continuous improvement of teaching, learning, and assessment;
3. Each university must define its graduate attribute indicators. This study has highlighted a few practical approaches adopted in some international institutions. These approaches consist of developing graduate attribute indicators rubrics for assessment at the faculty level;
4. Rather than being considered as a set of additional statements to the course description, graduate attributes may be used, as a tool, for reflection on teaching and assessment approaches, and curricular review and design as pointed out in this study.

VI. RECOMMENDATION

It is important to note that graduates' training is generally not restricted to class, laboratory, and library. To bring more coherence, extracurricular activities could be connected to academic activities and taken into account in the context of graduate attributes to build and recognize skills and expertise. It is recommended that a generic framework be developed using the best practices as discussed in this paper.

While reviewing programs and their constituent modules, the learning outcomes and contents would provide clarity about where/how attributes are explicitly and specifically addressed. Evidence showing how teaching methods and learners' task are enacted in practice to enhance the achievement of attributes could be reviewed regularly. Assessment of students' attainment of the minimum requirement could be reviewed as well.

ACKNOWLEDGMENT

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REFERENCES

[1] World Economic Forum, "The Future of Jobs: Employment, skills and workforce strategy for the fourth industrial revolution," In Global challenge insight report., Geneva: World Economic Forum, 2016.

[2] "International Engineering Alliance," [Online]. Available: https://www.ieagreements.org/. [Accessed 27 July 2020].

[3] International Engineering Alliance, "Graduate Attributes and Professional Competencies," Version 3, 21 June 2013.

[4] E. C. o. S. Africa, Qualification standard for Bachelor of Science in Engineering (BSc(Eng))/ Bachelors of Engineering (BEng): NQF Level 8, Johannesburg: E-02-PE, 2019.

[5] Engineering Council of South Africa, Qualification standard for Bachelor of Engineering Technology Honours: NQF Level 8, Johannesburg: E-09-PT, 2019.

[6] E. C. o. S. Africa, Bachelor of Engineering Technology: NQF Level 7, Johannesburg: Document E-02-PT, 2016.

[7] Engineering Council of South Africa, Qualification Standard for Diploma in Engineering Technology: NQF Level 6, Johannesburg: Document E-08-PN, March 2016.

[8] A. J. Swart and M. Havenga, "Correlating Learning Outcomes to the Graduate Attributes of the International Engineering Alliance in a Problem-Based Learning Module," in Global Engineering Education Conference (EDUCON)(pp34-38) IEEE, Dubai, 2019.

[9] J. Case and B. Collier-Reed, "Embedding and Assessing Graduate Attributes in Engineering Curricula at UCT. University of Cape Town Teaching and Learning.," in University of Cape Town Teaching and Learning., 2010.

[10] A. Radloff, B. de la Harpe, H. Dalton, J. Thomas and A. Lawson, "Assessing graduate attributes: Engaging academic staff and their students.," in ATN Assessment, 2008.

[11] H. Snyder, "Literature review as a research methodology: An overview and guidelines. Journal of Business Research, .," Journal of Business Research, vol. 104, pp. 333-339, 2019.

[12] B. De la Harpe and C. David, "Major influences on the teaching and assessment of graduate attributes.," Higher Education Research & Development, vol. 31, no. 4, pp. 493-510, 2012.

[13] J. Hill, H. Walkington and D. France, "Graduate attributes: Implications for higher education practice and policy: Introduction.," Journal of Geography in Higher Education, vol. 40, no. 2, pp. 155-163, 2016.

[14] J. Jawitz, "Priorities for the new engineering education movement in South Africa.," Australasian Journal of Engineering Education, vol. 9, no. 2, pp. 173-177, 2001.

[15] N. Wald and T. Harland, "Wald, N., & Harland, T. Graduate attributes frameworks or powerful knowledge?," Journal of Higher Education Policy and Management, vol. 41, no. 4, pp. 361-374, 2019.

[16] P. G. Altbach, "Academic freedom: International realities and challenges.," in Tradition and Transition, Brill Sense, 2007, pp. 49 -66.

[17] S. Nagarajan and J. Edwards, "(2014). Is the graduate attributes approach sufficient to develop work-ready graduates?," Journal of Teaching and Learning for Graduate Employability, vol. 5, no. 1, pp. 12-28, 2014.

[18] E. F. Crawley, "The CDIO syllabus: a statement of goals for undergraduate engineering education (No. s 36). Cambridge, MA: Massachusetts Institute of Technology.," Massachusetts Institute of Technology., Cambridge, MA, 2001.

[19] E. F. Crawley, Cha Jianzhong, J. Malmqvist and D. R. Brodeur, "The Context of Engineering Education.," in Proceedings of the 4th International CDIO Conference Hogeschool Gent, Gent, Belgium, June 16-19, 2008.

[20] E. F. Crawley, J. Malmqvist, W. A. Lucas and D. R. Brodeur, "The CDIO syllabus v2. 0. An updated statement of goals for engineering education.," in In Proceedings of 7th international CDIO Conference, Copenhagen, Denmark., 2011.

[21] L. A. Sosniak and L. W. (Ed) Anderson, Bloom's taxonomy, Chicago, IL: Univ. Chicago Press, 1994.

[22] R. Paul, R. J. Hugo and L. C. Falls, "International expectations of engineering graduate attributes.," in In Proceedings of the 11th International CDIO Conference., Chengdu: University of Calgary, 2015.

[23] G. Cloutier, R. Hugo and R. Sellens, "Mapping the relationship between the CDIO syllabus and the CEAB graduate attributes: an update.," International Journal of Quality Assurance in Engineering and Technology Education (IJQAETE), vol. 2, no. 2, pp. 34-44, 2012.

[24] University of Manitoba, "Graduate attribute rubrics"," June 2015. [Online]. Available: https://umanitoba.ca/faculties/engineering/deans_office/pdf/Rubric_Handbook_-_University_of_Manitoba_FINAL_June_2015.pdf. [Accessed 15 June 2020].

[25] McGill University, "Graduate Attribute Indicator Rubrics from," nd. [Online]. Available: https://www.mcgill.ca/engineering/files/engineering/rubrics.pdf . [Accessed 10 February 2020].

[26] S. M. Easa, "Framework and guidelines for graduate attribute assessment in engineering education.," Canadian journal of civil engineering, vol. 40, no. 6, pp. 547-556, 2013.

[27] A. S. Halibas, S. Mehtab, A. Al-Attili, B. Alo, R. Cordova and M. E. Cruz., "A thematic analysis of the quality audit reports in developing a framework for assessing the achievement of the graduate attributes.," International Journal of Educational Management, 2020.

[28] S. M. Easa, "Innovative method for graduate attribute assessment in large classes.," International journal of research in education methodology, vol. 6, no. 3, pp. 926-935, 2015.

Technical Papers

Short-term study abroad: Enhancing engineering students' motivation for global experience

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***Abstract*—Engineers are required to work in a culturally diverse environment. Many institutions have begun including a global perspective as a part of their education and introduced various types of study abroad programs to improve student's competencies. The authors conducted a multifaceted evaluation of learning outcomes of short-term courses. These discussions indicated that students who have studied abroad multiple times show higher performance in global competence. It was suggested the evaluation of the programs should also consider the impact on students' motivation for another study abroad as a process in the educational cycle. This paper presents a case study of a survey that explored how students conceive of a short- term study abroad program and motivate themselves to gain further global experience. The data are based on a quantitative and qualitative questionnaire survey with a sample of 79 participants. The analysis is based on a comparison of students who had previous experience of study abroad with those who participated for the first time. Findings show that short-term programs can enhance student motivation for further global experience, in particular for those who participate as the first step in studying abroad. Participants who have frequently studied abroad tend to be able to acclimatize to a cross-cultural environment and engage deeply with the content of the program.**

Keywords—short-term study abroad, motivation, global experience, case study

I. INTRODUCTION

Engineers today are required to understand and demonstrate skills to work in a culturally diverse environment. Many institutions have begun including a global perspective as part of their education and introduced study abroad programs to improve students' competencies. Several studies have examined the effect of short-term programs on students, as these programs have become increasingly popular [1][2][3][4]. Most of these assessments are, however, based on a comparison of intercultural competency between pre- and post-programs, or participants and non-participants.

The authors have conducted a multifaceted evaluation of cross-cultural and multi-disciplinary project-based learning short-term courses since 2015, applying assessment tools such as a generic skills test, the CEFR-based engineering communication can-do list, a learning outcomes rubric, and questionnaires [5][6][7]. These discussions indicate that students who have studied abroad multiple times show greater communication, leadership, and intercultural abilities. It was suggested that the evaluation of short-term programs should also take into consideration an analysis of the impact on students' motivation for another study abroad experience as part of the educational cycle. Short-term study abroad programs need to be assessed not only by examining learning outcomes of the programs themselves but also by considering the impact on students' motivation for continuous learning.

This paper presents a case study of a survey that explored how students conceive of a short-term study abroad program and motivate themselves to gain further global experience through it. The data are based on a quantitative and qualitative questionnaire survey with participants in a project-based learning course, the Cross-cultural Engineering Project (CEP), held at Shibaura Institute of Technology (SIT), Japan, in December 2019. This 10-day course required participants to solve contemporary social/industrial problems together with diverse project members. Analysis of the data was based on a comparison of students who had previously studied abroad with those who were participating for the first time. The study used the KH Coder [8], open-source software for qualitative data analysis.

II. THE CROSS-CULTURAL ENGINEERING PROJECT (CEP)

While there are many different types of short-term study abroad experiences, most institutions define them as programs with a duration of less than a semester or quarter. Many include elements such as homestays, travel to multiple sites, and service or research experiences [9]. A previous study suggested that a good short-term program is connected to coursework and forms an integral part of a larger learning experience [10].

The CEP courses are designed as one of the modules in the master's degree program of SIT's Graduate School of Science and Engineering. Faculty members of SIT and its partner universities conduct the CEP courses in Portugal, Japan, and Thailand in an academic year.

The main project themes are based on the Sustainable Development Goals and local issues specific to Thailand, corporate and community issues in Japan, and innovative creation in Portugal. The basic program structure involves carrying out intensive activities for 10 days and is the same for these three courses, as shown in Table I. We expect participants to solve problems by applying systems engineering methods to their project management.

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The participants in the CEP 2019 held in Japan were a total of 79 engineering/science students from 17 countries, as shown in Table II. Participants included both undergraduate and master students. SIT undergraduates were also able to obtain credits as part of their coursework. Each student was assigned to a project team with 5–6 members from diverse cultures and disciplines, and they then worked together throughout the course. That could provide global experience to Japanese students even it was held in their home country. This paper discusses the survey of this course as a case study.

***TABLE I** Program structure of the CEP*

Day 1	Opening Ceremony, Briefing and Ice Breaking Session Introduction of Project Themes, Assigning Groups
Day 2	Group Activities: problem identification and requirements analysis
Day 3	Group Activities: idea generation for solutions Design Review Group Activities: reflection and redesign
Day 4	Study Trip: field study and workshop
Day 5	Study Trip: workshop and group presentation
Day 6	Factory Tour
Day 7	Group Activities: building proposals or prototypes
Day 8	Group Activities: preparation for presentation Final Presentation
Day 9	Assessments Closing Ceremony

***TABLE II** Participants of the CEP 2019 in Japan*

Nationality	Number of participants	Nationality	Number of participants
Australia	1	Mexico	1
Brazil	3	Mongolia	1
Brunei	1	Netherland	1
Cambodia	1	Poland	2
China	5	Singapore	1
India	3	Taiwan	1
Indonesia	3	Thailand	17
Japan	30	Vietnam	5
Malaysia	3	Total	79

III. SURVEY METHOD

Surveys using both quantitative and qualitative questionnaires were conducted at the end of the course. The former used a five-point scale for the following topics:

(1) Previous experience of study abroad.
(2) Importance of motivation/conditions to apply to the CEP.
(3) Difficulties during the team activities in the CEP.
(4) Effectiveness of the CEP to motivate for further study abroad.

The qualitative survey asked participants about what they had realized and gained throughout the course. The texts of these answers were analyzed with KH Coder, free software for quantitative content analysis.

The analysis was based on a comparison of students who had previous experience of study abroad (group A) with those who did not have experience of study abroad before participating in the CEP (group B). The purpose of the comparison was to understand how the course enhanced students' motivation and impressions of studying abroad.

IV. RESULTS AND FINDINGS

A. *The proportions of the groups in the CEP*

Group A (participants with study abroad experience) accounted for 54.4%, while group B (those with only the current CEP experience) made up 38.0% of the total number of participants, as shown in Table III.

***TABLE III** The proportions of the groups*

	Number of non-Japanese	Number of Japanese	Total number	
Group A: participants with study abroad experience	24	19	43	54.4%
Group B: participants without study abroad experience	21	10	31	38.0%
No answer	4	1	5	6.3%
Total	49	30	79	100.0%

B. *The importance of motivations/conditions to apply to the CEP*

Figure 1 shows the average rating from both groups of participants regarding the importance of motivations/conditions to apply to the CEP. The results demonstrate that: (1) Both groups A and B were strongly motivated to network with people from other countries, acquire new knowledge, and experience other cultures; (2) Group B showed higher motivation compared to group A in broadening future career opportunities and practicing for long- term study abroad; and (3) Availability of scholarships was more important to group B students to help them step into their first study abroad experience. SIT provided scholarships to participants from overseas from a Japanese governmental fund which could cover their accommodation and program fee.

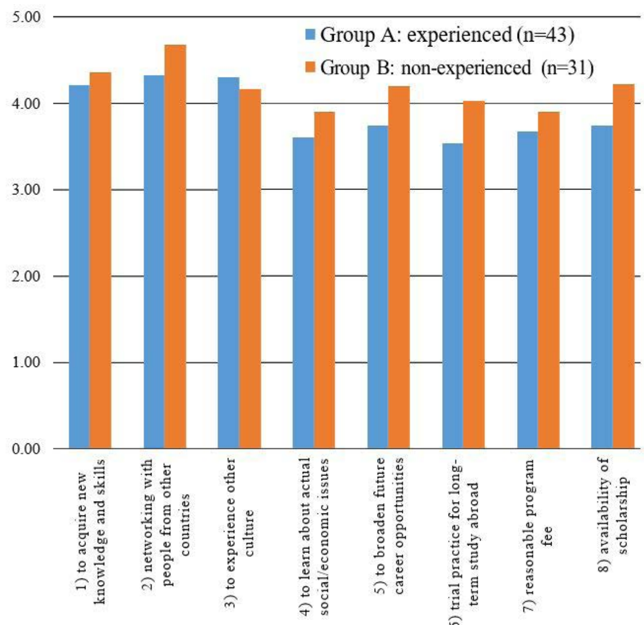

***FIGURE 1** Average score for the importance of motivations/conditions to apply for the CEP*

C. Difficulties during the team activities in the CEP

Figure 2 shows the average scores regarding difficulties experienced during the team activities in the CEP by each group. It shows (1) both groups noted difficulties in understanding and accepting the attitude or behavior of other cultures, communicating in English, and facilitating constructive discussion, and (2) Group B recognized communication in English as the greatest problem.

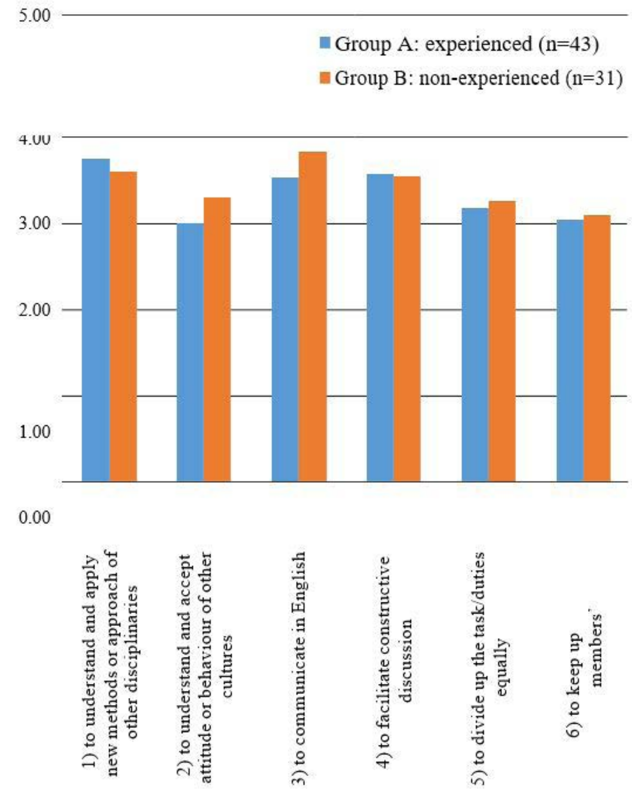

FIGURE 2 *Average score for the difficulties during the team activity in the CEP*

D. Effectiveness of the CEP to motivate for further study abroad

After completion of the course, 83.9% of group B students answered that the CEP was effective or very effective to motivate them to study abroad again, while the equivalent figure for group A was 72.1%, as shown in Figure 3. The course had a greater impact on students in group B to enhance motivation for further global experience.

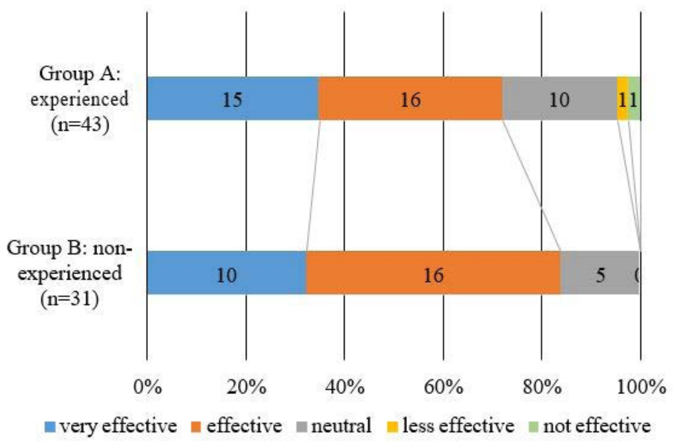

FIGURE 3 *The effectiveness of the CEP to motivate to attend further studying abroad program*

E. Expected program for further studying abroad

As a result of being motivated to attend a further global program, 37.2% of students in group A were interested in masters/Ph.D courses, while group B preferred to participate in short-term and semester exchange programs (both types of programs marked as 38.7% in Figure 4). For the question regarding the probable venue for further programs, 29 out of 49 international students answered that they hoped to study at SIT again. Hosting the short-term program may lead to an increase in the number of international students attracted to the university for long-term studies.

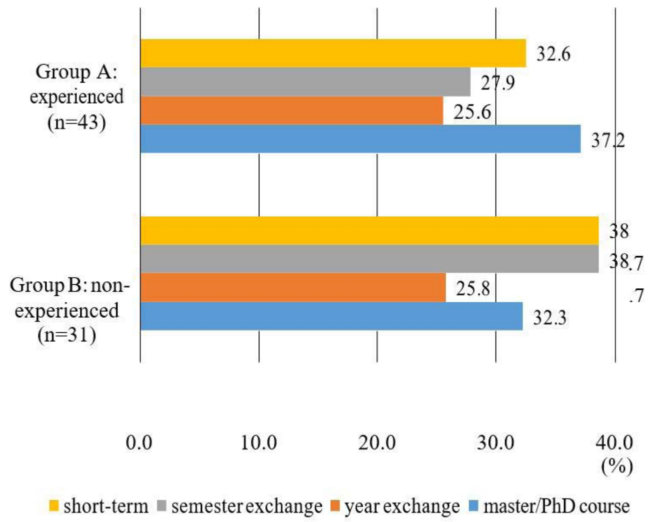

FIGURE 4 *Proportion of students expecting to participate in each studying abroad program*

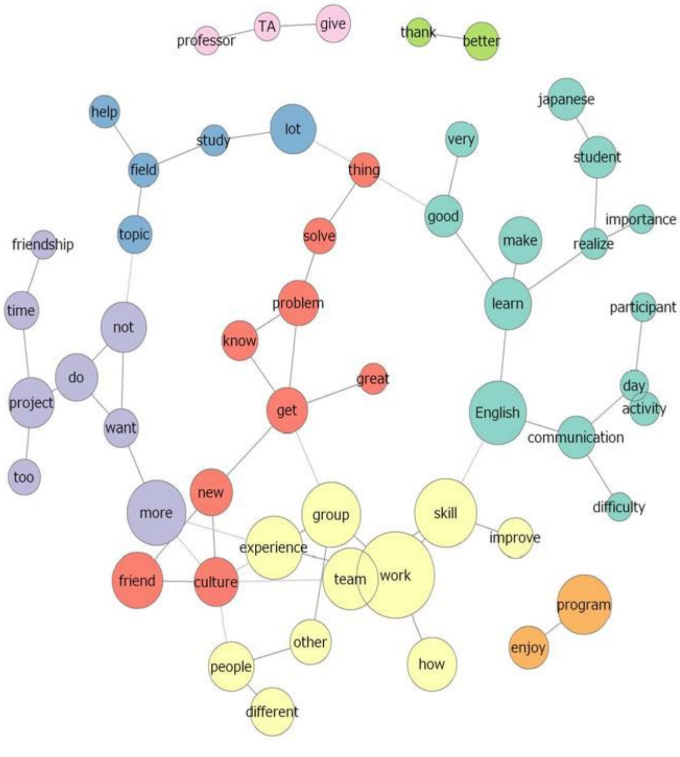

FIGURE 5 *Co-occurrence network of words from participants' impressions and opinions toward the CEP*

F. What the participants realized and gained throughout the CEP

The free-response question about participants' impressions and opinions of the course resulted in feedback with a total of 2,445 words from 67 out of 79 participants. The purpose of this analysis was to find out the factors connecting experience to motivation.

KH Coder was used for this text analysis. The software presents co-occurrence networks which are the collective interconnection of terms based on their paired presence within a specified unit of text. Networks are generated by connecting pairs of terms using a set of criteria defining co-occurrence. The co-occurrence is visualized by lines between nodes, not by the position of nodes. The cluster of words is shown in different colors. Larger nodes indicate higher frequency words.

Based on the analysis shown in Figure 5, we can categorize and prioritize the topic of participants' learning experience as (1) team/group working, (2) importance and difficulty of English communication, (3) new friends and culture, (4) problem solving, (5) limited time for the project, and (6) enjoying the program.

TABLE IV *Commonality in impressions and opinions toward the CEP In each group by the Jaccard Index*

Group A: experienced (n=41)		Group B: non-experienced (n=26)	
work	0.400	work	0.400
more	0.342	more	0.342
English	0.271	English	0.271
group	0.267	group	0.267
people	0.256	people	0.256
program	0.234	program	0.234
project	0.233	project	0.233
different	0.205	different	0.205

Table IV shows the commonality in participants' impressions and opinions toward the course by the Jaccard index, which was also indicated by KH Coder. The index is a statistic used in understanding the similarities between sample sets. Larger values in the table indicate higher similarity among the participants in each group.

Group A members tended to mention more, English, group, people, program, project, and different, while group B used words such as new, friend, experience, skill, team, and culture. The word of 'more' was mainly used in sentences which requested improvements in program schedule, project themes, or supports from teaching assistants and lecturers.

We can see a tendency where (1) group A paid attention to the content and elements of their activities, and (2) group B had impressions of what they gained during the course. Facilitation of less-experienced students would enable them to achieve a deeper level of learning.

V. CONCLUSIONS

Short-term programs are more than just sightseeing trips, and need to be connected to coursework to promote continuous learning. Based on this point of view, the authors have conducted a multifaceted evaluation of short-term study abroad programs since 2015. This paper has discussed the continuous learning motivation of participants in the CEP 2019 in Japan as another case study.

The survey results showed that students applied for the course expecting to acquire new knowledge and skills, network with people from different countries, and experience other cultures. Availability of scholarships was also an expected step into the global experience. Participants experienced difficulties with understanding and applying new methods or approaches of other disciplines, communicating in English, and facilitating constructive discussions. Their impressions and opinions showed that they realized the importance of these skills which were considered as a part of global engineering competency [7]. It could be said that the CEP – a cross-cultural and multi-disciplinary project-based intensive-learning course – provided participants with opportunities to enhance their learning motivation.

Participants also recognized team working and English language skill as major issues in the course activities. Facilitation to deal with these challenges is required to enhance students' learning motivation. Based on this perspective, the authors and other co-researchers have worked on applying cyber-physical systems [11] into the CEP to monitor and feedback on group activities in real-time.

This survey, together with our previous work, has shown that students who are repeating their study abroad experience can gain deeper learning from the program. It is important to lead the participants to their next global experience. In this case study, nearly 80% of participants found the CEP course was effective or very effective to motivate them to attend further study abroad programs. The impact was greater for those experiencing it for the first time. Nearly 60% of international students were willing to return to SIT for their next study abroad. There were several former participants of past CEPs who attended a semester exchange program or enrolled in master's/Ph.D courses at SIT. The short-term program serves as an effective trial and promotes longer-term programs.

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REFERENCES

[1] L. Chieffo, and L. Griffiths, "Large-scale assessment of student attitudes after a short-term study abroad program," Frontiers: The Interdisciplinary Journal of Study Abroad, 10.1, pp. 165-177, 2004.

[2] C. Walters, J. Charles, and S. Bingham, "Impact of short-term study abroad experiences on transformative learning: A comparison of programs at 6 weeks," Journal of Transformative Education, 15.2, pp. 103-121, 2017.

[3] A. Nguyen, "Intercultural competence in short-term study abroad," Frontiers: The Interdisciplinary Journal of Study Abroad, 29.2, pp. 109- 127, 2017.

[4] J. S. Coker, E. Heiser, and L. Taylor, "Student outcomes associated with short-term and semester study abroad programs," Frontiers: The Interdisciplinary Journal of Study Abroad, 30.2, pp. 92-105, 2018.

[5] S. Oda, A. K. Yamazaki, and M. Inoue, "Assessment of global competency in engineering students in multicultural and multidisciplinary project based learning course," The 7th World Engineering Education Forum (WEEF), Kuala Lumpur, November 13-16, 2017.

[6] A. K. Yamazaki, M. Inoue, H. Hasegawa, K. Yoshimura, M. Kimura, and N. Matsumura, "Development of a list of can-do statements for global communication in engineering and its applications," The 7th World Engineering Education Forum (WEEF), Kuala Lumpur, Malaysia, November 13-16, 2017.

[7] S. Oda, A. K. Yamazaki, and M. Inoue, “A comparative study on perceptions of cultural diversity in engineering students,” 10th annual International Conference on Education and New Learning Technologies (EduLearn), IATED, Palma de Mallorca, July 2-4, 2018.

[8] K. Higuchi 樋口耕一, Quantitative Text Analysis for Social Researchers: A Contribution to Content Analysis 社会調査のための計量テキスト分析. Kyoto: Nakanishiya Shuppan ナカニシヤ出版, 2014. KH Coder can be downloaded from https://khcoder.net/en/

[9] L. Donnelly-Smith, “Global learning through short-term study abroad,” Association of American College and Universities Peer Review, vol.11, No. 4, Fall 2009.

[10] S. E. Spencer, and K. Tuma, eds, The guide to successful short-term programs abroad. Washington, DC: NAFSA: Association of International Educators, 2002.

[11] Cyber-physical systems are “engineered systems that are built from, and depend upon, the seamless integration of computational algorithms and physical components.” Definition from National Science Foundation, “Cyber-Physical Systems,” Program Solicitation 16-549, NSF document number nsf16549, March 4, 2016.

Technical Papers

Role of Community of Practice (CoP) to facilitate change in STEM instructional practices through faculty development programs

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***Abstract*—The last decade has seen numerous calls from academicians, government agencies, and policy agents to systematically transform instructional practices in STEM programs. In alignment with these calls, institutions have been organizing numerous faculty development programs with a goal to motivate their faculty and promote large scale reforms in STEM instruction. In spite of many years of efforts by faculty developers and institutions, traditional teaching methods continue to dominate as the primary mode of STEM instruction. The failure in achieving change is often attributed to the lack of support received by faculty post the faculty development program, when they try to implement the learnings and transform their classroom instruction.**

In this study, we explore the role of a Community of Practice (CoP) in achieving sustainable change in instructional practice after the completion of the faculty development program in India. A CoP was established at the start of a 6-week faculty development program on technology-enhanced learning to foster a sense of community among the participants. Qualitative data was collected during the 6-week program to analyze the different ways in which the CoP helped the participants to achieve the outcomes of the faculty development program. Results from the thematic data analysis revealed that the members of the CoP helped each other through exchange of ideas, clarification of misconceptions, providing of feedback, and exchange of knowledge. It was observed that participants with varied prior teaching experience supported each other as they designed and developed course websites (developing tacit knowledge). After the completion of the 6-week program, the participants continued to meet with other members of the CoP to share the experience of how they adopted to technology- enhanced learning in their respective courses. The CoP members after the end of the semester started to share their learning to other faculty thereby promoting sustainable instructional change in the institution. At the end of the study, recommendations are provided for faculty developers to incorporate the CoPs during the design of their faculty development programs.

Keywords—Faculty Development, Communities of Practice, Change in STEM

I. INTRODUCTION

In the last few decades, there have been numerous calls for fundamental change in the teaching of Science, Technology, Engineering, and Mathematics (STEM). Multiple communities of change agents which include education researchers, practitioners, professional organizations, and policy makers have taken up efforts to drive systematic changes in STEM instruction and practice. STEM education researchers with support of government and private funded research projects have spent numerous amounts of time and money to collect evidences that would inform the improvement of teaching and learning. A systematized literature review that was conducted to understand the efforts taken to promote instructional change in undergraduate STEM courses revealed four distinct strategies [1]. One of the most common change strategies found in the literature was to disseminate curriculum and pedagogical innovations through faculty development programs. In spite of all these efforts, there has been modest success with respect to instructional change in undergraduate STEM instruction [2].

A review of successful strategies with respect to faculty development programs highlighted the time needed to effectively facilitate change in the faculty mindset and instruction [3]. Gallos et. al. revealed that faculty development programs need to be well coordinated and should involve focused efforts that last for an extended period of time [4]. Programs that were successful and facilitated change in STEM instruction varied from 4 weeks to a semester and longer. However, most faculty development programs that are conducted were short in duration due to organizational and other logistics concerns. Institutions often invite faculty developers to conduct short training programs hoping that they would lead to instructional change. This paper explores the role of Communities of Practice (CoP) in sustaining faculty development efforts and how the CoPs can lead to large scale institutional level change in undergraduate STEM instruction. We explore the various ways in which the establishment of a CoP at the start of a 6-week faculty development program impacted and resulted in sustainable change in instruction during and after the end of the program,

II. BACKGROUND

A. Communities of Practice

A Community of Practice (CoP) consists of a group of people who share a concern or passion for the work they do and learn how to do it (better or differently) by regularly interacting with other members of the CoP [5], [6]. As compared to a social network, a CoP is characterized by its three distinctive characteristics: 1. A Domain – an identified shared purpose or value among the members of CoP, 2. A Community – a group of people who are interested in pursuing the domain and engage in joint activities to share information and help each other, and 3. A practice – a set of ideas, initiatives, resources, and tools that the members of the CoP share as a part of their membership [7]. CoPs take on multiple forms: they can be located at the same place or distributed across a geographic region, they can cease to exist after the short-term or long-term goal is achieved, the domain of

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interest could be homogenous or heterogeneous, they can be housed within a single organization or spread across multiple such units, and they can be informal or recognized officially by organization. While forms of CoPs can differ, the current literature mostly reports on ones that emerge within an organization, and often involve a community of members who are already working with one-another [7]. The key activity of a CoP is to advance its domain, which is the focus of the community. The domain defines the identity of the community, which sets the tone for developing the shared resources for practice. The community operates through multiple ways such as sharing information, problem solving, learning from experts from outside the CoP, and visiting individuals from different organizations or COPs [8].

B. Communities of Practice and Professional Development

Organization of faculty development programs among participants who are part of CoPs have reported to have multiple benefits. Individuals who are part of the CoP would get diverse perspectives of the topic of interest when they collaborate and engage in group work [9]. Carter in her work suggested that individuals in a CoP can be assigned to a critical friend whose role would be to probe questions and help the individual gain new insights about the topic [10]. This would be particularly beneficial to individuals who might have trouble reflecting and might need the probing question to think critically. CoPs formed in the same workplace will facilitate informal discussions among individuals outside of the faculty development sessions and help sustain interest about the topic [11].

Online CoPs can also be established to expand and sustain large scale professional development efforts [12]. After considering the multiple benefits of CoPs in professional development, a CoP was established with the participants of the study prior to the start of a 6-week faculty development program. The domain of interest was decided to be "integration of technology in undergraduate engineering courses" after seeking consensus from all the participants. All the participants agreed to follow a set shared norms that required them to support each other in the process of facilitating change in STEM instruction. They mutually agreed to actively engage and collaboratively work on activities that were organized during faculty development sessions. Participants were also expected to assist each other as they worked towards completing their final design project. The CoP members agreed and decided on the 6- week professional development program to be the first practice that would help them evolve in the domain of interest. A consensus on other additional practices of the CoP was expected to be made after the end of the 6-week program..

III. METHODOLOGY

In this study, we explore the role played by a CoP that was formed prior to the start of a 6-week faculty development program. The faculty development program was conducted for 7 faculty from KG Reddy College of Engineering in India and the focus of the program was the design and development of technology-enhanced courses. During the program, all the participants re-designed a course of their choice to integrate it with educational technology tools. Instead of merely picking

a technology tool and using it to drive the course design, the participants were made to reflect and understand how the technology tools can be constructively aligned to the course content and the pedagogy.

A. Research Questions

We make an attempt in this study to understand the interplay between the process and outcome of a faculty development program with the formation and development of a Community of Practice by asking the following research questions

1. How do participants describe their experience of being part of a Community of Practice as part of a faculty development program?
2. How did the members of the Community of Practice engage with each other during the faculty development program?
3. How does the formation of a Community of Practice influence instructional change in a STEM undergraduate institution?

B. Methodology and Data Collection

As the goal of the study was to understand the experiences of the 7 participants, we used a qualitative case-study [13] as the research methodology to answer these questions. The case in this study was the 6-week professional development program, as the goal was to examine the phenomenon of how the membership in a CoP would influence the experiences of faculty during the program. The unit of analysis was the individual experiences of each of the participants during the entire six weeks of the program.

Multiple sources of data were collected to examine the experiences of the participants during the 6-week professional development program. During the 6-week program, each of the participants was individually interviewed at the end of every two weeks (week 2, 4, and 6) using a semi-structured interview protocol. One round of semi-structured interviews was also conducted with the participants prior to the start (week 0) of the 6-week program. The semi-structured interview protocol was designed to probe different facets of the participants' experience every two weeks. Cognitive interviews were conducted with other engineering faculty from the same institution to test the language of the semi- structured interview protocol. Cognitive interviews assess the respondents' understanding of the questionnaire and are used to improve instrument design [14].

Another source of data was collected in the form of field notes during the 6-week professional development program. Field notes were taken throughout the professional development sessions as the participants interacted with each other, shared their queries, worked on various activities, and completed their final design project. We made a note of observations that would potentially be important and useful to answer the research questions being addressed in the study. Participants were also asked to maintain a reflection journal throughout the 6-weeks of the program. The participants were provided with prompts to reflect at the end of each day of the professional development and asked to answer the questions in their reflection journal.

C. Data Analysis, Validility and Reliability

A thematic analysis approach was employed to analyze the data and the six-phase approach as suggested by Braun and Clarke was used to thematically analyze the data [15]. The six stages include - familiarizing yourself with the data, generating initial codes, searching for themes, reviewing themes, defining and name themes, and then producing the final report.

Tracy's eight "Big-Tent" criteria for excellent qualitative research was utilized to showcase the rigor and the quality of the study [16].

The validity of the findings was verified using thick descriptions, triangulation, and member reflections. we detail the themes that emerged from the data by providing quotes from the participants' interviews and reflections.

The findings were triangulated using two approaches – 1. Intercoder reliability checks on the codebook; 2. Triangulation of findings with semi-structured interviews, field notes, and reflection journals. After recording and transcribing the data, member checking was conducted with all the participants where they were asked to report any discrepancies in the transcribed data. The same was also carried out with the participants after data analysis to ensure that the findings provide a true interpretation of their experiences during the 6- week professional development program.

D. Site of Study

The site of the study is KG Reddy College of Engineering and Technology, which is a small private undergraduate teaching-focused institution in the south of India. The institution identifies itself in the tier-3 category of engineering colleges in India, and it is non- autonomous (no flexibility in deciding the curriculum and conducting student assessment). There are more than 2000 similar tier-3 engineering colleges that are affiliated to their respective state regional universities and they collectively represent more 60% of engineering in India and beyond. [17]. The qualitative nature of the study could potentially make the findings transferable to a large number of engineering colleges in India.

IV. RESULTS

The results of the thematic analysis are presented in this section as we characterized them into themes and sub-themes. Each of the themes were focused on a specific facet of the participants' experience during the 6-week faculty development program. Illustrative quotes from the data sources are provided for each theme to give additional context.

A. Theme 1 – Community of Practice Enabled Sharing of Knowledge among the Participants

During the faculty development program, the participants were observed to regularly engage with each other for varied reasons. While some of the engagement was structured by the facilitator, participants also engaged with each other outside the faculty development sessions. This was attributed to the formation of the CoP as participants now as members of the CoP worked collectively towards their agreed domain of interest.

1) Sub-theme 1.1 – Knowledge of educational technologies

Participants used the CoP to share their knowledge educational technology with each other. For instance, one of the challenges that the participants encountered during the program was the usage of technology tools. Participants with low technology-self efficacy were observed to be hesitant while exploring and integrating technology tools into their courses. They encountered trouble-shooting errors while utilizing the technology tools and sought help from their peers:

"I started first by creating a blog. Then I tried using the Wix platform and found that I cannot share videos through Wix. The I tried platforms such as Adobe, Edmodo but I found it difficult. It is not user friendly. I asked and got help from my peers who used these tools and I was slowly able to get comfortable with using them" Members of the CoP who were teaching courses in the computer science and engineering departments had high technology self-efficacy and were observed to support the other participants during the 6- week program.

2) Sub-theme 1.2 – Knowledge of teaching methodologies

Sharing of knowledge was also observed among participants who had varied prior teaching experience. Participants who were new to teaching got support from experienced teachers about the various pedagogical techniques they could implement in their course: *"Through the community of practice, I was able to get good inputs from the faculty with lesser teaching experience. Because experienced faculty will always be using the same approaches [pedagogic techniques] they used previously and might limit it to that. But the less experienced faculty would not have such limitations. They are more willing to explore as many tools and methodologies possible and evaluate what is best suitable to their course. Less experienced faculty are also closer to their own experience as students, so they are in a better position to understand what is best for the students, as compared to an experienced faculty like me who has not been a student for more than 10 years. So, the mixture of having instructors with diverse teaching experience was helpful to my learning."*

B. Theme 2- CoP Members Supported each other for the Development of Tacit Knowledge and Skills

In this theme, we presented how the participants with varied prior teaching experience supported each other in developing tacit knowledge and skills such as engaging in reflection, critical thinking, and metacognition skills. All of these skills were essential for the participants to successfully complete the faculty development program and technologically enhance their courses.

1) Sub-theme 2.1 – Support for engaging in reflection

Participants in their interviews mentioned that they often reflected on their prior teaching experience as they were redesigning the course by using technology tools. When they wanted to take the learners into consideration, they often resorted to their prior experience with teaching the course: "*While working on the final project, I was aware of students' attitudes and motivation in the class. I was also aware of the students who are slow learners [lower performing students] and advanced learners [higher performing students]. Through my past experience, I have learnt to use different teaching strategies to teach different students. For slow learners, I need to provide detailed explanation and then give them many opportunities to practice"*. Participants who were new to teaching were unaware of the concept of reflection and had to take support from the other participants.

2) Sub-theme 2.2 – Support for critical thinking

The participants during the faculty development program were constantly encouraged to critically think about their prior offering of the course. They were asked to use that information while making design based decisions that are student-centric. For example, participants during week 2 and 3 had to identify the pedagogical and technological tools for their course by critically thinking about the past offering of the course. This would help them identify the challenges students faced and later identify tools that would help overcome them. Participants mentioned working together to provide constructive and critical feedback: *"When I was identifying the pedagogy and technology tools, my peers gave me critical and constructive feedback about my choices and this helped me improve my project."*

3) Subtheme 2.3 – Support for metacognition

By end of week 6 of the faculty development program, many of the participants neared the completion of their final design project. During this process, the participants were required to develop a meta-conceptual awareness of how to intersect the knowledge of content, pedagogy, and technology to address some of the limitations they encountered as an instructor and the learning needs of students. This was challenge for few of the participants as they seemed to lack the ability to think metacognitively: *"The first challenge was deciding about the final project. I wasn't able to think in a way to bring all aspects of the concept map together. When I spoke to [Participant 6], he showed me all the websites that are available and could support interaction between instructor and peers. I then narrowed down on the platform which I thought was most user friendly."* Participants while completing the final design project often met outside of the training program: *"I was meeting with other participants whenever I was working on the final project. Not only when we met for the sessions every week, but we also interacted when we needed help. I was discussing with [Participant 2] on what should be our final project. Sometimes we disagreed but it was a good discussion. Everyone in the group was involved to integrate technology and this reflected on our final projects."*

All of the skills mentioned in this theme – reflection, critical thinking, and metacognition are considered as tacit knowledge which cannot be easily taught to the participants [18]. The participants reported to benefit from the diversity (in terms of prior teaching experience) among the community of practice members as they could help each other build the tacit knowledge while working on their final design project. Without the access to a supporting community, the facilitators are usually expected to help the participants build these skills. However, tacit skills are usually hard to teach and can be built through an apprenticeship model [19]. It was observed the CoP members followed a similar structure by collaborating with peers with prior experience and build the skills during the course of the 6-week program.

V. DISCUSSION

Before the start of the professional development program, a CoP was established with the participants agreeing to focus on a common domain of interest i.e., integrating technology into their respective course. The 6-week professional development program was organized as one of the first practices of the CoP that would help the members build knowledge and expertise in the domain. During the professional development sessions, the participants were provided with multiple opportunities to collaboratively work on specific activities and interact with the other members of the CoP while working on the final design project.

The CoP members were observed to help each other during the generation of ideas, clarifying misconceptions, and providing feedback to each other. Participants with higher prior teaching experience also mutually benefited from the interaction with their peers as they got feedback on the design choices for the final project. Participants utilized their peers to receive constructive feedback as the CoP members helped them ask critical questions while engaging in discussions and group activities. It is therefore necessary to highlight that the formation of CoP helped the participants utilized the CoP members to navigate through key challenges and successfully complete their final design project.

A. Sustainability of faculty development efforts through Community of Practices

Follow-up conversation with the participants a few months after the program revealed that the CoP members, after the end of 6-week faculty development program, have included additional practices that would help them to continue building expertise in technology-enhanced learning. The CoP participants later organized a 1-day workshop by themselves to share their experiences of designing technology enhanced courses as part of the 6-week professional development. The 1-day workshop was organized to motivate and generate interest among other faculty in the institution to join the community. The initial CoP members now planned to conduct additional professional development programs where they could share their knowledge and help the new members learn to integrate technology into their courses.

The organization of new the activities by the CoP members indicate the strong sense of community that was fostered among the participants. The initial CoP members have started to transition as the core members of the CoP and invite other faculty in the institution to be the peripheral members of the society [8]. This indicates the growth of the CoP as the community is recruiting and inviting more members to collectively work towards a common domain.

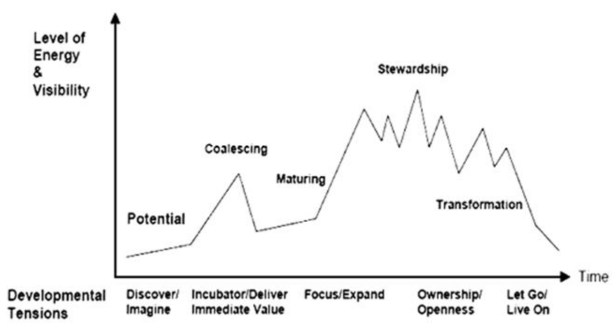

FIGURE 1 *The different stages of a CoP [20]*

Figure 1 highlights the lifecycle of a CoP. During the 6- week program, the CoP was still in the potential stage where the community gets established as a small network and has a potential to grow and form more connections. After the 6- week program, the CoP started evolving to the coalescing phase as more members showed willingness to join the community.

VI. CONCLUSION

The establishment of CoP therefore provided an opportunity for faculty development efforts to become sustainable and scale inside the institution through a core group of members who were part of the training program. Faculty developers could assist the CoP members to initiate additional activities that could be implemented after the end of the program. This would help the CoP evolve to the coalescing and maturing stage. After the completion of the faculty development program, faculty developers could serve as mentors to the members of the CoP through eLearning platforms [21] to ensure the sustainability of the CoP. After serving as mentors to the CoP during the coalescing stage, faculty developers can gradually end their association later as the CoP transitions to the maturing stage. The extended interaction after the programs could contribute to the sustainable development of faculty development efforts inside institutions. By ensuring the successful design of courses and mentoring the participants after the program, faculty developers can move a step further to evaluate the faculty development program by measuring the impact on students' learning outcomes. The impact on students' learning outcomes is considered as the highest level of evaluating professional development programs and often perceived to be ultimate goal of facilitating faculty development programs [22]. A positive impact on students learning outcomes could later be used as an evidence for successful instructional change.

REFERENCES

[1] C. Henderson, A. Beach, and N. Finkelstein, "Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature," J. Res. Sci. Teach., vol. 48, no. 8, pp. 952– 984, Oct. 2011, doi: 10.1002/tea.20439.

[2] D. Bok, Our Underachieving Colleges: A Candid Look at How Much Students Learn and Why They Should Be Learning More-New Edition, vol. 50. Princeton University Press, 2009.

[3] G. Gibbs and M. Coffey, "The impact of training of university teachers on their teaching skills, their approach to teaching and the approach to learning of their students," Act. Learn. High. Educ., vol. 5, no. 1, pp. 87–100, 2004.

[4] M. R. Gallos, E. van den Berg, and D. F. Treagust, "The effect of integrated course and faculty development: Experiences of a university chemistry department in the Philippines," Int. J. Sci. Educ., vol. 27, no. 8, pp. 985–1006, 2005.

[5] V. Allee, "Knowledge networks and communities of practice," OD Pract., vol. 32, no. 4, pp. 4–13, 2000.

[6] E. Wenger, "Communities of practice: Learning as a social system," Syst. Think., vol. 9, no. 5, pp. 2–3, 1998.

[7] E. Wenger, "Communities of practice: A brief introduction," Oct. 2011, Accessed: Jan. 16, 2018. .

[8] E. Wenger, R. McDermott, and W. M. Snyder, "Seven principles for cultivating communities of practice," Cultiv. Communities Pract. Guide Manag. Knowl., vol. 4, 2002.

[9] R. Donnelly and T. Maguire, "Supporting Teaching and Learning Transformations through the National Professional Development Framework: Establishing and Recognising an Inclusive Community of Practice for All who Teach in Irish Higher Education," AISHE- J Irel. J. Teach. Learn. High. Educ., vol. 10, no. 1, pp. 3391–33917, Spring 2018.

[10] M. Carter, "Communities of Practice for Professional Development," Exch. 19460406, no. 190, pp. 20–24, Dec. 2009.

[11] K. McArdle and A. Ackland, "The demands of the double shift: communities of practice in continuing professional development," J. Vocat. Educ. Train., vol. 59, no. 1, pp. 107–120, Mar. 2007, doi: 10.1080/13636820601145739.

[12] C. B. Vavasseur and S. K. MacGregor, "Extending Content-Focused Professional Development through Online Communities of Practice," J. Res. Technol. Educ., vol. 40, no. 4, pp. 517–536, Summer 2008.

[13] R. E. Stake, The art of case study research. Thousand Oakes, CA: Sage Publications, 1995.

[14] K. Knafl et al., "The analysis and interpretation of cognitive interviews for instrument development," Res. Nurs. Health, vol. 30, no. 2, pp. 224–234, 2007, doi: 10.1002/nur.20195.

[15] V. Braun and V. Clarke, "Using thematic analysis in psychology," Qual. Res. Psychol., vol. 3, no. 2, pp. 77– 101, Jan. 2006, doi: 10.1191/1478088706qp063oa.

[16] S. J. Tracy, "Qualitative Quality: Eight 'Big-Tent' Criteria for Excellent Qualitative Research," Qual. Inq., vol. 16, no. 10, pp. 837–851, Dec. 2010, doi: 10.1177/1077800410383121.

[17] A. Krishna, "Examining the Structure of Opportunity and Social Mobility in India: Who Becomes an Engineer?," Dev. Change, vol. 45, no. 1, pp. 1–28, 2014, doi: 10.1111/dech.12072.

[18] C. Golding, "Educating for critical thinking: thought encouraging questions in a community of inquiry," High. Educ. Res. Dev., vol. 30, no. 3, pp. 357–370, Jun. 2011, doi: 10.1080/07294360.2010.499144.

[19] E. A. Kinsella, "Professional knowledge and the epistemology of reflective practice: The Epistemology of Reflective Practice," Nurs. Philos., vol. 11, no. 1, pp. 3–14, Jan. 2010, doi: 10.1111/j.1466- 769X.2009.00428.x.

[20] E. Wenger, R. A. McDermott, and W. Snyder, Cultivating communities of practice: A guide to managing knowledge. Harvard Business Press, 2002.

[21] C. Figg and K. Jaipal-Jamani, "Developing TPACK in Higher Education Faculty: An eLearning Mentor Strategy," Mar. 2017, pp. 2319–2323, Accessed: Feb. 27, 2019.

[22] T. R. Guskey, "Professional development and teacher change," Teach. Teach., vol. 8, no. 3, pp. 381–391, 2002.

[23] J. Fairweather, "Linking evidence and promising practices in science, technology, engineering, and mathematics (STEM) undergraduate education," Board Sci. Educ. Natl. Res. Counc. Natl. Acad. Wash. DC, 2008.

Technical Papers

Exploring the curricular content of engineering ethics education in Ireland

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***Abstract*—Our contribution aims to determine the main curricular themes employed in engineering ethics instruction. In the use of the term 'curricular content", the study is guided by an understanding of curriculum in terms of the syllabus content of a specific discipline or set of units taught to students [1]. The research study has been conducted in cooperation with the national accrediting body Engineers Ireland and includes 23 Engineering programmes from 6 institutions in Ireland that underwent accreditation between 2017-2019. The research method employed is a documentary analysis of the materials prepared by the programmes for accreditation or made available on the website of all participant programmes. The findings reveal three themes amenable to the implementation of ethics across the curriculum (sustainability, Health and Safety, legislation), which are present in a variety of courses, such as technical courses, design courses, professional formation courses, capstone projects, legal studies courses, business studies courses, as well as in work placement. The curricular themes purporting to professional ethics, responsibility and the societal context of engineering have a strong presence in courses of professional formation, which have the role of acculturating students to the profession of engineering and its norms. Thus the main conclusion of our study highlights the need for a hybrid implementation of ethics across the curriculum as well as in dedicated single modules, in order to promote a comprehensive engineering ethics education.**

Keywords—engineering ethics education, curriculum content, documentary analysis

I. INTRODUCTION

The literature on engineering ethics education notes a diversity of approaches in regards to the content of engineering ethics education. We find coverage such as professional codes, ethical theories, ethical heuristics, plagiarism science and technology studies, humanist readings and service learning ([2]; [3]; [4]; [5]). However, not all types of coverage is considered of "equal value for the implicit goals of enhancing divergent thinking, helping engineers to see their work through the eyes of the broader community" [3]. Colby and Sullivan [6] highlight the uneven coverage of key issues, claiming that engineering ethics education shows a strong emphasis on professional codes, while the broader mission and implications of engineering are neglected. Polmear et al [7] note there are geographical differences in terms of coverage, linked to the formulation of the accreditation criterion dedicated to ethics. As such, a higher percentage of non-US Anglo and Western European educators were found to teach sustainability and environmental issues in their courses compared to US respondents, while educators based in the US teach codes of ethics, ethics in design, and safety more often than those in Western Europe [7]. Nevertheless, Atesh et al [5] claim that in engineering programmes in the UK, there is a higher focus on issues such as plagiarism and honesty than on respect for life, law and public good, reflected in the higher importance attributed by students to these former issues.

Mitcham and Englehardt [8] point out that while more attention is being given in engineering ethics to professional codes, the critical histories of ideas about engineering and engineering ethics are neglected. In their view, discussions about public safety, health and welfare should be complemented by reflection on the historical and social character of public safety, public health and societal welfare. Bielefeldt et al [9] also highlight the poor understanding of the extent to which macroethical topics are included in engineering ethics education. This is consistent with the difference in perception between instructors and students in regards to the coverage of ethical issues revealed in the survey by Holsapple et al [10]. Despite the fact that faculty describe their instruction as including not only codes but also a nuanced treatment of complex issues, students reported hearing "simplistic, black-and-white messages about ethics" ([10], p.101).

The aim of the research study is to examine the curricular content used in engineering ethics education in the context of the Irish Engineering education system. By"curricular content", it is understood the syllabus content of a specific discipline or set of units taught to students [1]. The examination includes 23 engineering programmes from 6 institutions in Ireland that underwent accreditation between 2017-2019. In Ireland, ethics falls under the scope of programme outcome E formulated by the accrediting and professional body Engineers Ireland [11]. Outcome E requires programmes to provide evidence that graduates gained "(i) the ability to reflect on social and ethical responsibilities; (ii) knowledge and understanding of the social, environmental, ethical, economic, financial, institutional, sustainability and commercial considerations affecting the exercise of their engineering discipline; (iii) knowledge and understanding of the health, safety, cultural and legal issues and responsibilities of engineering practice, and the impact of engineering solutions in a societal and environmental context; (iv) knowledge and understanding of the importance of the engineer's role in society and the need for the commitment to highest ethical standards of practice; (v) knowledge, understanding and commitment to the framework of relevant legal requirements governing engineering activities, including personnel, environmental, health, safety and risk issues" [11]. The research questions set to address the aforementioned aim are (RQ1) what are the main themes employed in engineering ethics education, and (RQ2) how can these be interpreted in light of the different theoretical conceptualizations of engineering ethics education?

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II. RESEARCH METHOD

To address the research questions of the study, the method employed is documentary analysis. An advantage of this method is that documents are a stable and non-reactive source of data [12], and can thus offer a broad picture of the type of curricular content purporting to ethics offered by the participant institutions.

Three main sources have been used for the documentary analysis,. A first source of data was the self-assessment rubric present in all documents submitted for accreditation by the participant programmes. Secondly, 17 of the 23 programmes have provided the description of their courses, either as an annex to the documentation submitted for accreditation (6 programmes) or part of the evidence presented during the accreditation events observed by the researcher (11 programmes). A third source of documentary data consists of the syllabus and the description of courses posted on the website of all participant programmes. The analysis is focused on 83 mandatory courses deemed by the participant programmes to have the highest contribution to meeting learning outcomes purporting to ethics. To identify these courses, we relied on a mandatory rubric in the documentation submitted by the programmes for accreditation, in which the programmes are required to self- assess with a numerical score ranging from 0 (no contribution) to 4 (strong contribution) how their courses meet each of the seven criteria for accreditation.

The process of collecting data was based on course descriptors containing learning outcomes and topics, as well as a rubric in the accreditation document in which programmes describe their contribution to outcome E. The process of analyzing data underwent several iterations until it generated a first codebook containing 28 topics employed for meeting the accreditation outcome purporting to ethics. During the second iteration stage, the initial thematic codes have been grouped and subsumed under broader categories, which led to the identification of 11 major thematic categories of curriculum content purporting to engineering ethics education. Table 1 mentions what type of curricular content is comprised by each of the 11 thematic categories identified.

TABLE 1 *Coding of the content of engineering ethics education*

THEMATIC CATEGORY	CONTENT
Sustainability	Referring to the principles of sustainable development, environmental impact and protection, climate change, carbon management, energy efficiency, renewable energy, life cycle analysis, waste management, sustainable economic growth, eliminating poverty traps
Health and Safety	Referring to health, workplace safety, accident prevention, environmental and societal hazard prevention, prediction and risk assessment
Legislative	Referring to national and international standards, directives, regulations, and legislation, CE marking, product liability, contract documents and planning requirements, policy making, intellectual property and patent law, security, privacy and GDPR
Professional ethics	Referring to Codes of Ethics, organization and regulation of the profession, professional and public bodies
Business studies	Referring to management, business, finance, cost effectiveness, organizational culture
Societal context	Referring to the cultural, economic and socio political dimension of engineering, science and technology studies, globalization and international context, diversity, implications of robotics, AI, automated and autonomous systems
Responsibility	Referring to responsibility towards society and the ecosystem, corporate social responsibility
Value design	Referring to value design, universal design, design centred on user needs and characteristics
Plagiarism	Referring to referencing, plagiarism and academic honesty
Ethical theories	Referring to ethical theories, ethical dilemmas, ethical reasoning and decision-making, computer ethics, cyber ethics, environmental ethics
Humanitarian engineering and community service	Referring to humanitarian engineering, social commitment and community engagement or service

III. FINDINGS

Our analysis found that three main themes dominate the engineering ethics curricula, being present in more than half of the courses self-assessed as having a strong contribution to the accreditation outcome E. As seen in Table 2, these themes are related to sustainability coverage (present in 59% of courses), health and safety coverage (58% of courses) and legislation (p54% of courses).

These themes are also present in a wide variety of course types, such as technical courses, design courses, professional formation courses, capstone projects, legal studies courses, business studies courses, as well as in work placement. The distribution of sustainability, health and safety and legislation topics seems to suggest that these are the preferred topics for integrating ethics across the engineering curriculum.

TABLE 2 *The distribution of ethics content (N = 83)*

THEMATIC CATEGORY	TOTAL (N = 83)	% OF TOTAL
Sustainability	49	59%
Health and Safety	48	58%
Legislation	45	54%
Professional ethics	21	25%
Business studies	21	25%
Societal context	20	24%
Responsibility	19	21%
Value design	14	17%
Plagiarism	13	16%
Ethical theories	13	16%
Humanitarian engineering and community service	1	1%

With a presence in approximatively a quarter of the courses analyzed, professional ethics (25%), business studies (25%) and societal context (24%) represent other three popular themes used in engineering ethics instruction.

Professional ethics includes coverage related to the code of ethics and the organization and regulation of the engineering profession. This curricular theme is addressed in 92% of the courses categorized as courses of professional formation, but has a weak presence in other type of courses. Inspired by the definition provided by Riley [13], professional formation courses are understood to address considerations regarding the development of students' engineering identity, their acculturation to the profession and its norms, knowledge of professional practice, as well as the development of professional skills and perspectives. Typically, these courses are first year courses which are part of the common syllabus for the entire student cohort, and can be considered to serve as a gateway for introducing engineering students to ethics.

Business studies are present in all courses dedicated to this topic, whose title points to management, business, finance and economics. This content can be also found in 67% of the professional formation courses. Societal context is most often covered in courses of professional formation, where it is present in 50% of this type of courses, and in technical courses, where it is present in 22% of the courses. Although the societal dimension of engineering has been found by evaluators to be present in the teaching materials, it is less prominent in assignments.

Responsibility is addressed in 21% of the courses self- assessed as having a strong contribution to the accreditation outcome purporting to ethics. This theme features most extensively in courses of professional formation, being present in 75% of courses of this type.

Value design is included in 17% of the courses self-assessed as having a strong contribution to the accreditation outcome purporting to ethics. It has the highest occurrence in design courses, being present in 40% of courses of this type, followed by technical courses, where is present in 17% of courses of this type.

Plagiarism is included in 16% of the courses self-assessed as having a strong contribution to the accreditation outcome purporting to ethics. Capstone projects have a high emphasis on this type of curricular content, as it is present in all courses of this type. Plagiarism is also present in 25% of courses of professional formation. As capstone projects are taking place in the final year of studies, and professional formation courses are typically a common first year course, it can be said that students are introduced to this curricular area early in their studies.

Ethical theories, dilemmas and reasoning is included in 16% of the courses self-assessed as having a strong contribution to the accreditation outcome purporting to ethics. It is present in 50% of the courses of professional formation, and also in 11% of technical courses.

Humanitarian engineering and community engagement is the theme which is the least represented in the engineering ethics curricula, being present in only 1% of courses. It is worth noting that this theme is present in extracurricular activities offered by the participant programmes across the country and Northern Ireland, under the form of the competition 'Where there is no engineer" organized by Engineers without Borders Ireland. The initiative aims to encourage engineering students to "design creative solutions to development challenges globally" and "improve resilience within communities." Among the projects designed by students are a solar powered battery bank, low cost heaters and a menstrual pad washing system for women living in refugee camps [14].

In examining the content of the courses in terms of the debates presented in the literature review, a major finding points to the extent of coverage of what the literature labels as macroethical issues. Sustainability, legislative and societal related coverage are among the themes most present in the engineering ethics curriculum. The strong presence of macroethical curricular content is consistent with the findings about ethics coverage revealed by the study conducted by [7]. Polmear et al's [7] investigation points to the prevalence in Western European Engineering programmes, compared to US programmes, of topics related to sustainability, the societal impact of technology and professional practice issues. This seems to suggest that compared to the US, the coverage of ethics by the participant programmes in Ireland is more geared towards macroethical topics.

Considering topics associated with the microethical approach, while safety is indeed the second most popular theme used to convey curricular content pertaining to ethics, receiving 60 mentions in 43 courses, the themes of plagiarism and ethical theories, which are traditionally associated with microethical approaches, are among the three least used themes. Curriculum content pertaining to ethics education does not bear as heavy emphasis on plagiarism in participant engineering programmes in Ireland as it does in the UK and Portugal, according to studies conducted by [5] and [15]. Ethical theories also have a low presence in the curricula of participant engineering programmes in Ireland, unlike the emphasis reported in studies conducted in US Engineering programmes [6].

It is important to note the attempt to encompass several themes in one course deemed to have a high contribution to the outcome purporting to ethics. There is an average of 3 themes addressed in each of the courses analyzed. Several courses describe the attempt to address ethics from both a micro and macroethical perspective. As Devon and Van de Poel [16] argue, the "social [macro] ethics approach and individual [micro] ethics approach do not exclude each other", and this is visible in many teaching interventions that were analyzed.

IV. CONCLUSION

In examining the curricular content of the courses deemed to have a strong contribution to the accreditation outcome purporting to ethics, the study noted a particular emphasis on the incorporation of sustainability, health and safety and legislation throughout the engineering curriculum, as these topics are present in a variety of course types.

There are two major characteristics of the prevalence of teaching ethics through the prism of sustainability, legislation and safety related topics. First, compared with the other thematic areas identified, these themes have a particular strong presence in technical courses. Second, these themes are closely linked to the conceptualization of ethics in practical terms and the instruction through realistic case studies reflecting contexts of engineering practice.

Furthermore, by examining the curricular content of courses in terms of existing research, the study notes a low engagement with philosophical theories, similar to the findings of Hess and Fore [17]. While professional ethics aspects such as rules and codes are often touched upon, these do not represent the main focus for the integration of ethics, as Hess and Fore [17] found. It can thus be argued that while the development of propositional and theoretical knowledge is the locus of concern when exposing student to the technical dimension of engineering ([18], p.263), in engineering ethics education the emphasis is on a practical and hands-down ethics instruction, by enabling students' situational responses in decision making and in the context of the design of engineering artefacts.

Reflecting on the integration of ethics through sustainability, it is considered that higher education institutions are "far from reorienting themselves towards sustainability" and that sustainability appears to be "integrated in a piece-meal fashion" ([19], p.64). While it cannot be said that the implementation of sustainability is carried in a systematic and even manner in the programmes in the study, what does emerge is a desire to address ethical issues through the prism of sustainability. Setting a foundation for ethics education rooted in sustainability topics is seen by Biedenweg et al ([20], p.7) as a critical component in the education of engineers because it provides "a structure for understanding the moral basis for decisions about which technique or strategy to employ".

Having highlighted the popularity of engineering ethics instruction through sustainability and Health and Safety topics, as well as the focus of legislative topics on standards, an advantage of this approach is that it can be tailored to the expertise of engineering faculty ([21], [22]). These themes can be considered to suit the expertise of engineering instructors, more than ethical theory would, thus addressing a common challenge rooted in the lack of familiarity and expertise of engineering instructors with ethics ([15]; [23]; [24]). An issue then is how we can use this appetence of engineering instructors to teach ethics through sustainability, safety and legislation related coverage as a mechanism for broadening engineering education, as to more fully integrate the technical, the social, and the environmental dimensions of engineering in one comprehensive form of education, as suggested by Nicolaou et al [25].

Another key finding is the extent to which what might be considered macroethical issues are included in engineering education in Ireland. For example, if we combine items related to sustainability, legislative aspects, the societal dimension of engineering, responsibility and community engagement, we can see that these themes associated with the macroethical approach outnumber themes associated with the microethical approach, such as health and safety, professional ethics, ethical theories and plagiarism. Existing research points out that a focus on sustainability and policy may facilitate the broadening of engineering ethics education beyond a micro ethical approach ([26], [27], [28], [29]). The integration of these thematic areas through a macroethical lens is considered to empower students to address the pressing socio-political, socio-economic and biophysical aspects of environmental problems ([30], [31]).

It is notable the overarching focus of professional formation courses on curricular content purporting to professional ethics, responsibility and the societal context. This emphasis can be explained in light of the aims promoted by professional formation courses of introducing students to the role of the professional engineer and the nontechnical specifications of engineering. It can thus be suggested that engineering programmes should promote the implementation of ethics in dedicated courses, such as professional formation courses, in order to facilitate the socio-technical enculturation of students into the engineering profession. A hybrid model of implementing ethics both in courses of professional formation and throughout the curriculum can provide a more comprehensive model of ethics education, which has the potential of making students aware of the core nature of ethical concerns for engineering practice, and the intertwining of ethical and technical knowledge and skills.

The study also brings to light the existing confusion as to what counts as ethical content. The theme of Health and Safety, for example, revealed itself to lead to problematic understandings regarding whether its coverage falls under the scope of ethics or not. Based on the module descriptors and evidence in support of how the programmes meet the accreditation outcomes, while some course developers did not associate content related to Health and Safety as falling under the scope of ethics, other course developers interpreted the contribution of their course to ethics solely through the lens of its mathematical and technical application, with no discussion of the safety considerations involved by these calculations. A similar confusion was remarked in connection with the coverage of legislative issues such as intellectual property and protected disclosures, with some course developers not including this curricular content under the scope of ethics education. The confusion as to what counts as engineering ethics education has been previously pointed out by Reed et al ([32], p. 169), especially in connection to topics such as "copyright, building codes and other similar concepts covered in technology education."

As the present study has identified three topics (sustainability, safety and legislation) amenable to the implementation of ethics across the curriculum, further research can examine the integration of ethics topics and curricular units at the level of specific programmes and institutions. A particular focus can be given to case study research of programmes that report positive results or describe initiatives for implementing ethics across the curriculum, similar to those exposed by Riley et al [33] and Mitcham & Englehardt [8]. Further research is also needed to explore the challenges in implementing curricular themes which have a rare presence in engineering ethics education, such as humanitarian engineering and community engagement, as well as presenting best practice examples that can inspire instructors and programme chairs.

Finally, given the diminished familiarity of engineering instructors with ethics and the confusion as to what falls under the scope of engineering ethics, education, a recommended avenue for further research is to provide an in- depth exploration of the challenges experienced by lecturers for teaching ethics, as well as to examine the effectiveness of different strategies countering these.

REFERENCES

[1] Lattuca, L.R. & Stark, J.S. (2009). Shaping the college curriculum: academic plans in context, San Francisco, CA: Jossey-Bass

[2] Lynch, W.T., & Kline, R. (2000). Engineering practice and engineering ethics. Science Technology and Human Values, 25(2), 195–225.

[3] Haws, D.R. (2001). Ethics instruction in engineering education: A (mini) meta-analysis. Journal of Engineering Education, 90 (2), 223-229

[4] Kline, R. (2001). Using history and sociology to teach engineering ethics, IEEE Technology and Society, 20(4), 13-20

[5] Atesh, M., Baruah, B. & Ward, T. (2017). A new framework for measuring the ethical awareness and perception among engineering students in Higher Education. 6th New Perspectives in Science Education, Florence,Italy

[6] Colby, A., & Sullivan, W. (2008). Ethics Teaching in Undergraduate Engineering Education. Journal of Engineering Education, 97(3),327-338

[7] Polmear, M., Bielefeldt, A., Knight, D., Canney, N. & Swan, C. (2019). Analysis of macroethics teaching practices and perceptions in engineering: a cultural comparison, European Journal of Engineering Education

[8] Mitcham, C. & Englehardt, E. E. (2019). Ethics across the Curriculum: Prospects for Broader (and Deeper) Teaching and Learning in Research and Engineering Ethics. Science and Engineering Ethics, 25(6), 1735- 1762

[9] Bielefeldt, A.R., Canney, N.E., Swan, C., & Knight, D. (2016), Efficacy of Macroethics Education in Engineering. 2016 ASEE Annual Conference and Exposition, New Orleans, Louisiana

[10] Holsapple, M. A., Carpenter, D. D., Sutkus, J. A., Finelli, C. J. & Harding, T. S. (2012), Framing Faculty and Student Discrepancies in Engineering Ethics Education Delivery. Journal of Engineering Education, 101,169-186.

[11] Engineers Ireland. (2007). Accreditation Criteria for Engineering Education Programmes.

[12] Bowen, G.A. (2009). Document analysis as a qualitative research method. Qualitative Research Journal, 9(2),27-40

[13] Riley, D. (2014). Professional Formation of Engineers. National Science Foundation - Spring 2014: ENG Advisory Committee Meeting

[14] McCarton, L., O'Hógáin, S. (2018) Where There Is No Engineer - Designing for Community Resilience. Development Technology in the Community (DTC) Research Group, Technological University Dublin (DIT) & Engineers Without Borders (EWB) Ireland, 2018.

[15] Monteiro, F., Leite, C. & Rocha, C. (2016). Ethics and Civic Education in the Curriculum of Engineering courses in Portuguese Higher Education System. 8th International Symposium on Project Approaches in Engineering Education and 14th Active Learning in Engineering Education Workshop Proccedings

[16] Devon, R. & Van de Poel, I. (2004). Design ethics: The social ethics paradigm, International Journal of Engineering Education, 20(3),461-469

[17] Hess, J.L. & Fore, G.A. (2018). A systematic literature review of US engineering ethics interventions. Science and Engineering Ethics, 24(2), 551-583

[18] Radcliffe, D. (2006). Shaping the discipline of engineering education. Journal of Engineering Education 95(4),263–64

[19] Lambrechts, W., Mulà, I., Ceulemans, K., Molderez, I., & Gaeremynck, V. (2013). The integration of competences for sustainable development in higher education: an analysis of bachelor programs in management, Journal of Cleaner Production, 48, 65-73.

[20] Biedenweg, K., Monroe, M.C. & Oxarart, A. (2013). The importance of teaching ethics of sustainability", International Journal of Sustainability in Higher Education, 14(1), 6-14

[21] Walczak, K., Finelli, C. J., Holsapple, M. A., Sutkus, J. A., Harding, T. S., and Carpenter, D. D. (2010). Institutional obstacles to integrating ethics into the curriculum and strategies for overcoming them. Proceedings of the 2010 ASEE Annual Conference & Exposition, Louisville

[22] Sinha, S.K., Thomas, R., Kulka, J.R. (2007). Integrating ethics into the engineered construction curriculum. Journal of Professional Issues in Engineering Education and Practice, 133, 291–299

[23] Romkey, L. (2015, June). Engineering, Society, and the Environment in the Teaching Goals and Practices of Engineering Instructors. 2015 ASEE Annual Conference & Exposition, Seattle, Washington

[24] Polmear, M., Bielefeldt, A.R., Knight, D., Canney, N & Swan, C. (2018). Faculty perceptions of challenges to educating engineering and computing students about ethics and societal impacts, Proceedings of the ASEE Annual Conference & Exposition

[25] Nicolaou, I., Conlon, E. & Bowe, B. (2018) Into the Deep: The Role of Paradigms in Understanding Engineering Education for Sustainable Development. Irish Journal of Social, Economic and Environmental Sustainability. 1 (2), 23-41

[26] Gorman, M. E., Mehalik, M. M. & Werhane, P. H. (2000). Ethical and Environmental Challenges to Engineering, Englewood Cliffs, NJ: Prentice Hall.

[27] Byrne, E.P. (2012). Teaching engineering ethics with sustainability as context, International Journal of Sustainability in Higher Education, 13(3), 232 – 248

[28] Bekker, R. & Bombaerts, G. (2017). Introducing broad skills in higher engineering education: the patents and standards courses at Eindhoven University of Technology. Technology and Innovation, 19, 493

[29] Herkert, J. R. (2000). Ethical Responsibility and Societal Context: Integrating Ethics and Public Policy Considerations in the Engineering Curriculum, 30th Annual Frontiers in Education Conference

[30] Warburton, K. (2003). Deep learning and education for sustainability, International Journal of Sustainability in Higher Education, 4(1), 44-52

[31] Bender, H. (2012). Reshaping Environments – an opportunity for envisioning the future', in H. Bender (Ed.), Reshaping Environments, An interdisciplinary approach to sustainability in a complex world, Cambridge University Press, Cambridge, 1-13

[32] Reed, P. A., Hughes, A., Susan, P., & Stephens, D. I. (2004). The status of ethics in technology education. In R. B. Hill (Eds.), Ethics for Citizenship in a Technological World. Peoria, IL: Glencoe/McGraw-Hill, 163-186

[33] Riley, D., Ellis, G., and Howe, S. (2004). 'To Move People From Apathy': A MultiPerspective Approach to Ethics Across the Engineering Curriculum. In Proceedings of American Society for Engineering Education Annual Conference.

Technical Papers

Ethics in Engineering Education 4.0

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Abstract—**The advent of the fourth industrial revolution (4IR), commonly referred to as Industry 4.0, has had an all-pervasive influence on virtually every aspect of high-quality manufacturing and associated services. As a consequence, it has triggered an increasing demand in industry to drive technological transformation. By implication, the situation has also propelled a transformation in the requirements of Higher Education (HE) during the process of training engineers, towards more blended or online modes of delivery. The objective of this paper is to examine the extent to which ethics has been considered during the process of educating engineers in contemporary times. Thus, the purpose of this scoping review is to summarize and present current practices to uphold ethical standards in engineering education, including the review of proposed and implied ethical guidelines, and thereby identify gaps in existing literature.**

Accordingly, guided by a framework provided by Jasanoff [1], 17 peer-reviewed articles from selected engineering databases, that were published in the last decade were examined to identify international practices and ethical guidelines pertaining to blended or online engineering education. Emerging themes concerning the ethical use of technology for engineering education were identified through three lenses which were (1) hidden costs associated with the use of technology, (2) exclusivity due to the use of technology and (3) agency due to technology. This scoping review found that unless we, as engineering educators have a better understanding of the impact of technology on structures of hierarchy in society and social interaction, words like "citizenship", "equality" and "democracy" lose their meaning as cardinal markers for an open society. Ultimately, this scoping review highlights questions that need further discussion.

Keywords—Engineering Education, Industry 4.0, Blended Learning, e-Learning, Online Education

I. INTRODUCTION

The term Industry 4.0 was originally used by the German government [2] to describe a future vision in a high-tech strategy to achieve a high degree of flexibility in production and individualized mass production through the use of information, communication technologies, the Internet of Things, Physical Internet and the Internet of Service. To realize this vision the adaption in HE is essential, in particular engineering education since engineers with expanded design skills that orientate towards interoperability, virtualization and decentralization and the development of intelligent autonomous manufacturing systems that depend on cyber systems which are monitored, coordinated, controlled and integrated by a computing and communication core. Several researchers [3], [4], [5] refer to this as Engineering Education 4.0. Moreover, the research of Jeganathan, Khan, Raju and Narayanasamy [4] confirms that blended and online learning approaches and an integrated curriculum are key ingredients for Engineering Education 4.0 programmes that develop engineers for Industry 4.0.

Significantly, while blended and online delivery modes have generally been accepted as an improvement [6] to engineering education, little regard has been given to ethical considerations surrounding online engineering education, for example privacy concerns and access. Moreover, the recent global COVID-19 pandemic has brought these challenges into sharp focus. Therefore, notwithstanding that it is widely accepted that new technology has a significant positive impact in many areas of our everyday lives [7] including the HE landscape, it is also notable that some commentators are now raising questions about whether our new technological scenario implies new ethical challenges.

Thus, the purpose of this scoping review is to summarize and present current practices to uphold ethical standards in engineering education, including the review of proposed and implied ethical guidelines, and thereby identify gaps in existing literature.

II. METHODOLOGY

A. Framework selection

The basis of this work is to expand the perspective of ethics in engineering education, with particular focus on the examination of complex relationships between our institutions and societies with technology, and the implications (good or bad) of those relationships for ethics, rights and human dignity. Therefore, a framework proposed by Jasanoff [1] was selected to position this literature review, since she argues that every form of technology developed was originally designed with the idea of adding some value to our institutions and societies. Jasanoff's [1] framework consists of three primary concepts, which have been reframed as research questions and are referred to as ethical research lenses in this literature review. These research questions with associated lenses in parenthesis are:

1) Research question one: *While it is known that technology has the potential to make life easier, in the context of Engineering Education 4.0, could that same technology be harmful?* (Ethical research lens one - Unintended negative consequences)
2) Research question two: *Has the development and spread of technology made Engineering Education 4.0 more inclusive or exclusive?* (Ethical research lens two - Discrimination)
3) Research question three: *Has there been a transformation in 'educator' or 'student' agency as a result of the onset of Engineering Education 4.0?* (Ethical research lens three – Agency and digital identity)

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B. Praxis

The scoping review procedure described by Arskey and O' Malley [8] was used for this study. The authors advocate a five-step approach which includes (1) identify a research question, (2) identify relevant studies, (3) study selection, (4) chart the data and finally (5) collate, summarize and report the results.

Following the identification and formulation of the aforementioned research questions, research data bases and search terms (i.e. keywords/phrases), and inclusion and exclusion criteria were selected to facilitate the identification of relevant research studies. The primary search terms were *"Engineering Education 4.0", "e-Learning"* and *"Ethics"*. Due to the wide range of definitions for these words, subsets of word combinations were used to facilitate a more focused search. Associated synonyms from a thesaurus in each database were included in this search to ensure that terms were consistent and transferable across databases. The aim was to create a search string that required limited modifications from one database to another. Thus, the search string was *"Engineering Education 4.0*" or *"Engineering Education"* or *"Industry 4.0 training"* or *"4IR training"* AND *"e-Learning"* or *"eLearning"* or *"online learning"* or *"distance learning"* AND *"Ethics"* or *"Ethical practice"* or *"Ethical considerations"*. Too few hits were returned by the initial search sting however, therefore the search string was modified to *"e-Learning"* or *"eLearning"* or *"online learning"* or *"distance learning"* AND *"Engineering Education 4.0"* or *"Engineering Education"* or *"Industry 4.0 training"* or *"4IR training"* OR *"Ethics"* or *"Ethical practice"* or *"Ethical considerations"*.

Following the development of the search string, all the data bases hosted by the Engineering Faculty Library at the university where this research took place were screened and 12 databases were selected on the basis of their perceived relevance to the study. These were:

- EBSCOhost (included Academic Premier Search, ERIC and MasterFile Premier) – multidisciplinary and education databases includes noteworthy articles in general interest, health, consumer science, business, general science, engineering and education;
- Emerald Engineering – collection of 26 engineering journals and e-journals focused on engineering in aerospace, automotive, industrial and manufacturing sectors;
- Directory of Open Access Journals (DOAJ) – multidisciplinary, community curated online directory of scholarly articles;
- Credo Reference – online collection of academic reference books;
- Wiley Online Library – multidisciplinary collection of online journals, books and research resources;
- SpringerLink – collection of scientific, technological and medical journals, books and reference works;
- Google Scholar – academic search engine for multidisciplinary scholarly literature;
- IEEE Xplore Digital Library – research database for journal articles, conference proceedings, technical standards and related material on computer science, electrical engineering, electronics and cognate disciplines;
- JSTOR – online digital library of academic journals, books and primary resources;
- Proquest (included eBook Central, Education Database, Sci Tech Premium Collection and Social Science Database) – collection of databases on multiples disciplines includes journals, newspapers, dissertations and reference works
- ScienceDirect – journals, books and articles on scientific, technical and medical research, and
- Scopus – database of peer-reviewed literature in the fields of science, technology, engineering and medicine.

Inclusion criteria were, only peer-reviewed publications and eBooks published from 2010 until 2020 since this period aligns with the heightened adoption of e-learning in Engineering Education and the emergence of Industry 4.0, and also only articles where the full text was available were selected for review. Moreover, the focus of this review was specifically on HE. The initial search returned 4344 publications. Thereafter exclusion criteria were applied. All publications that focused on 'teaching ethics' in the engineering field were removed, as this research was on the application of ethical principles. Furthermore, the publications were then examined to determine their suitableness to answer any of the research questions of this study. Thus ultimately, only 17 publications remained in the dataset for this review, however it is worth noting that none of these publications directly addressed the research questions. Table I below presents a tabular depiction of the filters that were applied.

TABLE I *Publication selection from databases*

Database	Publications			
	Included	Excluded	Final	Research Question
EBSCOhost	224	223	1	1
Emerald	413	412	1	1
Engineering	13	13	0	-
DOAJ	133	132	1	1
Credo Reference	42	38	4	2,3
Wiley Online	27	27	0	-
SpringerLink	1671	1668	3	1,2,3
Google Scholar	8	5	2	1,2
IEEE Xplore	95	92	3	1,2
JSTOR	1340	1338	2	1
Proquest	369	369	0	-
ScienceDirect	9	9	0	-
Scopus				

III. ANALYSIS OF REVIEW

Each of the final 17 publications satisfied the inclusion criteria, however all publications examined 'engineering education', 'ethics' and 'e-learning' from a distinctly different perspective to the aim of this study. Consequently, none of them directly answered the research questions posed above as none of the publications were written specifically for the context Engineering Education 4.0. In this literature review, publications were examined in three phases namely, initial examination, comprehensive examination and thematic chronicling of results. The primary aim of the initial examination was to identify any noteworthy observations in each and summarize.

Thereafter the full text of each of the 17 articles were expansively reviewed and characterized on the basis of their orientation towards answering one or more of the research questions. Finally, the content of each article was thematically coded and emerging themes were categorized and reviewed for appropriateness. These themes are presented in the result section below.

IV. RESULTS

A. Ethical research lens one: Unintended negative conseqeunces (n = 7)

1) Unintended consequences theme one: Ethical dilemmas related to student and industry

The results of a study by Noesgaard and Ørngreen [9] focused on the effectiveness of e-Learning and concluded that despite e-Learning being an effective approach, there are several inherent disadvantages of e-Learning. From student perspective this includes limited communication skills development and e-Learning also has the potential to cause social isolation among students. With reference to the impact of e-Learning on Industry 4.0, e-Learning platforms are more suited for theoretical training, thus in certain discipline such as engineering graduates where practical is very important, the authors suggest that students may not be adequately prepared for what will be required of them in the industry.

This is confirmed by Tam [10] stating that e-Learning presents a drawback with respect to practical training such as that which is required for the training of engineers however adds that significantly more prior planning may be a successful approach to overcome this disadvantage.

2) Untintended consequences theme two: Ethical dilemmas related to the institution

Coulton, Nicholas, Bailey, Arora, King, Taylor, and Durham [11] assert that protecting the authenticity of an online examination is complicated when compared to traditional assessment methods. They mention barriers to the use of emerging technologies which include infrastructure, educator perceptions, educator confidence, educator training and information sharing. These authors specifically state that ethical concerns and issues related to bias and sharing of data also need consideration.

3) Unintended consequences theme three: Ethical dilemmas related to privacy

Although many advances have been made in the mechanics of providing online instruction [12], it is significant that security and privacy concerns around e-Learning have largely been largely ignored. To date, at best, these have been accommodated in a patchwork or ad-hoc fashion. This view is aligned with that of Ivanova, Grosseck and Holotescu [13] who aver that emerging intelligent solutions for eLearning, and also commonly used web applications for example Google Drive, are used by educators to collect, process and store a big array of students' personal data. The authors suggest however that in general, educators at HE institutions pay little attention to the type of private data being collected and the relevance for successful learning. Moreover, the authors raise questions about whether the data is being adequately protected against unauthorized use and point out that this represents an ethical concern involving students' privacy.

These authors suggest that privacy in eLearning could be achieved through a combination of actions from student's side, third parties' side and appropriate design of educational software. Significantly, several countries have legislation governing data protection for example, the General Data Protection Regulation (GDPR) in European Union countries [14] and the Protection of Personal Information (POPI) Act in South African [15] however notably, no literature could be found on the protection of student data in certain countries, such as South Africa, during this literature review.

B. Ethical research lens two: Discrimination (n = 6)

Several researchers [2], [4], [16] agree that online solutions and educators are becoming more digitally innovative which helps to address the needs of contemporary university students, however Gachago and Cupido [17] raise questions around epistemic access and equity due to e- Learning in HE. These concerns are foregrounded by the global move to online learning in HE due to the COVID19 pandemic in 2020. They add that much still needs to be done to ensure inclusivity, especially along class, race, gender, and geographic location at certain universities. These authors and Rowe [18] emphasize the importance of designing simple remote teaching solutions that facilitate access, instead of high-tech, complex modes of delivery which automatically exclude some students due to factors for example, the availability of a data and an upmarket smartphone.

The views of these authors are aligned to Jasanoff [1] who expressed a view that global social environments constantly undergo transformation due to technological change. She argues that societal focus is on the extraneous features of technology and suggests that society thus declares this to be the "savior of the world", but does not always consider the bigger picture. For universities to meet their challenge of being an essential agent to ensure knowledge and development of competencies in the fourth industrial revolution, effort has to be made to understand this evolution and in particular Engineering Education toward Industry 4.0.

C. Ethical research lens three: Agency and digital identity (n = 4)

To understand 'agency' in the context of Engineering Education 4.0, guidance was sought from Rocchi [7] who suggests that one needs to compare the lives of two similar persons, for example an educator in current times to that of one who was active 50 years ago, to provide a point of reference. From a technological perspective, the lives of the two educators would be significantly different, yet from an anthropological perspective the two individuals have the same inner structure and the same 'big questions' about identity and human purpose. The same would apply to a student in 2020 and a person who was a student in 1970. From this perspective the 4IR has a significant influence on the agency of both educators and students.

This is aligned with the views of Bertolaso and Rocchi [19] who agree that the essential roles of responsibility of educators and students remain unchanged in the digital era. Godwin, Potvin, Hazari and Lock [20] highlight that function of engineers are to devise innovative solutions to the world's complex global problems and they argue that agency beliefs are critical to identity development and ultimately the decision to become an engineer. Another finding of this study was that agency is also critical predictor of the field of engineering that students will decide to study.

V. DISCUSSION AND SUMMARY

Technology and technological choices shape our physical and social world, enabling some things and rendering other things difficult. Therefore, the advent of Industry 4.0 signifies an important milestone in Engineering Education. Managing technology wisely, requires the users of technology and gatekeepers to look beyond the surfaces of machines towards the judgements and choices which determine how the lines are drawn between what is allowed and what is not allowed.

This scoping literature review highlights that there is a significant dearth of literature on ethical considerations around Engineering Education 4.0, as there are no publications that directly addressed this research topic and an extensive literature search of 12 databases returned only 17 indirectly related publications. Notably, no guiding principles or guidelines could be found. Using three ethical research lenses namely, (1) hidden costs associated with the use of technology (unintended negative consequences), (2) exclusivity due to the use of technology (discrimination) and (3) agency due to technology (agency and digital identity), this study highlights areas where further research is recommended.

A. Hidden costs associated with the use of technology

It is undeniable that e-Learning has several significant advantages, such as having no geographical boundaries or restrictions; however, it is equally important to note that there are concerns that arise with e-Learning that should govern the behavior of the educators (and by implication, students too) when e-Learning takes place. Specific to an Engineering Education, this literature review outlined examples of the most noteworthy hidden drawbacks of e-Learning. Three key themes emerged from the analysis of literature on this topic which were (1) ethical dilemmas related to the student and industry, (2) ethical dilemmas related to the institution and (3) ethical dilemmas related to privacy.

From the literature reviewed on unintended negative consequences it may be deduced that to overcome certain challenges engineering educators need to apply additional strategies to compensate for the lack of physical contact time with students. Examples of problems that could arise are lack of communication skills in engineering students or a feeling of social isolation. It is believed that such problems are compounded in periods where global restrictions on movement and social gathering were implemented due to the COVID19 pandemic. To address such concerns, it is recommended that engineering educators design innovative interventions, for example personalized feedback and when personalized feedback is not practically possible, a system of peer feedback should be used.

Engineers cannot be completely adequately trained with exclusive online training [21], since no amount of online lessons can substitute industrial training of competent engineers required by Industry 4.0. The author however proffers that research conducted in the case of nursing students showed that blended learning courses achieved similar posttest results as traditional course formats, while simultaneously increasing satisfaction ratings of participating student significantly. Thus, engineering educators are advised to explore suitable blended learning strategies overcome these ethical concerns. It is recommended that further research is perform on this topic.

From an institutional perspective, protecting the authenticity of online engineering examinations is complicated when compared to traditional assessment methods since students cannot be easily observed during assessments without video feed. Meilleur and Ge [22] recommend some strategies that engineering educators may use to mitigate this, such as informative anti-cheat materials to prevent unintentional cheating, randomized quizzes, open-ended examinations, peer evaluations, discussion forums and personalized assessments where possible. A recommendation of this literature study is that these be further explored to overcome ethical challenges associated with online assessments.

Security and privacy concerns around e-Learning are significant, especially in the light of its global importance. It is therefore imperative that engineering educators find a balance between privacy and multiple competing issues around delivering the curriculum. A recommendation derived from the review of literature is that engineering educators be given guidance the ensure ethical treatment of students and other stakeholders. As open source e-learning platforms are available for educators to use it is important that they understand and are able to distinguish between important concepts identity management, anonymity and pseudonymity, privacy in social networking, authentication, cyberbullying, third party management and the safe storage and usage of student data and personal information.

B. Discrimination

Literature was also reviewed to determine if the development and spread of technology as a result of the adoption of online approaches aligned with Engineering Education 4.0 has led to more inclusivity or exclusivity. The findings of this examination underscored questions around epistemic access and equity due to e-Learning in HE. These concerns are foregrounded by the global move to online learning in HE due to the COVID19 pandemic in 2020.

From this literature review it has been deduced that engineering educators could benefit from universal principles for learning task design to develop e-Learning solutions that facilitate access, instead of high-tech, complex modes of delivery which automatically exclude some students due to factors for example, the availability of a data and an upmarket smartphone. These principles include (but are not limited to), for example (1) prioritize asynchronous interaction, (2) opt for simplicity over complexity, (3) where possible, privilege text over video or audio, (4) adopt contextualized teaching solutions and (5) embrace empathy and co-creation.

C. Agency and digital identity

This scoping review has illuminated the insight that online identity development is an integral part of Engineering Education 4.0. The essential roles of responsibility of educators and students remain unchanged in the digital era; however, Industry 4.0 presents an opportunity to reflect on our digital identities and question if those should be different to our real identities. In a modern world with virtually thousands of endless possibilities, the real challenge is selecting what is worth doing, and what is worthy of our still limited time.

VI. CONCLUSION

The intention of this scoping review is not to provide answers, but merely to raise awareness and critically reflect on Engineering Education 4.0. This review has demonstrated that technology itself is neutral. It is the way that technology is used and the consideration given to that which may be regarded as good or bad. For this reason, having ethical guidelines for Engineering Education 4.0 is essential. A comparison may be drawn by saying this is akin to giving someone a loaded gun, but not teaching that person about gun safety. Jasanoff [1] refers to something called the responsibility gap. She cautions that unless we better understand how technologies affect basic forms of social interaction, including structures of hierarchy and inequality, words like "democracy" and "citizenship" lose their meaning as compass points for a free society.

REFERENCES

[1] S. Jasonoff. The Ethics of Invention: Technology and the Human Future. New York: W.W. Norton & Company, 2016.

[2] S. Coskun, Y. Kayikci, and E. Gençay. (2020, July 12). Adapting Engineering Education to Industry 4.0 Vision. Technologies. [Online]. Available: https://www.researchgate.net/publication/330281868_Adapting_Engi neering_Education_to_Industry_40_Vision

[3] S. Frerich, T. Meisen, A. Richert, M, Petermann, S. Jeschke, U. Wilkesmann and A. Tekkaya. Engineering Education 4.0 Excellent Teaching and Learning in Engineering Sciences. Springer, Cham, 2017.

[4] L. Jeganathan, A. N. Khan, J. K. Raju, and S. Narayanasamy. "On a Frame Work of Curriculum for Engineering Education 4.0" in 2018 World Engineering Education Forum - Global Engineering Deans Council (WEEF-GEDC), 12 -16 November on Alburquerqu, New Mexico, 2018

[5] R. A. Ramirez-Mendoza, R. Morales-Menendez, H. Iqbal and R. Parra-Saldivar. "Engineering Education 4.0: proposal for a new Curricula" in 2018 IEEE Global Engineering Education Conference (EDUCON), Sant Cruz de Tenerife, Spain, 2018 pp. 1273-1282, doi: 10.1109/EDUCON.2018.8363376

[6] Tait, A. (2020, February 15) Engineering Education: Online and Distance Programmes [Online]. Available from: http://oasis.col.org/bitstream/handle/11599/3051/2018_Tait_Engineer ing-Education-Online-and-Distance-Programmes.pdf?sequence=1&isAllowed=y

[7] M. Rocchi. (2020, February 15) What are Industry 4.0's ethical challenges? [Online]. Available: https://www.rte.ie/brainstorm/2019/1209/1097985-what-are-industry- 4-0s-ethical-challenges/

[8] H. Arksey and L. O'Malley. "Scoping Studies: Towards a Methodological Framework" International Journal of Social Research Methodology: Theory and Practice, 8(1), 19–32. 2005. https://doi.org/10.1080/1364557032000119616

[9] S. Noesgaard and R. Ørngreen. "The Effectiveness of E-Learning: An Explorative and Integrative Review of the Definitions, Methodologies and Factors that Promote e-Learning Effectiveness". Electronic Journal of e-Learning 13(4) 278 – 290. 2015.

[10] S. Tam. "Disadvantages of e-Learning" Journal of Computing Research 33 (3) 285-307. 2019.

[11] J. Coulton, J. Nicholas, L. Bailey, K. Arora, D. King, A Taylor and W. Durham.. Understanding changing expectations of the use of technology in assessment. National Foundation for Educational Research: Berkshire. 2019

[12] C. Hui-Lien and C. Chen. "Beyond Identifying Privacy Issues in e- Learning Settings – Implications for Instructional Designers" Computers and Education 103 (2016): 124–133. 2016.

[13] M. Ivanova, G. Grosseck and C. Holotescu. "Researching data privacy models in eLearning" in 2015 International Conference on Information Technology Based Higher Education and Training (ITHET), Lisbon, 2015, pp. 1-6, doi: 10.1109/ITHET.2015.7218033

[14] M. Marković, S. Debeljak and N. Kadoić. "Preparing Students for an Era of General Data Protection Regulation (GDPR)." Technology Information Management Journal 8/2019(1) 150-156. 2019.

[15] M. De Bruyn. "The Protection of Personal Information (POPI) Act: impact on South Africa" International Business & Economics Research Journal, 13(6):1315-1340. 2014.

[16] T. Liyanagunawardena, A. Adams, N. Rassool and S. Williams. Developing government policies for distance education: Lessons learnt from two Sri Lankan case studies. International Review of Education 60(6) 821-839. 2014.

[17] D. Gachago and X. Cupido. (2020, March 27) Designing learning in unsettling times [Online]. Available: http://heltasa.org.za/designing- learning-in-unsettling-times/

[18] M. Rowe. (2020, April 17). Universal principles of learning task design. Crisis edition. [Online] Available: http://heltasa.org.za/universal-principles-of-learning-task-design- crisis-edition/

[19] M. Bertolaso and M Rocchi, M.. "Specifically human: Human work and care in the age of machines." Business Ethics: A European Review 00 1-11. 2020.

[20] A. Godwin, G. Potvin, Z. Hazari and R Lock. "Identity, Critical Agency, and Engineering: An Affective Model for Predicting Engineering as a Career Choice" Journal of Engineering Education. 105(2), 312–340. 2016.

[21] e-Student. (2020, June 16) Disadvantages of e-Learning [Online]. Available: https://e-student.org/disadvantages-of-e-learning/

[22] C. Meilleur and X. Ge. (2020, July 14) Online Training: 8 anti- cheating strategies (online). Available: https://knowledgeone.ca/online-training-8-anti-cheating-strategies/

Technical Papers

A journey to visibility: Making explicit the teaching and learning of ethics within the engineering undergraduate programme

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***Abstract*—How learning is conceptualized and negotiated is affected by the theory of learning implicit in the design of the curriculum. The shift to online learning provides the opportunity to build capacity into the curriculum with new appreciation of the effect of the change of context and process.**

Three theories of learning will be presented and compared: a theory of learning that assumes transference and is acquisition-based; a theory of learning that assumes transference by means of participation within a community and a theory of learning that is activity-centered and aims to be transformative. Each of these theories foregrounds particular affordances to privilege different teaching strategies. The effects and opportunities of these are evaluated within specific initiatives for teaching and learning ethics in a particular context.

This paper will describe and evaluate the teaching of ethics in two capstone courses that form part of the undergraduate engineering program at the University of Cape Town. The analysis identifies teaching strategies that are utilized and highlights differences in the way assessment operates to capture learning. Teaching and learning relating to ethics within engineering is seen to gain distinct emphases from the wider course curriculum, where the particular context affects the learning outcomes and the knowledge, skills and values developed.

Keywords—ethics in engineering, online learning, teaching and learning ethics, graduate attributes, engineering identity

I. INTRODUCTION

The process of accrediting engineering programs involves specifying the educational requirements for the specific qualification, defining broad areas of knowledge to be covered, and specific graduate attributes that students need to acquire competence in [1] rather than detail as to how the curriculum is to be constituted. Graduate attributes are typically expressed in terms of a combination of attributes that relate to the particular program and generic attributes that are common to all or most graduates [2]. Gutiérrez, Fitzpatrick & Byrne identify these as combining core knowledge, transferable skills and professional values and attitudes [3] and emphasize the need for the nuanced assessment of graduate attributes, beyond that of core knowledge, distinguishing knowledge that incorporates skills, values and attitudes. In the context of South Africa, the Engineering Council of South Africa (ECSA), defines the standard for engineering programs in terms of three sets of criteria including: program design, knowledge profile and a set of graduate attributes (GAs) [4]. The program design criteria specify the allocation of credits across the different knowledge areas to a minimum number of credits. The different knowledge areas include mathematical, natural and engineering sciences, design and synthesis, complementary studies and 25% course credits from other disciplines.

Ethics is addressed explicitly in one of the eleven ECSA graduate attributes, that of Engineering Professionalism (GA10), defined as demonstrating: "critical awareness of the need to act professionally and ethically and to exercise judgment and take responsibility within own limits of competence" [4]. The ostensive justification for the inclusion of ethics in the curriculum is thus the recognition of ethics as a competence to be assessed in the achievement of specific discipline-specific graduate attributes.

In their research to improve the teaching of ethics in engineering, Bombaerts, Doulougeri and Nievien [5] point to the necessity of de-linking the drive for quality in engineering education from the definitions of competence that determine international comparability of engineering programs, rather than enabling a more nuanced understanding of quality. Bombaerts et. al. distinguish between what is intended in the curriculum, formulated in the vision and formal intentions, what is implemented, demonstrated through what is perceived and experienced by the participants, and what is attained, defined as what can be measured. This highlights potential discrepancies between the standards promulgated by the accreditor, the vision for the curriculum and that which is operationalized. Their extensive literature search demonstrates the variety of approaches that explore how to further improve the teaching of ethics within engineering and in order to identify discrepancies between the outcomes that are assessed and the learning that is experienced. Similarly, Balakrishnan, Tochinai and Kanemitsu [6] conclude their study on student attainment of the objectives of ethics education by noting that "well-structured, integrated, and innovative pedagogy…has an impact on the students' attainment of ethics education objectives and their attitude towards engineering ethics".

Mitcham [7] challenges engineering educators that the focus on problem-solving in engineering does not provide engineers with the tools to reflect on themselves and their world-transforming enterprise. Because engineering knowledge has historically been seen as rational and objective, building self-reflection as an independent form of knowledge into ethics education may provide an effective way to build reflexivity and critical thinking into the engineering curriculum so as to enable reflection on engineering identity and the mandate of engineering in a broader social and environmental context [7].

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Hekert's research [8] into the scope of engineering ethics in American universities distinguishes three key areas that include the individual, professional and social. Hekert is critical of the tendency of many engineering programs to reduce the teaching of engineering ethics to what he terms "micro-ethics" prioritizing individuals and their internal relationships to the engineering profession. He recognizes the need to broaden the scope of engineering ethics to include "macro-ethics" that he defines as applying to the "collective social responsibility of the profession and to societal decisions about technology" [8]. He emphasizes the importance of ethical policies and viewpoints that need to be sensitive to social problems and issues. In this regard, ethical problem-solving is positioned within the complexity of the wider social context. Hekert contrasts two approaches to teaching ethics. These are the approach that positions individual moral dilemmas, that are relatively well- defined and able to be "solved", with the macro-ethical challenge, that is complex and not clearly defined and that involve social values and varied stakeholders. Contrasted with this approach is Stappelbelt's analysis of the development of professional identity amongst Australian engineering graduates, where she cautions the need to distinguish the intent to "teach ethics" from "engendering and enabling" positive ethical development [9]. In her analysis of the development of engineering identity through the curriculum, Nudelman similarly draws attention to the way in which learners acquire skills/identity [10]. This juxtaposition of two approaches to teaching ethics provides an important segway to a critical analysis of two distinct approaches to the teaching of ethics within the engineering faculty at the University of Cape Town.

In their work investigating different approaches to teaching ethics within the engineering faculties of two South African universities, research by Gwynne-Evans, Junaid and Chetty [11] distinguishes five facets of teaching ethics that operate as a conceptual gateway [12]. These include teaching ethics as a concept distinct from other familiar concepts; teaching ethics as knowledge and skill; and teaching ethics as values and attitudes. These distinct approaches to teaching ethics require the utilization of diverse educational strategies within the engineering curriculum and impact the way assessment is planned and implemented. This recognizes the importance of two key aspects: how ethics is formulated in the graduate attributes to be assessed and the understanding of the role of learning theory to affect how the intended goal of teaching ethics is translated in practice.

Research into how ethics can be taught and learned conceptualizes knowledge in multiple ways: as objective knowledge of content external to the learner; as individual skill

– consisting of the knowledge of how to do something; as self-knowledge relating to attitudes and values and as conceptual knowledge [13]. Competence in a learning outcome requires engagement with the different levels of learning taking place relative to the different forms of knowledge that have been identified. This study will examine the teaching and learning of ethics in two fourth year engineering courses in different disciplines at the University of Cape Town in order to distinguish features of structure, integration and innovation in the pedagogy that contribute to the effectiveness of the teaching and learning of ethics.

II. RESEARCH QUESTION

How does the shift to online learning enable teaching and learning about ethics to be made more visible in the engineering curriculum?

III. METHODOLOGY

This research will contrast two case studies consisting of examples of undergraduate courses within the Engineering and Built Environment Faculty at the University of Cape Town, where ethics is assessed as a graduate outcome. It will look at specific examples of curriculum innovation that have been introduced in the courses, particularly as a result of the shift to online learning. The courses are from different disciplines: one from chemical engineering and one from electrical engineering, where the respective discipline is recognized to provide a wider context for the teaching and learning of ethics within the two programs. Evidence from the online learning management system of each course is contrasted to see how the courses manifest the different learning theories. The data is analyzed and conclusions are drawn as to possible affordances of the different approaches to teaching ethics. One of the courses is a fourth-year chemical engineering course titled Business, Society and the Environment and the other is a fourth-year electrical engineering course in Professional Communication, run in tandem with a course in New Venture Planning.

The research engages in a case study analysis using qualitative data and interpretive method in order to show new understanding and insight about the teaching and learning of ethics within an engineering undergraduate degree.

Three theories of learning are contrasted and positioned as relevant for examining what is achieved in a final year engineering course in relation to the teaching and learning of ethics. Two of these theories are formulated by Sfard and the other emerges from activity theory.

IV. THE ROLE OF LEARNING THEORY

Sfard [14] distinguished two basic metaphors of learning that are important as they influence the understanding of how learning takes place and why learning is important. She highlights the power of metaphor to affect our view and use of concepts in significant ways. She emphasizes the value of metaphor to suggest and make visible implicit understanding rather than to be prescriptive and exclusive. Metaphors are not seen to be mutually exclusive, but rather to bring to light particular aspects of the activity that may not be visible through another lens. It is important that Sfard does not recommend one metaphor rather than another, but rather draws attention to potential benefits and affordances of different aspects of learning.

The metaphor of *learning as acquisition* focuses on learning as a commodity that can be identified, transferred and that has value. This metaphor conveys the value of learning as capital to an individual, or to a community, that can be acquired and utilized. In terms of this metaphor, learning within engineering can be seen to be the intentional *transference* of knowledge and skills – of competence – that results in a qualification with economic and professional value to individuals, the profession and to the wider community. The other metaphor Sfard identifies, is that of *learning as participation*. This places attention on the active learning that takes place by participating in a community, and on the multiple ways learning can be absorbed and communicated. It brings to the foreground the barriers to participation that may act to exclude participation as much as to include participation. This places the emphasis on identity within a *particular community,* on what enables members to participate – to act – within the community, where discourse and practice may be distinguished as characterising the community. Use of the specialist discourse of the community needs to be developed over time through practice and participation.

Both these metaphors assume knowledge to be something fixed and existent – that can be transferred or absorbed. They do not account for the creation of new knowledge or the application of knowledge in new environments. Engeström and Sannino [15] critique the sufficiency of the two metaphors in that the models of learning they become associated with assume learning to be something already existent, that can be received or passed on, but do not account for the creation of new knowledge.

Engeström and Sannino posit a third theory of learning they term "expansive learning" that is intentionally more creative, where learners co-create learning. This theory can be characterized by the metaphor of learning as transformation. Learning as transformation necessarily requires time and involves process, where process is seen to be inherent in the teaching and learning relationship. This recognizes the inter- related nature of teaching and learning, where the contribution of both instructors and learners is significant in the process. Though the intention of instruction is seen as substantial, the goals of learning are seen to be extended in the gap between instruction and learning where they identify "interesting things" to happen [15]. This opens the possibility of transformative learning beyond the intended consequences of the instruction. Engstrom and Sannino's theory of expansive learning puts the attention on the collective activity of the learning community, where together, learners learn "something that is not yet there" [15]. The most important outcome of expansive learning is seen to be agency: the participants' ability and will to shape their activity systems. Their theory of expansive learning tackles issues of "subjectivity, experience, embodiment, identity, and moral commitment" [15] in a way that usefully speaks to the challenges of teaching and learning ethics within the professional space of engineering.

Expansive learning is an example of activity theory. It identifies a triangulated concept of subject, object (context) and mediated artefact. Actions are seen to have a defined beginning and end, whereas activity is conceptualized as a continuous, collective interaction of the individual subject within their context that produces a learning artefact. The introduction of the concept of a learning artefact enables the analysis of the artefact independent of either the subject or the object. In this research into the teaching and learning of ethics, the learner is positioned as the subject, teaching and learning ethics is seen to be the object and the online learning management system, that contains both the instructor's intent and implementation, and the learner's engagement and response, is positioned as the artefact.
The case studies below depict elements of the teaching and learning interface that relate to the three theories of learning.

V. CASE STUDY 1: BUSINESS, SOCIETY AND THE ENVIRONMENT

The 20-credit course, requiring 200 student hours, consists of two concurrent strands that provide a foundation for students to engage with key concepts and tools relating to an engineer's responsibility to the environment and society. This contrasts the application of an engineer's responsibility as economic managers and potential entrepreneurs with the practical innovation and design of a new business. The course originated in 2003 and has been part of a departmental curriculum redesign that saw significant changes in curriculum responding to a changed industry context and a significantly more diverse student cohort [16], [17], [18]. The capstone course assesses five GAs, where competence needs to be demonstrated in order to pass and graduate, see Table 1.

TABLE 1 *ECSA graduate attributes assessed in che4048f: business, environment and society*

Graduate attribute	Where it is assessed
GA6: Professional & technical communication	Individual & group pitch of business idea
GA7: Impact of engineering activity	Case study analysis
GA8: Individual, team & multidisciplinary working	Reflection on interaction with multidisciplinary expert
GA10: Engineering Professionalism Ethics essay	Ethics essay
GA11: Engineering management	Tutorial & test on management tools and finance

Specific topics covered include physical risk in the process industries, social impacts and license, innovation and entrepreneurship, business planning and engineering ethics. Climate change and environmental sustainability are positioned as the context within which the responsible engineer operates and tools such as cleaner production, environmental impact assessments and eco-efficiency are introduced to equip the students to be able to design sustainable and efficient systems. Students are required to identify hazards, to anticipate and manage risk and to measure cost within the different frames. As such the course requires students to develop engineering judgement by considering the impact of engineering on the environment and on society, developed in case studies of significant chemical engineering disasters from around the world and South Africa. The course provides models for defining and measuring short and long-term cost and benefit indicators, both key aspects in measuring the impact of engineering activity. The figure below shows the relationships of different aspects of the course to one another, specifically in relationship to ethics, which provides a foundation to the exploration of the other topics.

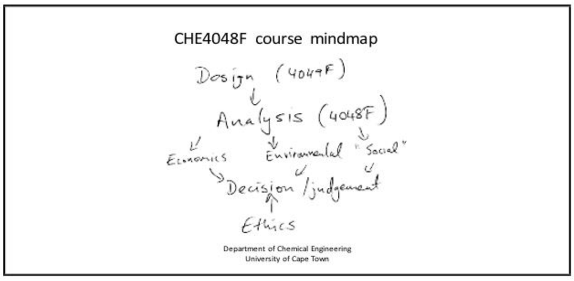

FIGURE 1 *Visual representation of the relationship of ethics to the course material Source: Course Intro CHE4048F Harro van Blottnitz [21]*

The figure shows the way in which this course extends the learning of the associated design course in practical and ethical ways, distinguishing engineering judgement and decision- making as founded in ethics.

In the course, there is a balance between group and individual tasks. Students begin learning how to quantify and cost financial processes and this skill and knowledge is built on in the group work. Current management tools relating to risk and cost and benefit are introduced. Students are tasked in groups with coming up with an innovative entrepreneurial idea that uses their engineering knowledge and takes into consideration specific criteria. They are required to develop and present a business plan, both as a formal document and to present the idea to potential industry investors. Course pedagogy utilizes formal lecture style presentations and slide packs with online resources. Students learn from the expertise of the lecturer and from practical knowledge demonstrated in the application of management tools. Students are encouraged to engage critically with topics and to contribute informally through forums and question and answer sessions. Tasks are scaffolded with tutorials to support students in applying new formula and tools. These tools enable students to use technology to effectively manage risk and responsibility.

Ethics is a foundational aspect of the course, where students explore their professional responsibility as individuals, as engineers and within business, to the public and future generations. This is positioned in terms of individual and corporate responsibility with consequences for society, the environment and the standing of the profession of engineering. They are introduced to the role of industry bodies and their own professional responsibilities and required to write up a reflective essay based in industry or work experience. The contextual emphasis on management tools can result in ethics being perceived as simply a technical and rational process.

VI. CASE STUDY 2: PROFESSIONAL COMMUNICATION STUDIES

The 8-credit, fourth year electrical engineering capstone course (EEE4006C) taking the equivalence of 80 student hours is run in tandem with another 8-credit capstone course in New Venture Planning (EEE4051C). Students had previously completed a second-year course in professional communication with a focus on the formal requirements of report writing. Students are required to work in groups on a common entrepreneurial project with multiple outputs across both courses. Students engage critically with their understanding of professional identity in order to develop confidence and assurance in effective communication as a foundation for their professional careers. This course provides the opportunity to gain knowledge of and practical experience in a variety of communication tools including eportfolios and pitching a business idea to an audience drawn from industry.

The course assesses three graduate attributes, as can be seen in Table 2. These are assessed in thirteen assignments of varying weight, combining shorter peer-reviewed reflections and collaborative documents with weightier individual and group assignments, leading to a final group presentation of a business plan that takes the place of an examination.

TABLE 2 *ECSA graduate attributes assessed in eee4006c: professional communication studies*

Graduate attribute	Where it is assessed
GA6: Professional & technical communication	Business summary and individual and group business presentation
GA8: Individual, team & multidisciplinary working	Business summary and individual and group business presentation
GA10: Engineering Professionalism Ethics essay	Ethics essay and annotated code

The transition of the course to online learning resulted in the course being presented as a set of six online lessons. The material covered engineering identity, teamwork, ethics, persuasive texts, presentation skills, product pitching and visual support for presentations, with two additional weeks where students developed their business pitches as group presentations uploaded as videos, with the opportunity to get feedback on their rehearsals before the final submission. Students were expected to work individually and as part of a group and assessments were split between those that required students to work independently and those that required collaboration and teamwork. Technology was identified as a key aspect enabling effective teamwork and students were required to use google documents, Zoom and/or Microsoft Teams and video packages such as Powerpoint and Screencast- o-matic. Co-ordinating, operating and managing a team at a distance, with very varied access to internet, became a significant test of professional skills and attitude.

The first three weeks of the course focused on developing the students' ability to reflect on their understanding of what being an engineer means and on the practical use of values in making decisions both as an individual and as part of a team. Three self-reflection tasks were set on topics relating to engineering identity: identifying personal experiences that contributed to their sense of engineering identity; describing a situation where the student experienced being part of a successful team and analyzing the specific role, in terms of Belbin personality types [22], that they had played; and with regards to their role as an engineer in Africa. These assignments required students to formulate and articulate coherent views on topics that were seen to provide impetus to their practicing as an engineer in the future and that contributed to their sense of being part of a team with a vision that extended beyond that of the client/customer relationship to serve society. Feedback on these self-reflections was devolved to anonymous peer-assessment which served three functions: ensuring that each student engaged reflectively and critically with their own and two other students' perspectives on the topics relating to engineering identity, and that students engaged critically with formatting and critiquing written work.

These three reflective pieces were seen to provide effective preparatory scaffolding for the other individual assessments: the eportfolio; the ethics essay and the teamwork analysis. The course required the students to develop and submit an online portfolio incorporating artefacts of their achievement over their undergraduate degree, communicating who they were as aspirant engineering professionals. This process challenged them to incorporate multiple aspects of their professional identity that could be communicated and integrated into the eportfolio and that made sense of their experience, their interests and social responsibility, positioning them strategically for the next stage of their professional journey. This was seen to be part of developing awareness of how students' achievements and accomplishments contributed to building up their sense of professional identity and integrity.

Teamwork was recognized as being a particular challenge in the lockdown situation where groups could not meet together face-to-face. As such, it required strategy and planning. Success in this was seen to be crucial for both the group assignments in this course as well as the co-requisite course on new venture planning. Because of this, additional assessment tasks were incorporated that required the students to engage proactively with working in a team, developing a mission statement, team values and a code of conduct as well as identifying how the group intended to use technology to keep in touch and to avoid communication problems.

The section on ethics built explicitly on the preceding weeks on identity as an engineer and on teamwork. Students were introduced to the professional code and required to annotate this in google documents, querying formulations and implications and both initiating and responding to teammates' comments. Input on ethics distinguished individual ethics from professional and corporate responsibility and positioned the aspirant engineer both as part of the professional team and as contributing to national development priorities.

Exercising professional responsibility and ethics was positioned as both an individual and a team pursuit – action-oriented – requiring motivation and justification in terms of values, legislation and vision. Confidence and facility in an appropriate skills-set of tools for making ethical decisions was seen to be important in the activity of practicing ethics. These skills consisted of the ability to identify an ethical rather than a technical or procedural problem, to anticipate alternatives, to formulate an argument, to use problem-solving tools to position and explore alternatives and to reach a decision for action, reflecting on the decision and, possibly, persuading others of the value of the decision. Practicing ethics is thus positioned as an activity requiring skill and self-knowledge and the support of a team. Students are encouraged to develop a sense of identity as part of a profession where they play a role in defining professional identity and in supporting colleagues.

The organization and pedagogy of the course was deliberately planned to encourage students to develop the ability to perform as part of a professional team, with the ability to plan and avoid problems, demonstrating professional and ethical judgment. Students were encouraged to explore topics outside of their direct curriculum, including the consequences of decisions in the history of engineering and in corporate engineering and to apply ethical problem-solving in these situations. Students contributed to online polls and forums where their responses relative to their peers were visible to challenge one another as to how professional identity is formulated and influences a sense of group identity.

In the second part of the course the emphasis was on communicating professionally in a persuasive way – either in written texts or oral presentation. The topics of the communication included business plans and summaries, posters, personal introductions and group presentations motivating for funding for the business idea to investors. In this there was an emphasis on justifying the business idea in terms of its social, environmental or economic impact. The experience of developing confidence in presenting, both as individuals and as part of a team, was seen to be important in terms of developing the confidence to exercise judgement and to persuade a team.

VII. DISCUSSION

Ethics has been demonstrated as a multifaceted concept [9], that permeates many aspects of the engineering undergraduate curriculum. Research [13] recommends that the assessment of competence within a qualification needs to be better nuanced and scaffolded in order to define the specific sorts of student learning that are possible and that need to be assessed. Competence is seen to be a necessary, but not a sufficient goal, for the assessment of ethics within the curriculum.

The shift online made learning more explicit and more visible. Ethics was presented as a combination of knowledge, skill, values and attitude and students were challenged to reflect critically on values and consequences, and on their established habits that assist them in making choices and decisions. Students were required to distinguish between compliance to an existing professional code, with the associated responsibility to conduct oneself as part of the profession, and rise to the challenge of exercising ethical judgement in situations which posed a dilemma or conflict of interest, both as individuals and as professionals. Here choice and decision-making impacted social, environmental or economic outcomes in significant ways. This process recognized that the graduate attribute specifically required that students demonstrate GA10 - "critical awareness of the need to act professionally and ethically and to exercise judgment and take responsibility within own limits of competence" [4].

In relation to the requirements of the ethics essay, both courses used a similar structure that provided the opportunity to explore one of two topics: a micro-ethical challenge relating to a dilemma faced by the student as part of the work experience or a macro-ethical challenge that would be faced by a professional working within industry. Dilemmas and conflicts of interest are explored as problems which are amenable to process of problem-solving process. While this can be seen to be effective with respect to the experiences of work experience as micro- ethical scenarios, macro-ethical scenarios involving the complexity of decisions relating to state-owned entities and energy choice and provision were less effectively discussed and resolved. Students who reflected on their work experience, found the discipline of scrutinizing a previously experienced ethical dilemma using a framework and reflecting on alternatives to be both liberating and transformative.

In the electrical engineering course, the overarching goal of the course was positioned as that of developing the student's sense of professional identity as an engineer, demonstrated in the student's ability to work independently and as part of an effective team, developing the skills to communicate persuasively across a variety of texts and in personal and group presentations and to demonstrate knowledge of professional and ethical responsibility. Where the graduate attributes of professional communication, individual, team and multidisciplinary learning and engineering professionalism were assessed in the capstone course, there was scope and flexibility in the curriculum to incorporate innovative pedagogic approaches and assessment that shifted the learning from a model where knowledge and skill is transferred from expert to student in a one directional approach to a constructivist model where learning is built in collaboration with peers and modelled in the interactions between participants and where learning takes place horizontally as well as vertically. This combines the strengths of the three theories and takes learning beyond objective expectations. This recognized the role that explicit engagement with both the ECSA Code and the graduate attributes plays in shaping the student's identity as an engineer. This required space for the student to explore and own their personal journey as an aspirant engineer, providing opportunities for the student to identify significant incidents which built up this sense of identity, and to collate artefacts that demonstrated their sense of who they are as engineers. Peer and self-reflection were built into the course structure, where preparatory reflective assignments were designed to build confidence and expand the student's ability to consolidate self-knowledge in a meaningful way. Developing the professional identity of the engineering student was seen to contribute to building their sense of professional responsibility which aligned with their ethical responsibility. In addition, building in opportunities to reflect on engineering identity, provided the space for students to claim aspects of engineering identity in a more personal way. This simultaneously developed their sense of professional responsibility. The reflection on work experience required students to reflect critically on previous decisions and to apply professional code to the analysis. Students found this contributed to their understanding of their own responsibility in a way that was both liberating and enabling.

In the chemical engineering course, the context in which students learn about ethics is enriched with tools for measuring, anticipating and avoiding harm, resulting in students' implicit awareness of their own power to effect change and of their responsibilities as part of a profession to avoid risk and to create benefit. The context of the course is sustainability as a rational alternative with clear benefits and affordances. Within this, there is a tendency for the ethics analysis to presume individual actors with agency exercising judgment to effect change. The particular focus to equip the engineer with practical tools and processes to measure risk and benefit, provides the vocabulary and conceptual tools to imagine sustainable alternatives. The effective transfer of knowledge expands the conceptual and discourse range of the students and allows them to participate within a community focused as change agents [18]. Here discourse is recognized to provide access and context to action.

The way ECSA's GA10 is formulated, focuses on the assessment of objective knowledge and skill rather than on attitude or values. This keeps the focus of teaching engineering ethics on objective fact and input relating to learning about an engineer's responsibility, including knowledge such as the requirements of the ECSA Code of Conduct [20] and what went wrong in various case studies involving disasters. Most importantly, current formulation of ECSA GA10 makes it possible for the student to avoid reflecting personally on their position on ethical matters or to account for attitudes or values. This misses important opportunities to engage with professional and engineering identity.

VIII. CONCLUSION

While the two courses examined ostensibly assess ethics in a similar way, as an ethics essay on either a reflection on an ethical dilemma experienced during work experience or a case study analysis of a scenario related to the particular engineering discipline, this analysis demonstrates that the particular curriculum context in which the module on ethics is framed, provides important structure that affects the focus and impact of the module. The analysis demonstrates that engineering ethics can be effectively incorporated in a variety of curriculum contexts, and that the particular context will affect the learning outcomes and the knowledge, skills and values developed.

Although ethics is explicitly mentioned in only one of the graduate attributes (GA10) of the Engineering Council of South Africa's graduate attributes, this paper argues that it is in the specific combination of the different graduate attributes that are to be assessed that ethics achieves its particular features and attributes within a course.

Engineering programs are weighted heavily in mathematical and engineering sciences, with an implicit hierarchy of what knowledge counts as important. In the sciences, knowledge is traditionally viewed as objective and neutral, to be transferred from the expert by means of instruction and application. This model may not work as effectively in the teaching and learning of ethics as the knowledge is not discrete but connects with identity and attitudes and values. Ethics needs to be approached in a variety of ways, where identity is seen as both an individual and a group matter. It can be difficult to get students (and staff) to shift gear to appreciate the different sorts of knowledge such as self-knowledge or strategic knowledge. Because of the professional requirement for engineers to act with integrity and responsibility [20], it is important that formative assessment requires the student to engage with their personal value system and to develop the skills to relate these values to the choices they will be faced with and the decisions that will need to be made. Wider departmental support for the teaching and learning of ethics within the undergraduate program is seen as important. This will require the development of a common discourse relating to values and attitudes that is broader than efficiency or technical proficiency.

In terms of the three metaphors of learning, learning as participation can be described as a process of coming to participate in the already existing discourses and practices of the engineering community, leading to taking on the identity of being a member of this community [21]. Developing a sense of identity as belonging to a particular group or profession is seen to be part of what enables participation in the profession [12] and is seen to be part of what affects the development of ethical identity and choice as ethical actors. In addition, the student is required to transfer general objective principles about case studies and the content of professional codes to a personal frame of reference and to transform conceptual knowledge and skill into the level of personal knowledge and meaning-making. In terms of learning as transformation, this analysis portrays students as able to contribute actively to the professional ethos rather than portraying them as passive receivers of an already established culture and ethos.

IX. IMPLICATIONS OF THE RESEARCH

This analysis has implications for curriculum and course designers in that it suggests the assessment of competence and graduate attribute within a qualification can be better nuanced and scaffolded to define the specific sorts of student learning that are possible and that need to be assessed. It further demonstrates the value of requiring sustained engagement with the teaching and learning process relating specifically to professionalism and ethics and challenges the role and responsibility of the course convener and/or lecturers in facilitating the students' shift from neutral observer to active upholder of behavior that is ethical and professional. It shows the role of research in promoting the agency and critical awareness of both teaching staff and students involved in a course and confirms the potential transformative impact of research on teaching ethics on the participants, including students, the academics responsible for planning and organizing the course and the researcher.

REFERENCES

[1] International Engineering Alliance (IEA), Graduate attributes and professional competencies, Version 3, Washington: International Engineering Alliance, 2013.

[2] S. Palmer, D. Holt, W. Hall, & C. Ferguson, "An Evaluation of an Online Student Portfolio for the Development of Engineering Graduate Attributes" in Computer Applied Engineering Education vol. 19, 2011, pp. 447-456. DOI 10.1002/cae.20324.

[3] F. Gutiérrez Ortiz, J. Fitzpatrick & E. Byrne, "Development of contemporary engineering graduate attributes through open-ended problems and activities", in European Journal of Engineering Education, vol ahead-of-print, 2020, pp. 1-16. DOI: 10.1080/03043797.2020.1803216.

[4] Engineering Council of South Africa (ECSA). Qualification Standard for Bachelor of Science in Engineering (BSc (Eng))/Bachelor of Engineering (BEng). NQF Level 08. Document E-02-PE. Revision 5 17 April 2019. [Accessed: 24 August 2020] [Online] Available at: https://www.ecsa.co.za/education/EducationDocs/E-02- PE%20

Qualification%20Standard%20for%20Bachelor%20of%20Science%20 in%2 0Engineering%20BSc- Eng_Bachelors%20of%20Engineering%20 BEng_NQF%20Level%208.pdf.

[5] G.J.T. Bombaerts, K. Doulougeri, N. Nievien, "Quality of Ethics Education in Engineering Programs using Goodlad's curriculum typology" in Proceedings of the European Society for Engineering Education (SEFI) 47th Annual Conference Research Papers, Budapest, Hungary, 2019, pp. 1424-1436.

[6] B. Balakrishnan, F. Tochinai & H. Kanemitsu, "Engineering Ethics Education: A Comparative Study of Japan & Malaysia" in Science and Engineering Ethics, vol. 25, 2019, pp.1069–1083. https://doi.org/10.1007/s11948-018-0051-3.

[7] C. Mitcham, "The true grand challenge for engineering: Self-knowledge" in Issues in Science and Technology, vol. 3, issue.1. pp. 19–22.

[8] J.R. Herkert, "Future Directions in Engineering Ethics Research: Microethics, Macroethics and the role of Professional Societies" in Science and Engineering Ethics, issue 7, 2001, vol.3, pp. 403-414. .

[9] B. Stappenbelt, "Ethics in engineering: Student perceptions and their professional identity development", in Journal of Technology and Science Education, issue 3, 2013, vol.1 pp. 3–10. https://doi.org/10.3926/jotse.51.

[10] G. Nudelman, "The development of engineering identity in an electrical engineering degree programme" in Proceedings of the Eighth Research in Engineering Education Symposium, Cape Town 10–12 July, 2019

[11] A. Gwynne-Evans, M. Chetty, and S. Junaid, "Towards a collaborative strategy to research the teaching of ethics within the engineering curriculum across South African higher education institutions" in Proceedings of the Research into Engineering Education Symposium (REES), Cape Town, 2019.

[12] J.H. Meyer and R. Land, "Threshold concepts and troublesome know-ledge: Epistemological considerations and a conceptual framework for teaching and learning" in Higher Education, vol. 49, 2005, pp.373-388.

[13] A Gwynne-Evans, "Student Learning at the Interface of University & Industry Relating to Engineering Professionalism" in Critical Studies in Teaching and Learning, 6, 2018, vol.2, pp. 1-20.

[14] A Sfard, "On Two Metaphors for Learning & the Dangers of Choosing Just One", in Educational Researcher, Vol. 27, No. 2, 1998, pp. 4-13.

[15] Y. Engeström & A. Sannino, "Studies of expansive learning: Foundations, findings and future challenges", in Educational Research Review Vol. 5, 2010, 1–24.

[16] H. Heydenreich & J.M. Case, "Faculty and Student Experiences of Curriculum Reform: A Case Study at the Chemical Engineering Program at the University of Cape Town" in Conference proceedings of the 2018 ASEE Annual Conference & Exposition. [Accessed: 14 Sep 2020] https://peer.asee.org/faculty-and-student-experiences-of-curriculum- reform-a-case-study-of-the-chemical-engineering-program-at-the- university-of-cape-town.

[17] H. Von Blottnitz, ""Life beyond the P&ID": Engagement of 4th year Chemical Engineering Students with Business, Society and Environment". Presented at the International Conference on Engineering Education in Sustainable Development, 2003.

[18] H. Von Blottnitz, "Promoting active learning in sustainable development: experiences from a 4th year chemical engineering course" in Journal of Cleaner Production, Vol 14 2006, pp. 916-923.

[19] Von Blottnitz, H. 2020. Slides for Course Introduction CHE4048F on Vula, the University of Cape Town learning management system.

[20] Engineering Council of South Africa (ECSA). 2017. Code of Conduct. Engineering Professions Act No 46 of 2000. Government Gazette. 142 (40691). 17 March. Government notice 41. Cape Town: Government Printer. [Accessed online 20 Sep 2020]. Available at: https://www.ecsa.co.za/regulation/RegulationDocs/Code_of_Conduct.pdf.

[21] S. Allie, M. Armien, N. Burgoyne, J.M. Case, B. Collier-Reed, T. Craig,
A. Deacon, D.M. Fraser, Z. Geyer, C. Jacobs, J. Jawitz, B. Kloot, L. Kotta, L., G. Langdon, K. le Roux, D. Marshall, D. Mogashana, C. Shaw, G. Sheridan & N. Wolmarans, "Learning as acquiring a discursive identity through participation in a community: improving student learning in engineering education", in European Journal of Engineering Education, issue 34 2009, vol.4, pp. 359-367.

[22] M. Belbin, Team roles at Work, Oxford: Butterworth-Heineman, 1993.

Technical Papers

Principles and pedagogies that shape a final-year Integrated Computer Engineering Project

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Abstract—**Accredited undergraduate engineering programs in South Africa are obligated to demonstrate that their programs successfully develop students in the twelve Engineering Council of South Africa Graduate Attributes (ECSA GAs). Graduate attributes are the skills and behaviors embraced in the application of knowledge. Universities exercise discretion in the manner in which GAs are assessed be it as individual activities or as a dynamic interplay between a progression of activities.**

At a University of Technology in the Western Cape, an integrated computer project (ICP) was selected as an effective opportunity where eight GAs was assessed. This is the first time GAs will be measured in the final year of an undergraduate program. Within the ICP a range of principles was identified and pedagogies were employed to deliver the assigned GAs. In meeting a diverse range of learning outcomes for the ICP, the knowledge areas applied range from design and synthesis to computing and information technology. Transferable skills employed include teamwork, leadership, personal motivation, time management, research skills, analytical skills, listening skills, and written communication skills. The ICP harnesses the sub-competencies of the eight GAs as the evaluation criterion for associated activities.

This paper offers a recollection of the development of the ICP from which the key principles framing the subject and the pedagogies employed to align the objectives and outcomes are identified and discussed. The principles and pedagogies form a framework that joins the five knowledge disciplines into a connected curriculum at a key point during the students' education to provide preparation for, and a small-scale experience of, professional engineering. This reflective study did not consider student perceptions or course evaluations at this time.

Keywords—competencies; pedagogy; project-based learning; authenticity skills, multidisciplinarity, motivation, self-efficacy

I. INTRODUCTION

The Diploma in Civil Engineering is a program offered at a University of Technology (UoT) in the Western Cape. The endorsed qualification (ECSA) develops graduates who can demonstrate focused knowledge and skills in a particular field. [1] Foucsed knowledge includes management, geotechnial and transport engineering as well as water and structural engineering. Skills include teamwork, leadership, personal motivation and time management, research and analytical skills, listening skills, and written communication skills. Therefore, the program pedagogy must provide students with opportunities where they can practice the application of their knowledge and skills in a workplace context. Pedagogical approaches used must also provide students with clear guidance as to what is expected of them to attain their graduate attributes (GAs). GAs is viewed by the department as the completion of an activity where GAs can be assessed directly or as a series of activities where the GA is assessed as a dynamic interplay of these activities.

The program was started in 2018, where exit level subjects were offered in 2020. One of the exit level subjects is the integrated computer project (ICP). It is a 30-credit subject, larger than the four other subjects of 7 credits and 14 credits. The ICP subject is presented as a project wherein eight of the twelve ECSA GAs will be assessed.

As the principal, on the ICP, I found little literature offering guidance on university projects solving real problems by investigating possible solutions. As well as projects where the learning experience uses real tools and processes in deriving solutions. Also, projects relying on integrated knowledge. Lastly, project measuring GAs.

The program within which the ICP subject resides is composed of knowledge areas such as Management, Geotechnical and Transportation Engineering, as well as Water and Structural Engineering. The lecturers wanted these knowledge areas present in the ICP. GAs would be allocated to knowledge areas based on similarities in activities which defined both the competence (GA) and the knowledge area.

This paper offers a recollection of the development of the ICP from which the key principles framing the subject and the pedagogies employed to align the objectives and outcomes are identified and discussed. Practical examples are presented throughout the paper, giving further insight into how a variety of approaches was used in a large-scale ICP.

II. RATIONALE

Engineering professionals are vital in society and their training and competency must be desirable by the community they serve. [1] Engineering practitioners perform distinct roles in society and this is evidenced by various ECSA categories of a professional engineer, a professional engineering technologist, a professional certificated engineer, or a professional engineering technician. The normal development of engineering practitioners has two important stages namely i) the education qualification aligned with a professional category and ii) completion of a candidacy program of training and experience. The person must demonstrate the competency required to register at the end of this time. In this program, the undergraduate will register as a candidate engineering technician to become a professional engineering

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technician who can study further and gain experience to become a professional engineering technologist. Current engineering programs require that GAs (competencies) be introduced during the attainment of the educational qualification. Thus, within the program, new principles and pedagogies are required to assess GAs in the attainment of their subject objectives and outcomes.

III. DEVELOPMENT OF THE PROJECT

In early 2019, a group of departmental lecturers came together to discuss an authentic civil engineering learning experience which would embrace a multidisciplinary approach to solve its problems. Lecturers agreed that they wanted students to make meaning out of their learning and recognize the connections between different learning experiences; thinking supported by Hapara. [2] It was agreed that the project would be of a small scale due to time constraints and that students would complete the ground-up design of a small freestanding retail structure.

The program within which the ICP subject resides is composed of knowledge areas such as Management, Geotechnical Engineering, Transportation Engineering. GAs would be allocated to knowledge areas based on similarities which defined both the competence (GA) and the knowledge area. Lai, Portolese, and Jacobson [3] conclude that educators must pay careful attention to design decisions such as activity sequence as it can have a meaningful impact without increasing learning time in authentic learning spaces. Table 1 presents the knowledge areas, arranged in sequence of how the project would unfold. Subsequently, the activities selected for each knowledge area are presented sequentially as it would be in the authentic space. A few activities were concurrent, such as the (e.g. Gant Chart).

TABLE I *Knowledge areas, gas and activities in ICP*

Knowledge Area	Graduate Attributes	Activities
Management	GA 8: Individual, Team & Multidisciplinary Working (1)	Activities at the beginning of the project Site Visit (G), Scope Statement (G), Gantt Chart (I) Activities during and at the end of the project Individual & Peer Evaluation after Geotech and Structures (I), Project Evaluation (I)
Geotechnical Engineering	GA2: Application of knowledge	Lab (G), Report (I)
Transportation Engineering	GA5: Eng. Methods & Information Technology	Geo Design & Environmental. Report & Drawings (I)
	GA6: Communication	
	GA7: Sustainability	
Water Engineering	GA4: Investigations	Catchment Design Report (G), Contour Map and Infrastructure Drawing (G)
Structural Engineering	GA8: Independent Learning	Structural Analysis Report (G)
	GA3: Engineering Design	Structural Design Report (G)

*(I) Individual = 6 activities

*(G) Group = 7 activities

Lecturers discussed the type of feedback which would support students to making meaning out of their learning and recognizing the connections between different learning experiences. Wiggins [4] recommends that feedback be value-neutral in that it would describe what the student did and did not do in relation to goals. Subsequently, the student knowledge area's activities span two weeks, with assessment and feedback occurring in weeks, 3, 6, 9, 12, and 15 of the semester.

Support (class meetings) and feedback are immediately available to the students. Class meetings are available weekly and supplement as briefings or progress meetings with clients (University). Feedback to students is offered after the knowledge area submissions. Feedback is framed by the range statement of the GA. Consultations with the lecturer are offered in support of the GA feedback. Where necessary, the activity is redone with the value-neutral feedback and re- assessed immediately, in line with the departmental GA policy. This is done so as not to adversely affect subsequent activities, thereby improving the competence of applying the knowledge and their skill in delivering the activity.

Activities took the form of a report, drawing, scope statement, Gantt chart, peer evaluation, and project evaluation. Table 2 presents the activity alignment with the knowledge areas below:

TABLE II *Detail of tools and activities*

Knowledge Area	Tool	Activities
Management	Scope statement	Provides an overall description of the students' work including deliverables, the justification for the project, constraints, assumptions, and inclusions, and exclusions.
	Gantt chart	Illustrates the timeline of how the project will run for items such as individual activities, durations, and sequencing of these activities.
Geotechnical Engineering	Laboratory work & Report	Retrieval of a soil sample from the site and carrying out a laboratory practical, capturing the results and subsequent subgrade design in a report.
Transportation Engineering	Report & Drawings	Developing a geometric and environmental design based upon the subgrade design and captured in a report with drawings
Water Engineering	Report & Drawings	Use the subgrade design in a catchment design and infrastructure design for the development
Structural Engineering	Analysis Tool, Report & Drawings	Benchmarking the structural design against the subgrade design and captured in a report with drawings

The completion of these activities included the use of MS office, drawing software such as AutoCad, and analysis programs such as MatLab and Prokon.Lefara and Swartz [5] suggest that undergraduates struggle to identify certain GAs because there is no direct link

Lecturers discussed the type of feedback which would support students to making meaning out of their learning and recognizing the connections between different learning experiences. Wiggins [4] recommends that feedback be value-neutral in that it would describe what the student did and did not do in relation to goals. Subsequently, the student should be able to adjust the following attempt. Each between the name of the attribute and the description of the attribute. GAs were allocated to knowledge areas based upon their similarity to the activities in that module (refer Table 1). For example, the communication GA is assigned to a report. Or based upon a dynamic interplay of activities such as the 'individual and teamwork' GA to a series of management activities such as a scope statement, Gantt chart, self, peer, and project reflection. Individual work and group work were distinguished to underpin the GA known as 'Individual, Team and Multidisciplinary Working". This GA was assigned to the knowledge area of management. Table 1 presents the management activities measured at the beginning of the ICP as well as those activities completed during and at the end of the project. Individual and group activities are presented in, similar quantities. The work of Mahdavinia and Modarres [6] support individual and peer reflections undertaken throughout the project so that focus can be on the process rather than on the product to reflect growth and change.

A semester plan would give representation to more detailed activities such as meetings and minutes but that does not serve the purpose of this paper.

A fundamental review of the 5 core knowledge areas was needed to support students learning. Lecturers deconstructed these knowledge areas and grouped sub-knowledge areas as

(1) that which is already known or 2) knowledge yet to be taught or (3) knowledge which could be researched. Also

- it became clear that the knowledge areas were not the connecting thread of the project but rather the sequence of activities and the skills and behaviors required to complete them (GAs),
- that some aspects of design (key to the project) was being taught simultaneously as the project (2). This concern was addressed by moving this module of the ICP to the end of the project (structural engineering). The teaching and learning of this content could then take place first and offer students a modicum of confidence in their design abilities.
- that research would have to form part of the learning of most activities and lecturers directly involved in the ICP would need to connect their teaching with research activities as part of the authentic learning process to close the gap of some knowledge areas which had not yet been taught (3).
- that a variety of transferable skills (e.g. time management, listening and communication) would be encountered by students in the application of knowledge in this multidisciplinary academic journey which would enhance the employability of students.

Subsequently, the project brief was re-formed. Firstly, as a general section outlining the purpose, program, objectives, outcomes, tools, and general site detail. Thereafter five assignments follow, each assignment representing a knowledge area. Each assignment describes their related activities, support material, and the activity rubrics. These rubrics connect the GAs with the activity. The GA sub- competencies are used as the criterion of the activity rubric with a performance assessment of emergent (≥0%), basic (≥25%), adequate (≥50%), and superior (≥75%).

Reflection of the development of the ICP ends here. After this reflection I realized that there were common principles and pedagogies embraced to enable the ICP. This is explored further in the next section.

IV. PROJECT PRINCIPLES AND PEDAGOGIES

During the conceptualization of the ICP, lecturers guided by more than 60 years of cumulative experience, suggested pedagogy with which they have had individual success to enable the project. The earlier reflection on the planning of the ICP presented emerging principles. These principles would define and direct the objectives and outcomes of the ICP. A literature review was carried out on the emerging project principles. It expanded the roles students would take on in the ICP, the tools they would use, how they would solve an authentic problem with a possible solution using transferable skills which could be taken into the workplace. The expanded principles are listed below:

- students would be taking on different roles as managers, laboratory technicians, etc. throughout the project *(multidisciplinarity)*
- the ICP is structured along with management principles such as planning (scope statement), organizing (Gantt Chart), leading (individual and peer evaluation), and controlling (project evaluation) *(project-based learning)*
- the students will complete authentic activities for real- world application *(authentic learning)*
- the abundance of individual and group activities will require transferable skills such as teamwork, leadership, personal motivation and time management, research and analytical skills, listening skills, and written communication skills *(skills)*
- support is evident throughout the ICP as feedback and multiple evaluations *(motivation)*
- at some point in the project, students will define their learning with authentic answers *(self-efficacy)*

These principles and associated literature are discussed in greater detail below, with examples of how they were realized in the subject curriculum.

A. Multidisciplinarity

In the first two years of undergraduate programs, problems are well defined where the problem is made clear and all applicable information is disclosed. However, in an authentic learning experience, such as the ground-up design of a small freestanding retail structure, there is a good chance of problems being broadly defined or complex. Many professional disciplines are evident in the problem, namely geotechnical, transportation, structural, and water engineering with management forming the common thread between disciplines. One of the sample problems from the project is that of a subgrade design (geotechnical) to support a pad footing (structural). This can be approached from the subject end or the student can be encouraged to applying new learning. A new approach would employ framing the problem, divining the approach and criterion (mathematics, knowledge areas), and interpolating the unknown with minimum design guidelines to put forward a proposal.

Use of analysis software illuminates weak points in the design and students can make recommendations for improvement. The improved design can then be presentedwith dimensions and materials.

Studying a topic from the viewpoint of more than one discipline (knwoledge areas) and solving a problem using a different disciplinary approach is termed a multidisciplinary approach by Klaassen. [7] The project has other examples demonstrating a similar philosophy. For example, the subgrade design (geotechnical) for a parking lot (transportation) using sustainable methods/materials (environmental). The integrated approach to the problem within the authentic learning scenario will engender in students the capacity to analyze the information as done in real-life cases,

B. Project-based learning

The ICP was designed around a student-centered pedagogy that includes a complex class approach in which students are expected to gain a deeper understanding by deliberately addressing an authentic learning experience; easily supported by project-based learning. This pedagogic engagement facilitates the assessment of GAs.

Almost every activity undertaken in professional practice by an engineer will be about a project. Significantly, Mills [8] deduces that project activities are closer to the professional reality in which students learn knowledge and skills by working for an extended period to investigate and respond to an engaging and complex activity or series of activities. Further, self-directed learning is stronger in project work since the learning process is less directed by the problem.

When the activity is authentic, then the two principles of project based learning and authentic learning align as students engage in workplace behaviors and tools to provide a solution.

The majority of activities in the ICP are focused on the design and progressing students through the various stages of the design cycle. From the scope statement and Gantt chart (management), to the laboratory work underpinning a road subgrade and parking lot design (geotechnical engineering), geometric design of intersections & accesses (transportation engineering), toward a catchment plan (water engineering) and structure loading and member sizing (structural engineering), culminating in the reflection of design and processes (project and peer reflection). The interconnectedness of these activities provides the space in which the skills of management, communication, collaboration, and problem-solving engage.

Mehaalik, Doppelt and Schuun [9] promote project-based learning among students from varied socio-economic backgrounds as this approach has met with more success than with other pedagogic approaches. Project-based learning follows the inquiry and scenario-based learning approach. As part of the only UoT in the Western Cape, the program facilitates the teaching of students from diverse socio- economic backgrounds where design subjects do not enjoy high pass rates. Perhaps a project-based learning approach in design areas can meet with more success in the ICP.

Based upon the mapping of knowledge areas and core activities (refer table 1) and the project brief and communications sessions where the purpose and expectations are made, clear there is a progression in terms of exposure to more complex problem-solving and design activities.

C. Authentic Learning

In education, authentic learning is an instructional approach that allows students to explore, discuss meaningfully, construct concepts and relations of concepts that involve real- world problems and projects that are relevant to the learner. Goh, Cochrane and Brodie [10] propose that authentic learning environments designed around scaffolded learning opportunities can change the values and behaviors of engineering students. In the ICP, students will undertake a sequence of activities that culminate in the ground-up design of a small freestanding retail structure. Students will authentically experience these activities so their behavior will mimic the workplace as they apply their knowledge using their skills toward designing a series of possible solutions.

Class meetings can simulate a project briefing and client progress meetings. Class time is scheduled and some of this time is formalized by the academic staff to demonstrate the purpose and the nature of professional communication. The student learning process has many opportunities to engage with learning material (their own time), peers (class time), and the academic staff (class time and consultations). It is expected that students may initiate these meetings if they see fit by taking up the unscheduled class time.

D. Skills

The endorsed undergraduate program (ECSA) provides undergraduates with technical and transferable skills per accreditation criteria by professional bodies. [11] The final year ICP provides an authentic learning experience in the form of project-based learning wherein most of these skills are practiced repeatedly and the competence assessed. These competencies (GAs) are assigned to specific activities or the interplay of a combination of activities and presented in the project brief at the beginning of the ICP to clearly define graduate expectations.

The first week of the ICP is spent addressing the purpose and expectations of the ICP, one of which is GAs and their assessment.

The assessment of GAs such as communication is easy as it can be measured at a moment or as an ongoing activity. A more complex GA such as 'individual and teamwork' requires a combination of activities, as well as post-activity reflection. Ellis, Han & Pardo [12] promote. 'productive collaboration' as it occurs robustly in a project-based learning environment where different perspectives and understandings promote deeper engagement with material and stimulate peer to peer learning.

It is worth noting that Mitchell, Nyamapfene, Roach, and Tiley [13] caution that when students are in a collaborative space, some students may be able to avoid practicing skills which they are less adept at and essentially hide in the collaborative space. The ICP minimizes this occurrence, by calling for equal amounts of individual and group activities (refer table 1) which supports good, productive collaboration.

As discussed previously, work is re-assessed immediately within a week after activities are returned utilizing the activity feedback so that activities that are still to be completed are not adversely affected by the preceding activity competence. Consultations are also encouraged to promote further understanding of 'mistakes' and improve future submission.

An objective of the ICP is to connect students to the workplace. One way is to provide them with templates (as is the case in the workplace) of reports, drawings, statements, charts, and reflections to convey the expectation in support of the behaviors which is required in demonstrating the various competencies.

Mitchell, Nyamapfene, Roach, and Tiley [13] promote the practice of reflection at several points in a project to improve participant perceptions of teamwork as well as their ability to work effectively with a team. Self, peer, and project reflection templates are provided at the onset of the project, and used intermittently, to assist with the understanding of these concepts and promote awareness of significant moments which populate these reflections.

The competencies assessed within the ICP as per the GAs defined in the accreditation literature [11] are listed in Table 1. Other GAs occurs naturally in this authentic project-based learning environment but are measured in other smaller final year subjects.

E. Motivation and Self Efficacy

Intuitively, we as educators all know the importance of motivating our students and delight in teaching motivated students. Motivation is distinguished as what a person will do not what they are willing to do. The ICP is driven by extrinsic motivation factors such as grades. The minimum investment by students is estimated at ten to fifteen hours a week. Mara and Wheeler [14] report that students find significance and value in pedagogical activities such as teamwork and hands- on authentic learning within a project environment. Students felt that they would use what they have learned in similar future experiences. Further, that engagement in teamwork is not always enjoyable but that participants could see the experience would be good for their future careers. At this time, it cannot be deduced if there are any intrinsic motivation factors in the ICP student experience. However, with regular feedback and support as provided in authentic learning environments, it is believed that the students will internalize and align their learning with their own experiences and identities.

Bandura [15] informs that self-efficacy refers to an individual's belief in his or her capacity to execute behaviors necessary to produce specific performance attainments. Dunlap [16] observes that within a project-based learning environment using pedagogy of authentic learning, collaboration and reflection increased levels of self-efficacy. Within the authentic learning of this project, there are a variety of activities that will require collaboration and independent studying by the student who is then compelled to find their own journey and define their own education and discover authentic answers which define the journey of self-efficacy. Thus, the performance of acquiring knowledge and applying skills can improve over time.

V. SUMMARY AND CONCLUSION

This work describes a reflection on the process undertaken to construct a multidisciplinary ICP in the final year of an undergraduate program. After reflection and literature review done at the same time, the core principles were identified, pedagogies utilized, as well as the activities related to the disciplines and transferrable skills. Authentic project activities are explained, student exposure to individual and collaborative elements at regular points throughout the ICP, and the diverse range of tools allocated to achieve the activities. The central connected purpose of the ICP is the sequence of activities and the skills and behaviors required to complete them which though multidisciplinarity, project-based learning, authenticity, skills, motivation, and self-efficacy enable the assessment of GAs. These findings in this reflection present a perspective that the adoption of suitable underlying principles and associated pedagogy reshape students' experience of engineering and their role of engineers in society.

VI. RECOMMENDATIONS

It is recommended that further research be conducted using subject evaluation to consider the impact of the subject on industry and student perceptions of their own competencies.

REFERENCES

[1] ECSA, "Engineering Council of South Africa," 1 February 2019. [Online]. Available: https://www.ecsa.co.za/education/EducationDocs/. [Accessed 9 August 2020].

[2] Hapara, 'Real-world, Hands-on, and Project-based, An Instructional Leaders Guide to Authentic Learning," [Online]. Available: https://cdn2.hubspot.net/hubfs/1546484/E-Books/Real- world,%20Hands-on,%20and%20Project- based%20Authentic%20Learning%20Guide.pdf. [Accessed 30 September 2020].

[3] P. K. Lai, A. Portolese and M. J. Joacobson, "Does sequence matter? Productive failure and designing online authentic learning for process engineering," British Educational Research Association, vol. 48, no. 6, pp. 1217-1227, 2017.

[4] G. Wiggins, "Feedback: How Learning Occurs," Big Ideas: An authentic Education e-journal, 2010.

[5] M. Lefera and J. A. Swart, "Assessing Senior Engineering Student's Ability to Identify Graduate Attributes," in 2018 International Conference on Multidisciplinary Research Track 4: Education ISBN: 978-99949-0-384-9, Culombo, 2018.

[6] M. Mahdavinia and B. T. Modarres, "An Evaluative Case Study: Reflectionfocused Assessment," Language Testing in Asia, vol. 1, no. 3, pp. 4-30, 2011

[7] R. Klaassen, "Interdisciplinary education: a case study," European Journal of Engineering Education, vol. 43, no. 6, pp. 842-859, 2018.

[8] J. Mills and D. Treagust, "Edgineering Education, Is Problem-Based or Project-Baed Learning the Answer.," Australian Journal of Engineering Education, vol. 3, 2003.

[9] M. M. Mehaalik, Y. Doppelt and C. D. Scholtz, "Middle-School Science Through Design-Based Learning versus Scripted Inquiry: Better Overall Science Concept Learning and Equity Gap Reduction," The Research Journal of Engineering Education, vol. 97, no. 1, pp. 71 - 85, 2008.

[10] S Goh, S. Cochrane and M. Brodie, "The impact on values and learning behaviours of engineering students from an authentic learning environment: Preliminary Analysis and Observations," in Annual Australian Engineering Education (AAEE) Conference, Melbourne, 2012.

[11] ECSA, "Qualification Standard for Diploma in Engineering: NQF Level 6 E-02-PN," ECSA, Pretoria, REVISION No. 4: 05 November 2019.

[12] R. A. Ellis, F. Han and A. Pardo, "When Does Collaboration Lead to Deeper Learning? Renewed Definitions of Collaboration for Engineering Students," IEEE TRANSACTIONS ON LEARNING TECHNOLOGIES, vol. 12, no. 1, 2019.

[13] J. Mitchell, A. Nyamapfene, K. Roach and E. Tiley, "Philosophies and pedagogies that shape an integrated engineering programme," HIGHER EDUCATION PEDAGOGIES, vol. 4, no. 1, pp. 180 - 196, 2019.

[14] R. M. Marra and T. Wheeler, "THE IMPACT OF AN AUTHENTIC, STUDENT-CENTERED ENGINEERING PROJECT ON STUDENT MOTIVATION," in 30th Annual Frontiers in Education (FIE) Conference, Kansas City, 2000.

[15] A. Bandura, "Self-Efficacy," 30 January 2010. [Online]. Available: https://onlinelibrary.wiley.com/doi/abs/10.1002/9780470479216.cor psy0836. [Accessed 15 August 2020].

[16] J. C. Dunlap, "Problem-based learning and self-efficacy: How a capstone course prepares students for a profession," Educational Technology Research and Development, vol. 53, no. 1, pp. 65 - 85, 2005.

Technical Papers

"Embedded Systems" international master's programme

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***Abstract*—The paper describes the "Embedded systems" international masters' educational program from the first implementation steps until the final version. The motivation of the program development was to produce the high-quality engineers for the industry, with the knowledge of English in addition to native Russian language, abilities to implement the projects, work in international project teams and study in international student groups. These skills are valuable for modern Russian industrial companies. The groups on this program are composed of the students from Russia, France and Finland. Paper shows the implementation of CDIO approach as the framework for implementing the whole program in accordance with these educational standards, provides the description of a new integrated curriculum, short description of a new dedicated workspace. Each of the components of the implementation of the new program provided us with a valuable experience that we want to share in this paper. In this paper, we describe in details our experience of implementation of the modern international masters' program in the university from Russian Federation. Our experience could be of use for other university management, faculty and the students, who intends to follow the modern trends in education.**

Keywords— SUAI, embedded systems, CDIO, master's program, implementation

I. INTRODUCTION

St. Petersburg State University of Aerospace Instrumentation is a multidisciplinary research complex. The SUAI's Mission is to train highly qualified and competent specialists capable of developing advanced technologies and modern industries. Eight institutes and four faculties of SUAI teach 135 educational programs. Nowadays SUAI does not focus on aviation only, but we also teach IT, economics, law, political science, international relations and linguistics. Currently there are 13 500 students enjoying the convenient facilities of education at SUAI. Only 800 of them come from other countries.

Russian Universities are poorly represented in the World Rankings. SUAI strategic goal is to be included to most popular university ratings like QS, THE etc. In the most ranking methods, the number of international students is one of the most important evaluation parameters [1, 2]. Therefore, it is very important to significantly increase this value. Such ranking parameters like publications, staff, etc. could be improved in observable time. However, the number of international students is depending on many other parameters and strategies. University decided to focus on this point and develop the strategy to engage the students from the other countries.

II. MOTIVATION FOR THE PROGRAM CHANGE

There are many things need to be done to change the situation with international students. It includes the facilities to information access [3], worldwide university promotion [4] and, of course, a new educational features and modern studying techniques. The last point is the one that we want to focus in the current paper.

The easiest way to improve number of international students for Russian university is to attract students from Russian-speaking countries. Of course, this strategy successfully works for many years, but it does not give any new experience for our students. The organization of double diplomas program with international universities is the other way. Although this approach is popular in Russia, but it could take a long time, require a lot of documentation, international agreements and aligning with ministry requirements. We needed an approach that would make it possible to quickly organize a students exchange, promote the program, and only then think about double diplomas.

One the most popular reasons for international students to go abroad is internships [5]. Therefore, it is possible to use a semester of exchange, which is the case for the most European universities. Universities in the Russian Federation use this approach (for example, SAU, MAI). So we decided to find one educational program, where teachers can lecture in English, and change it to the modern educational level to be attractive for the foreign students. In addition, we can start with implementation of one semester only, not with the whole program.

We decided to change the current educational program "Embedded systems" and launch a new international educational program for the master students to increase the internationalization. We decided to take the CDIO [6] approach as the framework for implementing the whole program.

The CDIO Initiative is an educational framework that stresses engineering fundamentals set in the context of conceiving, designing, implementing and operating real- world systems and products. Throughout the world, CDIO Initiative collaborators have adopted CDIO as the framework of their curricular planning and outcome-based assessment. The CDIO approach uses active learning tools, such as group projects and problem-based learning, to better equip engineering students with technical knowledge as well as communication and professional skills. Additionally, the CDIO Initiative provides resources for instructors of member universities to improve their teaching abilities. CDIO is 12 strong standards that could help to improve the educational quality. SUAI is a member of CDIO Community since 2015.

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At the very beginning, we looked at the "Embedded systems" programs at the other world Universities. In Europe we found good examples at KTH, Chalmers and Eindhoven University of Technology. In Russia there is only one international program at Kazan National Research Technical University. Therefore, in our region and neighbor regions we do not have Universities, which can graduate specialists with the skills that will be discussed in the current paper. European examples could be taken as a use case to get the best program in this field in Russia and try to attract students from other countries. We decided to focus on a few major aspects: implementation of project-oriented educational standards and organization of joint educational program for international students and English-speaking Russian students. In addition, we decided to find a way for the program to become double diplomas program.

Therefore, the educational process would be able to form not only the specific subject knowledge, but also the some personal and interpersonal abilities for the implementation of products, processes and systems. The newly developed curriculum would integrate personal and interpersonal skills.

In this paper we will try to describe the methodic that we used to improve and change the program and to get the international program, which is a good use case for the Russian Universities and could be helpful to the others also.

III. INITIAL EMBEDDED SYSTEMS MASTERS PROGRAM

At our department of Aerospace Computer and Software Systems we had an educational masters' program "Embedded systems", which was lunched a long time ago. During the implementation of the program, we revealed a number of problems. We saw, that current educational program did not make the studying process interesting and fruitful for the students. Most of the students saw this program as an inevitable step to the graduation, because bachelor in Russia is not recognized as a "ready engineer". Some students began to work in parallel with the studying; as a result – they did not have time to attend classes. Some of the courses in the program just gave deeper knowledge in the area, but most of the students would not use it in future. Moreover, most of the courses in program consisted of typical lectures and practical works, so the educational process did not attract interest and did not motivate students.

On the other hand, we have a research institute for High-Performance Computer and Network Technologies [7] as a research department of the university. This institute makes research in the embedded systems and aerospace areas, has the modern equipment, high-skilled specialists and young Profs, who has strong competences in the field. In addition, most of the staff is English speaking.

Therefore, we wanted to use our skills to change the current situation completely:

- increase the interest for the students with active learning and interaction;
- teach students the state-of-the-art knowledge;
- implement modern educational standards and techniques;
- attract international partners and students.

These could give us ability to train high-quality specialists: engineers for the industry and researchers for the Universities and R&D companies, make the students excited with the studying. High-quality students for us is not only people with a good level of knowledge, but also students with communication skills (including international), ability for project work, management, abilities for the scientific research and leadership.

IV. IMPLEMENTATION OF THE NEW PROGRAM

During the development of a new educational program firstly we defined purposes for this program and expected learning outcomes in full respect to the CDIO Syllabus and aligned with the Russian Ministry education requirements.

Then, in order to meet the real expectations of the industry and students, which skills and competences would they need in future, we have conducted several interviews with the key program stakeholders: current students, alumni, prospective employers and faculty members of the department. We have designed four questionnaires for these groups and offered to the stakeholders to fill them.

We figured out that current program does not meet the expectations:

- Industry wants to have specialists, that perfectly know the modern technologies, can work in project teams, communicate and does not need much time to adapt to the workplace;
- Students want to learn the hot topic subjects, do something with their hands, have ability to stage in the companies and participate the students exchange programs;
- Lecturers want to give the theoretical knowledge together with the hot topics, to have more skilled and active students, to make the real research with students and colleagues.

Based on the stakeholders' feedback we have designed a new integrated curriculum. This new curriculum incorporates several updates on the students' work in projects, new engineering disciplines and several supplementary non- engineering courses. The whole curriculum consists of the six main tracks producing different learning outcomes and students' competences (see Figure 1):

- Project track is related to the project management and business.
- Communication track gives international language communication skills and philosophy of engineering.
- Formal methods track prepares students for the research and gives mathematical background that was missing during the studying in bachelor.
- Embedded systems and Intelligent systems track are the main tracks for professional knowledge.
- R&D track stands for the work in multidisciplinary projects during the studying, including masters' thesis work and scientific seminars.

After a detailed review of the program we noted, that within the framework of some courses they give outdated information that does not correspond to modern realities. They are such courses as "Computer networks and telecommunications", "Information safety and security" and "Mathematical methods for scientific research".

In addition, we supplemented the program with "Artificial neural networks" and "Systems Modelling" removing old courses, which did not elaborate the required competences. The final detailed curriculum is shown at Figure 2.

The Project and R&D tracks were designed from the scratch.

The big work has been done to include the R&D track and project work to the program, because it was very difficult to find a place for the track, that requires so many students' time and credits. In "Embedded systems" program R&D track stands for design-implement students' experience. We had to find a space in the curriculum for the students to work on it, and time for the staff to supervise it.

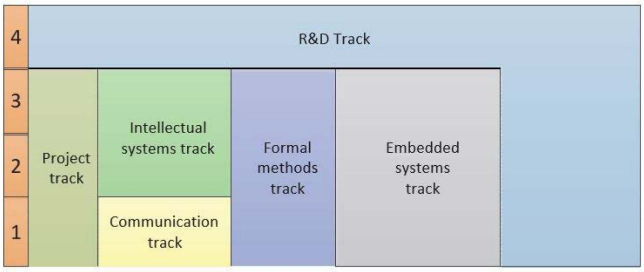

FIGURE 1 *Structure of the Embedded systems masters' program*

The first implementation step was to try to make a project only for one semester in terms of one particular course. That has been done to see the reaction of students for such kind of work and a real outcome of the project – would students better learn the material and get the expected skills. Typically, during the course laboratory exercises students had to accomplish a number of laboratory works specialized for this discipline. We replaced this practical works for the small project. Students had a project team and a project leader, and the interesting task, which they had to complete until the end of the semester. The lecturer was a supervisor for each project team. Such kind of small projects showed the positive result – student enjoyed this practical work, they got better results. The most interesting thing is that there were no students who did not successfully pass the practical work.

So we decided to move further and placed the project work as a separate course in the curriculum. Old curriculum for the masters had one day of Research work each week. We replaced this Research work by the Work on real projects that also could be the base for the master's thesis.

4	Teaching practice *8 credits*		Scientific seminars *2 credits*	***Master's Thesis + R&D project*** *20 credits*							30 credits
3	Artificial neural networks *3 credits*	Systems for digital image processing *3 credits*	Entrepreneurship basics *3 credits*	Information safety and security *3 credits*	Onboard networks for spacecraft & aircraft *3 credits*	Computer networks and telecom. *3 credits*		Scientific seminars *3 credits*	**Main R&D project** *9 credits*	30 credits
2	Intellectual systems *3 credits*	Systems for digital signal processing *3 credits*	Optimization methods 3 credits	Transmission of discrete messages *3 credits*	Systems- and Networks-on-Chip 3 credits	Architecture of parallel systems *3 credits*	Systems modeling *3 credits*	Scientific seminars *3 credits*	*6 credits*	30 credits
1	International language *2 credits*	Methodology of scientific cognition *2 credit*	Project management for inf. systems *4 credits*	Math. methods for scientific research *3 credits*	Embedded systems Design in VLSI *3 credits*	Parallel programming *3 credits*		Scientific seminars *2 credit*	**Introductory R&D project** *11 credits*	30 credits

FIGURE 2 *Embedded systems master's program curriculum*

In parallel, we lunched the English version of the program, so the students could choose at what language they want to study. Soon we got the response from our partner Universities in Europe that their students want to come to study to SUAI.

Starting from that time our students has ability to study in English with the students from Europe, participate in real projects and international project teams. This approach gives good results, a few very good projects has been finished, and results of that R&D work are very valuable.

For the research, project students usually choose between the following areas:

- Communication protocols for the onboard equipment;
- Simulation and verification of systems;
- Embedded systems design;
- Software development for embedded systems;
- Analysis and updates of the onboard hardware;
- Video processing;
- Heterogeneous computing.

The good examples of such projects are presented in the papers and conferences. For example:

- "Simulation of ExoMars2020's Rover Network Using SystemC" [8];
- "Tools for Analysis and Tracking of Deadlock-Free Routes in On-Board SpaceWire Networks" [9];
- "Developing the Indicators Framework for Creating Display Systems" [10].

Figure 3 shows the photos from the project defense and R&D conference, where the results of the students' projects were successfully presented.

Project work requires a project space. We organized the engineering workspace at our Department. We have built a space, where students can come anytime and work on their projects, use blackboards and monitors, discuss problems and meet with supervisors. In addition, we provided access to the specialized modeling software (e.g. IBM Rational TTCN Suite), embedded systems design software (Cadence Design Systems), 3D printers, test equipment: logical analyzers, multichannel digital oscilloscopes, etc.

So now working on the projects and research our students can implement the full embedded systems design cycle by using specialized professional tools and equipment and finally produce prototypes

In addition, students, who work on projects during the summer practice and internships, successfully use this project space also.

To increase the interest of the lectures, facilitate the study we implemented active learning methodologies. We made special interviews, question-answer sessions and tests that we have several times during the semester. This gives an ability to see, do students really understand the material. In some courses we spend additional time to answer all the students' questions and, if the lecturer sees that students did not get the material, repeat the most important parts of lecture to be sure that all the further material would be understood correctly. As the part of R&D track, we added the R&D seminars for students to communicate, present the intermediate results and discuss the progress. These seminars are attended by an outside Prof, who gives suggestions, helps to improve and shows other ways to solve the problems.

FIGURE 3 *Photos from the project defense and R&D conference*

Implementation of new learning assessment methodic made the control how students understand the material easier. Therefore, it helped to formally justify the final mark for the subject at the end of the semester. We moved from the old Russian 5-grade system to the 100-points system, where student can earn his points for different types of tasks, tests, answers or final exam. Less than 45 points for the whole semester is did not pass, 46-60 points means passed, 61-80 points means well passed and more than 81 points is excellent.

Teachers can give points for every type of work during the semester – tests, questions and answers, lectures participation, practical tasks, exam. The final mark would consist of different things that student should do. So students can choose what to focus on, what they can do to get the mark, that they plan to have.

After the implementation we saw that students became more responsible and attentive leaning the disciplines. They show better results on the exam and the better level of knowledge.

Of course, we do not want our program to stay as is. We do everything to evaluate. We made questionnaires for the students and ask them what did they expect from the course and did it meet the expectations, did they like it, was it clear, how could it be improved, what did they miss. This shows the students that they are really a part of the program and the educational process.

V. PROGRAM IMPLEMENTATION RESULTS

Since we started the implementation of the new masters' program, we see a few positive tendencies. The first one is that the number of partner European universities is increasing. We started with one French partner and now we have five universities from France, one in Finland. We started the students exchange discussions with China and Germany.

Number of Russian students who wants to attend the program increased: we started from 4 students in a group, and now we have 10. It is not easy to find a student, who knows English and is ready to study and communicate in English. For now, we got many positive responses from Russian students in the questionnaires and program results discussions.

We see that the interest for the program among the university staff becomes bigger. International program, that covers different aspects of the embedded systems development, implementation and exploitation, supported the intercommunication between the university departments and teachers.

Finally, the original task to find a way to attract international students to the University is solved. We implemented a program, which is taught in English. We started from one semester, invited international students for the European exchange semester. For the first time we got 4 international students, for now this number increased to 6. Next year we plan to make it 10. Our students say that the educational process is interesting, real projects and program courses give a good background for the future. Students indicated it in the semester reports and discussions in their universities. Number of students nominated from the foreign universities is growing from year to year.

In 2021, we plan to get the full group of 20 people that will study in English. Russian students will study for 4 semesters and international students would come for the exchange semester, which they would choose. Russian part of the group would be constant and the international part would be changed from semester to semester.

VI. CONCLUSION

After all the steps, the program is ready and successfully works for 4 years (in testing mode for one semester) and starting from 2019 we implemented the full 4-semester program (120 ECTS credits). The program is international – we have the international students, international lecturer, we have a student exchange with international Universities, we have a real international cooperation. This program is the base for the double-diploma international program with our partner University in Europe.

All the graduates of our program got good positions in companies and we saw only positive feedback. Along with professional skills these people already know, how to be a part of a team, how to work on a project, make a research, learn the missing topics on your own.

For now, the students and the staff are happy with the new program – for out University it is novel, it is interesting for the students and it gives professional engineers to industry. The level of students becomes higher, the project results more valuable. Number of incoming international students is increasing each year.

As the next step, we plan to implement more international programs in English. Moreover, we started the building of double diplomas program. We find new partners all over the world.

The rebuilding of the "Embedded systems" masters educational program and implementation of CDIO standards gave a good opportunity to combine the scientific knowledge with the practical experience, increase the quality of the graduates and find a new partner Universities and partners from the industry.

REFERENCES

[1] QS Rankings web-site, "Increase in Number of International Students", https://www.topuniversities.com.

[2] THE Rankings web-site, "Required reading: increasing numbers of international students", https://www.timeshighereducation.com.

[3] Digital Marketing Institute, "Digital Strategies to Attract International Students", https://digitalmarketinginstitute.com

[4] Worldwide College Tours, "How to Improve Your International Student Recruitment Strategy in 2020", https://www.worldwidecollegetours.com. 2020.

[5] Sh. Schulte, R. Choudaha, "Improving the Experiences of International Students", Change The Magazine of Higher Learning 46(6):52-58, 2014. pp. 1-12

[6] Web-site of Institute of High-Performance Computer and Network Technologies, https://vkist.guap.ru/en/

[7] Crawley, E., Malmqvist, J., Östlund, S., Brodeur, D., Edström, K. (2014). Rethinking Engineering Education: The CDIO Approach. Springer.

[8] Nairi A., Plante J., Sinyov N., Olenev V., Korobkov I. "Simulation Of ExoMars2020's Rover Network Using SystemC", Proceeding of the 24nd conference of FRUCT association (pp. 269-276), Moscow, Russia, 2019

[9] Olenev V., Karandashev A., Alexeeva K. "Tools for Analysis and Tracking of Deadlock-Free Routes in On-Board SpaceWire Networks", Proceeding of the 26th conference of FRUCT association (pp. 628-634), Yaroslavl, Russia, 2020

[10] A. Volk, V. Ivanova, A. Syschikov, B. Sedov "Developing the Indicators Framework for Creating Display Systems", Proceeding of the 26th conference of FRUCT association (pp. 700-701), Yaroslavl, Russia, 2020

Technical Papers

Decision skills in engineering programs - a key for a VUCA Era

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***Abstract*—Judgment and decision skills are now essential graduate attributes for the future engineer, in particular for facing the more frequent than ever volatile, uncertain, complex and ambiguous (VUCA) world in both professional and societal situations. One of the responsibilities of engineering programs is to train students to be agile and capable of taking decisions in challenging VUCA situations. This paper presents conceptual and practical results of an European project which explored, designed and iteratively analysed innovative educational learning and teaching activities to train decision-making skills. Following a design-based research approach, including both quantitative and qualitative analysis, the four VUCA dimensions were categorized, the relevant decision skills were defined, and activities to train decision skills were tested and evaluated. One outcome of this work is a rational selection of learning activities based on experiential learning to train specific decision-making skills, which can be integrated in the engineering curriculum. These learning and teaching activities are freely available for adaption in engineering programs. In addition, six reference models are proposed and delineated, in an effort to support the integration processes for curriculum revisions.**

Keywords—engineering education, decision-making skills, learning outcomes, VUCA, learning & teaching activities

I. INTRODUCTION

Engineers today are required to understand and In 2020, we are facing a new world due to the COVID-19 pandemic and this world is changing at a rapid pace in a way that we are unsure of. More than ever must technological universities prepare their engineering graduates for this volatile, uncertain, complex and ambiguous (VUCA) world [1], and in particular provide them with the skills needed to make good decisions. Engineering programs have no option but to make certain that their strategies and intended learning outcomes properly prepare their graduates for a changing and dynamic future and a new landscape of career opportunities. The question is how can we better prepare engineering students for this new VUCA world?

The current pandemic highlights the need for enhanced decision skills of engineers in a VUCA environment, and in particular on taking proactive and responsible decisions. An engineer need not only be expert in her or his field and have the knowledge of decision models, but also have the skills to make decisions in various situations.

The field of decision analysis was first introduced by Raiffa and Schlaifer [2] and was originally mostly a mathematical discipline. Later scholars like Frank Knight, Francis Galton, Milton Keynes, Oscar Morgenstern, Herb Simon and John von Neumann, just to name some few, paved the way for further understanding of how normative methods are connected to social sciences.

The works of Kahneman and Tversky [3, 4] are likewise instrumental in the development of decision analysis as discipline that both include mathematical and social science. VUCA, initially introduced by the US Army War College in the eighties is an interesting addition to the decision analysis context and has made its way to the business lexicon as explanatory platform to understand corporate decision making in our complex world [1].

The VUCA concept has also raised interest within education. Studies indicate that VUCA can be used to understand better the attributes that an engineer should possess meaning the ability to question, label patterns, model conceptually, decompose, experiment, visualize or ideate and communicate effectively [5]. Moreover, VUCA concept can be used to enhance the educational environment by making educational institutions more agile and adaptive to changes and diversity [6].

The aim of this paper is to provide ways on how engineering educational programs may integrate and implement training for decision-making skills in VUCA environments for their graduating engineers and offer tried out examples of training such skills. The following question is used to frame the analysis in light of the main aim: How can we approach and overcome the educational challenges in preparing engineering graduates for their future decision- making skills in a VUCA world?

II. SCOPE

The main objective of the Erasmus+ DAhoy project (www.dahoyproject.eu), lasting three years, was to explore innovative educational ideas on how to integrate decision- making skills in engineering educational programs. The project is grounded on an understanding of the perceptions of students and includes shared examples of innovative learning and teaching (L&T) activities. The project supports the coherent inclusion of active and engaging pedagogical models, to better prepare learners and professionals to face VUCA situations, echoing their future professional environments, may it be a pandemic, natural disaster, refugee crisis, social media disaster, financial crisis or internet overload, to name a few. DAhoy chose to investigate decision-making as a transversal skill, with three complementary dimensions:

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- Math-based decision-making, rational approach for large projects, including models and processes as found in multi-criteria and risk analysis;
- Social-based decision-making, includes individuals' interdependencies and social identities;
- Career-based decision-making, to choose own personal career path and manage her or his competence development.

The three dimensions are not exclusive, each having in the literature its own theories, methods and good practices, but sharing some common grounds. Math- and social-based decision making are conventional [e.g. 3, 4], but in the student-centered learning approach used in the DAhoy project the inclusion of career-based decision making is appropriate and coherent with new professional needs. A major outcome of the analysis in the project was the identification of seven skill statements (i.e. D-skills), i.e. learners should be capable of:

- D1 Recognise and qualify the VUCAlity of situations,
- D2 Analyse VUCA situations,
- D3 Make a judgement in VUCA situations,
- D4 Face complexity of VUCA situations,
- D5 Organise and implement actions in VUCA situations,
- D6 Take responsibilities in the decision process in VUCA situations,
- D7 Learn from his or her experience of VUCA situations.

The above seven skills can be summarized in the DAhoy project motto: "good decisions at right times".

III. METHOD

One efficient way to train students in decision-making under VUCA-like conditions is through experiential learning and teamwork pedagogical styles [7, 8]. Combining these two learning styles emphasize the concurrent math and social aspects of decision making [3, 4]. In 2018 and 2019, project partners analysed quantitatively and qualitatively six one- week innovative L&T activities with STEM and engineering students and faculty (reports and more detailed data analysis are available on the project's website). These and many of the L&T activities analysed in DAhoy can be adapted to different educational fields.

A. Design-based Research

During the project, decision skills statements and related outcomes were developed in the context of a design-based research (DBR) [9]. DBR focuses on real educational situations [10], which are potentially more complex than simulated environments. The DBR takes into account several variables – knowledge, skills and competencies, motivational factors, the learning situations and VUCA environmental factors in the DAhoy analysis.

The DBR commenced by taking into account high reliability organisational principles [11]. These principles provide guidance to a mind-set in avoiding catastrophes despite a high level of risk and complexity. Specific examples that have been studied are on nuclear power plants, air traffic control systems, naval aircraft carriers and more recently some healthcare organisations. In the project, specific high reliability variables were scrutinized during VUCA learning events, thus allowing for revisions of the design and L&T offerings [12].

B. Qualitative and Quantitative Analysis

The selected DBR theoretical framework allowed for more methodological robustness in the analysis. In a second DBR iteration, decision-making statements were selected and used for learning activities redesign and student assessments aside a VUCA situation analysis grid. Overall, 59 STEM students participated to the DAhoy L&T activities, and 30 faculty and staff. All participants completed the same questionnaires on decision-making and VUCA rubrics.

The questionnaires included Likert scale choices and open questions covering the satisfaction level, what was most appreciated, the VUCA results level, the skills acquired, the impacts level, what would be different for them afterwards when facing decision-making and VUCA situations, so as the level of lessons learnt. In addition, there were questions on the value of the L&T activities regarding decision-making and VUCA situations, both from the students' and teachers' perspectives, and on possible reutilization in further learning programs on the teachers' side.

Examples of questions are: "should you happen to encounter similar situations, would you react differently now (state examples of what would be different)"; "the activities enabled me to deal with uncertainty" / to develop specific or open field decision skills. The questionnaires were the same for all the L&Ts and there was consistency in the answers, even though the participants were not with the same profiles, but all engineering students or STEM teachers/faculty.

IV. VUCA RUBRIK AND ANALYSIS OF COURSE CAPSULES

One outcome of the project is a toolbox of 15 pedagogical activities that can be utilized by engineering institutions that want to develop learning activities to train decision-making skills in a VUCA context.

A. VUCA Analysis Grid

Depending on the level of VUCA (low-medium-high) for each D-skill, an institution may select activities or course capsules that can match their needs. Figure 1 is the VUCA situation analysis grid elaborated, inspired by Bennet & Lemoine [1], with the interpersonal component added in the first column, which includes team number and disciplinary / cultural dimensions. This grid aided in developing and analyzing the learning and teaching events.

Magnitude/ variability	Disruption components of a situation					
	Interpersonal		Volatility	Uncertainty	Complexity	Ambiguity
Low	1		Little variation in factors	Identified parameters	Simple factor organization	Plausible interpretation (of a rule or process)
Average	2 or more individuals	Mono-discipline and culture	Preditability of change and factors	Incomplete and limited information, partial knowledge	Several sources and components, simple structure	No obvious interpretation
High	2 or more individuals	Mutlidisci-plinary and multicultural team	High unpredictability of factors	Unidentified, unknown, and non-measurable parameters	Numerous parameters and factors, disorganization of these factors, many cause-and-effect relationships that do not allow for an established structure to be created	No interpretation possible undecidability, indemonstrable statements

FIGURE 1 *VUCA situation analysis grid with interpersonal component (iVUCA) from [9].*

In the 6 European mobilities of the project (overall 24 days), participants experienced about 30 different learning situations in the form of activity capsules, covering various dimensions, e.g. math-based, social-based, and career-based. Capsules were iteratively developed, each lasting from 2 hours to 2 days. These capsules are interwoven with the learning of related disciplinary knowledge and other skills, sometimes in professional-like environments. Each capsule relies on pedagogical intentions and style with the learning goal of enhancing decision-making skills in environments that could be VUCA (cf. Figure 2). These capsules are described and are available on the project's website under Creative Commons licence.

FIGURE 2 *VUCA characteristics of an activity capsule*

B. Course Examples and Capsules at the European Level

In the spirit of the DAhoy project, Reykjavik University ran a two-day intensive course called "Disaster Days" in September 2019 with 230 Icelandic engineering students and DAhoy engineering students from France and Scotland, using the experiential learning style [13, 14]. The pretend disaster, a VUCA scenario, for Disaster Days in fall 2019 was, ironically, the outbreak of a worldwide plague that forced the authorities to immediately isolate the island, and all supplies to the island were cut off. The task presented to the students was to make prompt decisions and plan the first reaction in Iceland, and estimate if and how the nation could survive in isolation for possibly a few months. The math dimension was preponderant, and social dimensions were also involved. In analyzing this event [15] focused on how this event fostered a positive journey for the student through the engineering program.

The engineering programme at Reykjavik University had run similar events for a few years. Analysis of the questionnaires following the event showed that the students appreciated mostly the teamwork in large international teams of students (social dimension) and the Disaster Days activity. There was a large and rich fan of answers regarding the skills acquired, including decision making capabilities. Most of the participants were taken aback by the learning style, even if it took place mostly in classrooms via project-based learning style.

At IMT Atlantique in France, engineering students from Iceland and Scotland were engaged in the "Reliability and Decision-Making via Inshore Cruising – we are all in the same Decision Ship" one-week experiential course for snap- decision training outdoors. In this training event, for a social dimension, part of the training included a capsule in which the students, novice in sailing, had to coordinate immediate reaction for man overboard and rescue [16], under iterative scenarios with various level of VUCAlity. Several unexpected events at sea were repeated with increasing complexity to facilitate confidence and reliability, followed by group discussions and analysis on the good or bad decisions they made, to learn from the experience. In another capsule, under a math-based dimension, students had to prepare navigation plan for a one-day coastal cruise under environmental constraints of weather, currents and tides, and then justifying its strengths and weakness including the risks, taking into account the crew and potential material failures. The students had to actually go sailing according to the plan they made, confront the associated risks, and manage unexpected events. It was clear from the questionnaires done at the end of the course that the students enjoyed the unusual environment and the outdoors activities at sea.

The students stated that they had learnt a lot, even if destabilized by the less formal organization of the learning activities, where they were confronted with unusually difficult and unexpected events calling for immediate decisions and actions. From the teacher's perspective, naturally, the reusability of such learning activities requires some adaptation.

For the career-dimension, the project partnership also led to the development of a professional career course, including several reusable capsules, to prepare students for VUCA careers [17]. Motivation factors for the first job were analysed at the very beginning of the project. According to students' responses, they consider the mission of the job as a primary criterion, followed by job well-being, style of management, culture and if the job matched their core personal values. Other criteria the students mentioned included teambuilding, responsibilities and autonomy, position or titles ('prestige job'), location (e.g. local/international), training options and lifelong learning. The DAhoy project has set up the 'YOU' continuum that can cover a 3-year curriculum, with three program components called Yourself, Open-mindedness and Up-to-you. Each components includes capsules, aligned with decision skills.

A formative evaluation integrated in the capsules are designed to continuously improve the judgement skills of each student. The YOU continuum can be quickly integrated or adapted as a ready-to-go toolkit in career training courses with evaluation and credits at Bachelor or Master levels.

These three course examples are indeed in line with recent papers that have used the VUCA-concept to analyse attributes of engineering students [5] and desired agility of educational institutions [6].

V. FINDINGS AND ADAPTATION

To facilitate the adoption of transversal decision-making skills in existing educational programs, including the various dimensions, the project developed a framework specified by six Reference Models (RMs). These models, or steps along the way of adoption, are intended to guide program directors and university leaders in continuous integration and implementation of L&T capsules for decision-making skills in and for VUCA-like environments. Based on the L&T activities conducted during the project in 2019-2020, partners proposed in 2020 a flexible process of analysis, design, evaluation and revision, as well as theoretical contributions on curriculum integration of decision-making skills.

As with all quality enhancement processes, adapting decision-making skills in engineering programs involves both the effort of the faculty and the leadership of the engineering programs. This involvement is even more relevant when dealing with transversal skills, aside accreditation graduate outcomes.

A. Reference Models

The six RMs provide program leaders with the core guidelines and quality enhancement procedures to implement training of decision skills. The six RMs are interconnected, each describing a major concern to be considered by stakeholders, which may have distinct responsibilities in educational programme design, development and quality assurance. The RMs are (see also Figure 3):

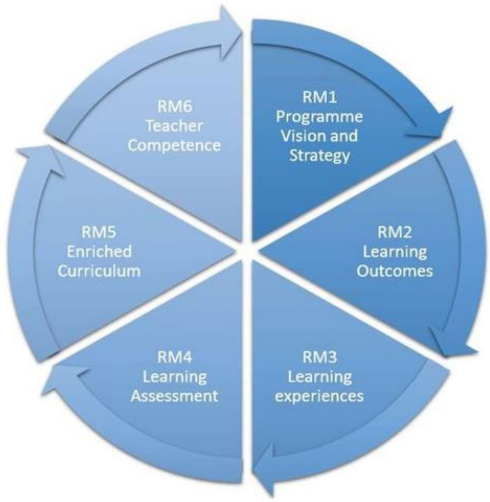

FIGURE 3 *DAhoy reference models for implementing and sustaining VUCA decision skills in an educational programme*

- RM1 VUCA D-Skills Programme Vision and Strategy, to fix the decision-making skills principles, and facilitate support from program leaders to sustain reform initiatives at systemic level;
- RM2 VUCA D-Skills Learning Outcomes, to emphasize decision-making skills in the learning outcomes, as recognition of these skills;
- RM3 VUCA D-Skills Learning Experiences, to underline VUCA capabilities at different levels of intensity the VUCA criteria of capsules and courses;
- RM4 VUCA D-Skills Learning Assessment, to highlight fair and accessible assessments modes and reinforce reflectiveness;
- RM5 VUCA D-Skills Enriched Curriculum, to emphasize methods and processes for decision skills curricular integration;
- RM6 VUCA D-Skills Teacher Competence, to train and commit adequate resources for faculty staff development.

B. Guidelines for Reference Models

The guidelines for RMs are inspired by pattern models as found in software and system engineering. A pattern is a general repeatable solution to a commonly occurring problem in software design. A design pattern isn't a finished design that can be transformed directly into the code, but is a description or template for how to solve a problem that can be used in many different situations. Patterns can speed the development process by providing tested, proven development paradigms.

Maturity models from quality assurance and quality enhancement processes were followed on their methodological foundations. Capacity and rubrics were formalized accordingly, with hierarchical scales of maturity. The DAhoy RMs and proposed maturity guidelines are also partly structured according to the guidelines from the ISO

organization (33020) and the CDIO standards (see i.e. http://www.cdio.org/content/cdio-standard-21).

C. Curricular Integration Process

For a concrete implementation of decision skills all along curriculum, various forms of activity capsules can be integrated within educational programmes. The L&T of decision skills should not be considered as the addition of a single course to a curriculum, but should be an integral part of it via several capsules in various existing courses to support transversality and for lifelong learning. An integrated curriculum should include decision-making learning experiences that lead to the acquisition of decision-making skills, under various dimensions, interwoven with the learning of disciplinary knowledge, other skills and application in professional environments.

Institutional management and culture differ on quality enhancement processes and curriculum renewal processes. These processes are also embedded at different levels in the European countries, i.e. different national qualification frameworks, different quality assurance agencies [18], and a range of approaches to the academic and to professional qualifications. As such, the RMs are to be adapted to the context of each programme and could be reorganized to the needs and priorities by programme leaders. However, the six RMs, with a shared scale on process maturity, have been developed in such a way that they are 'without barriers'; they can be used by most programme leaders and programme designers.

D. Future Work

The effectiveness of the learning activities developed in this project will continue to be evaluated as a good practice which is inherent in the continuous quality enhancement of engineering education programs in partner institutions. In particular, special consideration will be placed on the effectiveness of experiential pedagogy in developing decision skills. Building on the present work, including models, tools, and rubrik, is an ongoing research on how to implement and adapt the training capsules that take advantage of the natural environment or location of particular institution or university, guided by experiential learning methodology. [19]. Today we are experiencing an overwhelming "infodemic" [20], which is one example of the rapidly increasing flow of often poorly qualified information. This calls for research and development on how engineering programs can best prepare their engineering students for making good decisions in this realm of disinformation and biases. The needed agility by the programs is emphasized by e.g. [6]. Additional learning activities are needed specificly for such situations, including scholar analysis on their efficacy, and a good starting point for this development is the methodology, elements of analysis, and results attained in the DAhoy project.

VI. VUCA WORLD AND THE COVID-19 CRISIS

Iceland faced a volcano eruption in 2010 which echoed all over Europe. Indonesia or Japan regularly face tsunamis. Now the entire world faces the COVID-19 pandemic and its effect is predicted to last well beyond 2020. All these VUCA crises have societal and business impacts. In this VUCA world, during and after COVID-19, universities must train students to be more agile and use critical thinking to analyse, judge and appraise. Universities must transform themselves into learning spaces for students and to prepare them to become VUCA lifelong learners. The DAhoy project ultimately aims to transform the students to be effective leaders for change, especially in the VUCA world, via student-centered and experiential approaches, continuously.

Decisive decisions were made at the onset of the COVID-19 crisis giving the project an unprecedented chance to explore how the seven D-Skills were applied unconsciously under the unexpected VUCA conditions that fundamentally transformed the work within universities. As perspectives, the set of D-skills can be used to describe and analyze this unexpected international VUCA situation and how universities reorganized L&T activities and future semesters to remain resilient in at least the near future.

VII. CONCLUSION

As recalled by Kamp [21], educational change is not driven by science and technology but by university strategy, the changing nature of the student body and the decisions of individual faculty members. One of the responsibilities of engineering programs is to train engineering students to become global citizens, agile and capable of taking decisions in challenging VUCA situations.

The DAhoy analysis and tools presented in this paper is one contribution that engineering program leaders may find useful in tackling these new challenges. The inherent emphasis on experiential learning in the DAhoy tools and modules, including to question, decompose and experiment, is part of the necessary tools engineering students should possess when they graduate, and VUCA situations can help to stimulate [5]. For the post COVID-19 period in engineering education, transversal skills reinforcement is more than ever needed, and now is a great opportunity for engineering education institutions to revise or realign program outcomes. DAhoy transferable courses and activity capsules for VUCA exposure are a good start. The future of society is likely to depend on what governments, professional sectors, and educational institutions decide to do. Educational institutions need to be agile in adopting to changes and diversity in society [6]. Therefore, high expectations are placed on higher education, on how technological universities will prepare their graduates for taking good decisions in VUCA-like situations, under various dimensions, for working in the new emerging world and to take advantage of the new landscape of career opportunities.

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REFERENCES

[1] N. Bennett and J. Lemoine, "What VUCA really means for you," Harvard Business Review, 92(1/2), 27, 2014.

[2] H. Raiffa and R. Schlaifer, Applied statistical decision theory, MIT Press, Cambridge, MA, 1961.

[3] D. Kahneman and A. Tversky, "Judgment under Uncertainty: Heuristics and biases", Science, New Series, 185 (4157), 1124-1131, 1974.

[4] D. Kahneman and A. Tversky, "Prospect Theory: An Analysis of Decision under Risk", Econometrica, 47(2), 263-292, 1979.

[5] S. Latha and P. Christopher, "VUCA in Engineering Education: Enhancement of Faculty Competency For Capacity Building", Procedia Computer Science, 172, 741-747, 2020.

[6] P. A. Lemoine, P. T. Hackett and M. D. Richardson, Global Higher Education and VUCA – Volatility, Uncertainty, Complexity, Ambiguity, Handbook of Research on Administration, Policy, and Leadership in Higher Education, 2017.

[7] J. Dewey, Experience and Education. Kappa Delta PI Lecture Series, Collier-Macmillan Books, London, 1938.

[8] D. A. Kolb, Experiential learning: experience as the source of learning and development, Englewood Cliffs, NJ, Prentice Hall, 1984.

[9] S. Rouvrais, S. Gaultier Le Bris, and M. Stewart, "Engineering students ready for a VUCA world? A design-based research on decisionship," in Proceedings of the 14th International CDIO Conference, KIT, Kanazawa, Japan, pp. 872–881, June-July 2018,

[10] T. Anderson and J. Shattuck, "Design-based research: A decade of progress in education research?", Educational Researcher, 41(1), pp. 16-25, 2012.

[11] K. E. Weick, Making sense of the organization. Blackwell Publishing, Malden, MA, 2001.

[12] D. T. Campbell, J. C. Stanley and N. L. Gage, Experimental and quasi-experimental designs for research, Boston, Houghton Mifflin, 1966.

[13] I. Saemundsdottir, A. Matthiasdottir, H. Audunsson, and G. Sævarsdottir, "Facing disaster - learning by doing at Reykjavik University," in Proceedings of the 8th International CDIO 2012 Conference, Brisbane, Australia, 2012.

[14] H. Audunsson, T. V. Fridgeirsson, and I. Saemundsdottir, "Challenging engineering students with uncertainty in a VUCA situation," in Proceedings of the 14th International CDIO Conference, Kanazawa Institute of Technology, Kanazawa, Japan, 2018.

[15] H. Audunsson, A. Matthiasdottir, and T. V. Fridgeirsson, "Student´s journey and personal development in an engineering program," in Proceedings of the 16 th International CDIO Conference, hosted on-line by Chalmers University of Technology, Gothenburg, Sweden, 9- 11 June 2020.

[16] S. Rouvrais and S. Gaultier Le Bris, "Breadth experiential courses to flexibly meet new programme outcomes for engineers," in Engineering Education for a Smart Society, Springer, International Association of Online Engineering, M.E. Auer & Kwang-Sun Sim (Eds), Advances in Intelligent Systems and Computing Series, 627(1), pp. 326-342, January 2018.

[17] N. Chelin, M. Del Mar Socias Camacho, S. Rouvrais, and G. Matthiasdottir, "Career decision-making learning activities in STEM: An integrated capsule model earmarked for higher and VET educations," in Proceedings of the 12th annual International Conference on Education and New Learning Technologies, virtual conference, 6-7 July 2020.

[18] ENAEE (2017). The EUR-ACE framework standards and guidelines (EAFSG), The European Network for Accreditation of Engineering Education.

[19] H. H. Haraldsdottir, The future of experiential learning within the department of engineering at Reykjavík University, MS-thesis, Reykjavik University, June 2020.

[20] M. Buchanan, "Managing the infodemic", Nature Physics, 16, 894, 2020.

[21] A. Kamp, Navigating the landscape of higher engineering education: Coping with decades of accelerating change ahead. Delft University of Technology Edition, 4TU.Centre for Engineering Education, Delft, Netherlands, April 2020.

Technical Papers

Baseline 2020 in engineering research projects in a private institution of higher education

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***Abstract*—The present Baseline 2020 study is an applied investigation, carried out with the purpose of describing the current situation of the active research projects in the Faculty of Engineering. This information can be compared with objective subsequent measurements, as well as, can serve for generate changes in research institutional policy. The purpose of this documentary study was to analyze the social relevance, multidisciplinarity and diversity of the object of study of research.**

This study register the characteristics of the projects, beneficiaries (the students of the last years of the engineering careers), links with productive activities or services offered. The study method included the determination of the sampling skills, specification of the study variables and generation, storage and analysis of the data.

This referential framework has made it possible to demonstrate the strong presence of topics related to applicable technologies, but also the abundance of presentations aimed at solutions to environmental problems and sustainable development, and a few, oriented to take care of the health of populations.

There was also an imbalance between investments in rented dedications of researchers and project operating funds. Registered insufficient participation in financing projects granted by companies, associations or state agencies.

In turn, the potentialities of the valued research projects are high, in relation to their social projection due to the requirement to attend humanistic education programs and to encourage the participation of undergraduate students.

After presenting a characterization of the general problem, a proposal for a new research agenda was generated by set innovative goals. The institution will prioritize the need to search for alternative financing mechanisms that involve the national and international private productive sector.

Keywords—research, higher education, social relevance

I. INTRODUCTION

Modern Universities aspire for students to develop scientific capacities to learn to learn, build and solve the problems of the diversity of the social and natural environment. [1]

Recently, since 1995 in Argentina an agenda for the modernization of higher education systems was installed, fundamentally oriented to the reduction of state benefits for education. [2]

In this sense, it stands out that the Institutiom of Higher Education (IHE) that selfevaluates in this invetigation is privately managed. In Argentina, the highest concentration of university's students enrollment occurs at the public universities.

The percentage of privately managed universities went, in Argentina, from 20% to 44% in 11 years (2005 - 2016), however, the percentage of students for the same period considered went from 16% to 20%, this highlights the need of continuous improvement by the excellence in research management to stimulate the insertion in the labor market of the students of our institution. [2 y 3].

In this context, the research activities for the research itself, which were once carried out by the academic- researchers now through the development of technology, acquire new social and economics relevance. [4]

The researchers use the knowledge to generate other knowledge, through innovations, modifications and diffusion, promoting well-being, socio-economic development and changes within science and technology. [4]

The present study is an applied investigation, carried out with the purpose of describing the current situation of the active research projects in the Faculty of Engineering. [5]. This information can be compared with objective subsequent measurements, as well as, can serve for generate changes in research institutional policy. [5].

As in other disciplines, this baseline study constitutes a form of research aimed at obtaining basic benchmarks for the evaluability of research projects.

At the same time, this study is an essential instrument for improving knowledge management processes and decision-making in the scope of a development and innovation promotion institution.

The research is expected to continue in the coming years, and in turn, will represent the quantification of the impact of the research management of the academic unit.

The main beneficiaries of carrying out these scientific investigations are university students in the last years of engineering careers (currently 135) who can gain experience in applied science to solve problems that directly affect society.

The purpose of this documentary study was to analyze the social relevance, multidisciplinarity and diversity of the research projects carried out by the Faculty of Engineering, to generate changes in research institutional policy.

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II. METHODOLOGY

A. Initial analytical stage.

The study method included the determination of the sampling frame, specification of the study variables and generation, storage and analysis of the data, registering values of a set of indicators directly related to the key variables of the active research projects.

This work covered all the projects, which were active projects at the start of the Baseline 2020, also with the impact of investments, scientific affiliation, social relevance and main beneficiaries.

Following international standards, it was decided to characterize the direct beneficiaries made up of those participating entities that have strengthened their capacities in science, technology and innovation (research groups, undergraduate and graduate students, companies and public organizations).

B. Elaboration of rubric and validation.

Trying to improve the research standards of the ademic unit, we elaborate a single rubric for evaluating a range of multidisciplinary research projects. That is why, to carry out the evaluation of the quality of the projects, the rubric shown in Table I was prepared.

This rubric is based on the evaluation criteria used by the university that apply to all academic units, but which until now did not have a structured registration instrument.

In aspects related to institutional relevance, this grid gives greater weight to those projects that include students in their work groups and to projects that include activities of social projection, in accordance with institutional objectives of promoting the common good.

In the quality validation of the projects, the following items are considered (each one consist un another grid):

- Project Director: a) academic-scientific and technological training (publications related to the subject of the project, with reference and / or of recognized prestige in the general and particular area of knowledge in relation to the subject of the project), b) training of human resources (direction of scholarship holders, thesis of undergraduate and postgraduate degrees, and / or national or international subsidies of research projects), c) discoveries, awards, distinctions, transfer of innovative technologies, presentations at scientific meetings.
- Research Group: a) coherence and relevance of its composition in relation to the project (research Profs from the university or another universities and research and science and technology organizations; ascribed, independent professionals, undergraduate and graduate students from the university) b) background of the group (scientific publications, research experience, participation in scientific meetings, participation in results transfer activities).
- Project: a) importance of the topic, originality, relevance and social impact b) global approach to the problem, hypothesis, objectives, methodology c) possibility of transferring results d) viability of implementation and work plan.

Thus, most of the aspects that are included in rubrics of evaluation of research projects according to international standards are represented. [6]

TABLE I *Research project rubric*

Evaluation of engineering research projects					
	Criteria	E*	G*	P*	Score
Institutional relevance assessment	The Strategic Problem Area and the research lines defined by the Academic Unit.				
		5	4	2	
	Articulation with undergraduate and postgraduate teaching and training of human resources, undergraduate and postgraduate				
		10	5	2	
	Contribution to the production of new knowledge. Transfer of Project results to the environment.				
		5	4	2	
	Ethically consistent problem and objectives. Predictable social impact				
		10	5	3	
Quality	Project Director				
		30	20	10	
	Research Group				
		30	20	10	
	Project				
		40	25	20	
	Recommended (130-60p)/Not recommended (<60p)				

III. RESULTS

This referential framework has made it possible to demonstrate the strong presence of topics related to applicable technologies, but also the abundance of presentations aimed at solutions to environmental problems and sustainable development, and a few, oriented to take care of the health of populations. In accordance with this, 88% of the projects are in charge of the Engineering Faculty (Figure 1).

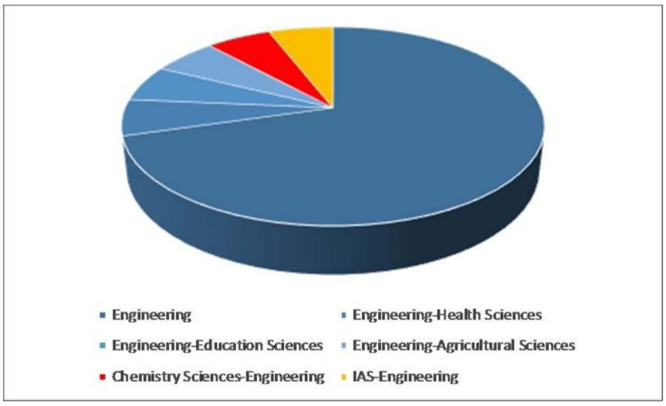

FIGURE 1 *Faculty of engineer research projects affiliation*

There was also an imbalance between investments in rented dedications of researchers (8500 USD/Project in 2020 average) and project operating funds (260 USD/Project in 2020) with very different amounts (Figure 2).

The average duration of the projects analyzed is 34 months. All have a duration greater than 30 months and a maximum of three years. 70.5% of the sample of projects has a duration of three years and 29.5% of two and a half years.

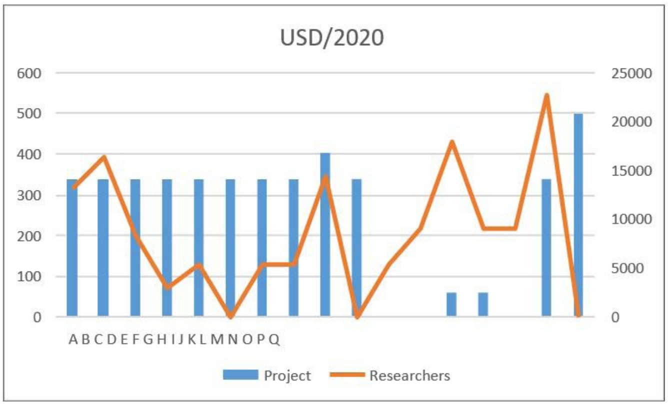

FIGURE 2 *University annual research investment (2020) in Faculty of Engineering*

Regarding the main problem areas, 76.4% of the projects are classified within Applicable technologies, 17.7% in Environment and sustainable development and 5.9 in Institutional practices and public policies. Whereas the problem areas derived are divided almost entirely between Environmental sustainable development and Population health (Figure 3).

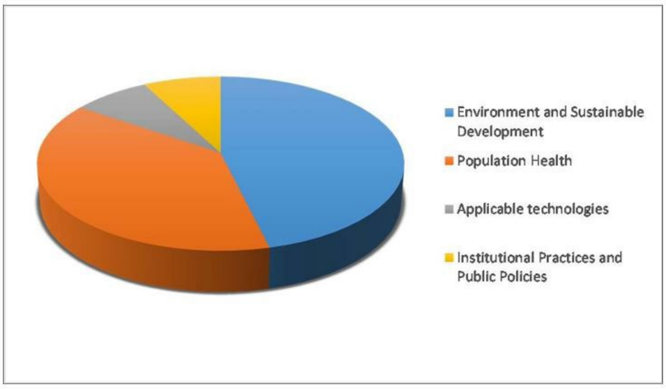

FIGURE 3 *Faculty of Engineering problem areas derived (% of projects)*

It is also exposed, the analysis of the initial measurements of impact indicators for direct beneficiaries, in the first instance, and because they are considered the main beneficiaries, undergraduate and graduate students, not exceeding a maximum of 7 per project in undergraduate students and 2 per project in graduate students (Figure 4).

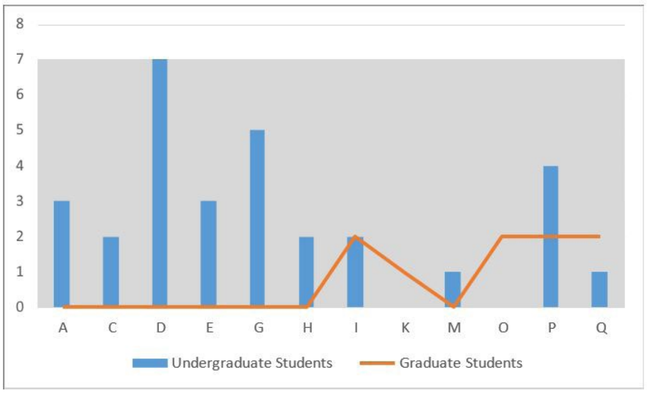

FIGURE 4 *Faculty of Engineering main beneficiaries of the research projects*

Second, we analized internal and external researchers, companies that were provided services through research projects, and state agencies with which agreements were made were considered.

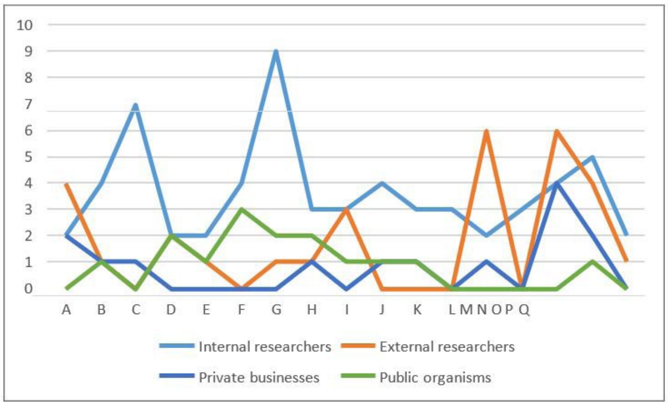

FIGURE 5 *Faculty of Engineering direct beneficiaries of the research projects*

The maximum number of internal researchers is 9 registering for a single project. 59% of the projects have agreements with at least one public institution. A single project provides services to 4 companies (max), however, only 47.2% of projects provide services (Figure 5).

There were difficulties related to not being able to individualize all indirect beneficiaries, this given that the institutions, specific individuals or vulnerable target populations had not been defined in detail at the time of project formulation.

Finally, through the analysis of the results of the rubric for the evaluation of research projects, which is evidenced in Figure 6, there is a strong influence of the quality of the projects for them to be recommended, a situation that is contrasted with the low investment from the University in their operating funds. Only four projects reach the maximum score related to institutional relevance.

Aspects related to the research group remain around an average rating of 26, out of a maximum of 30 requested. For this reason, an excellent quality of the group of researchers that is part of the projects is deduced.

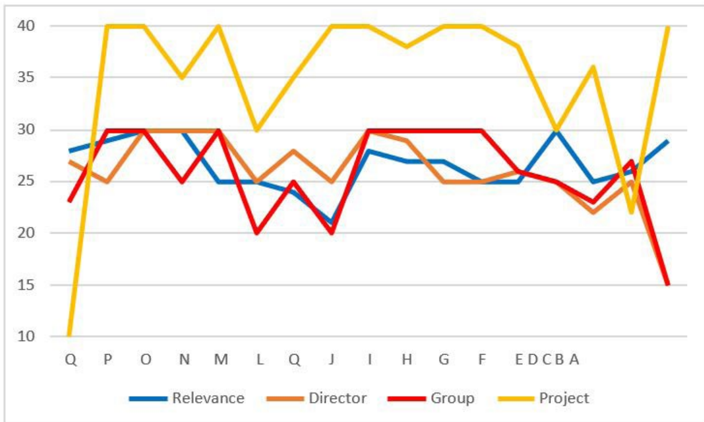

FIGURE 6 *Faculty of Engineering relevance and quality of research projects*

In Figure 7, the quality and relevance results are observed as a function of the total results, showing that the best standards are influenced by the quality of the projects.

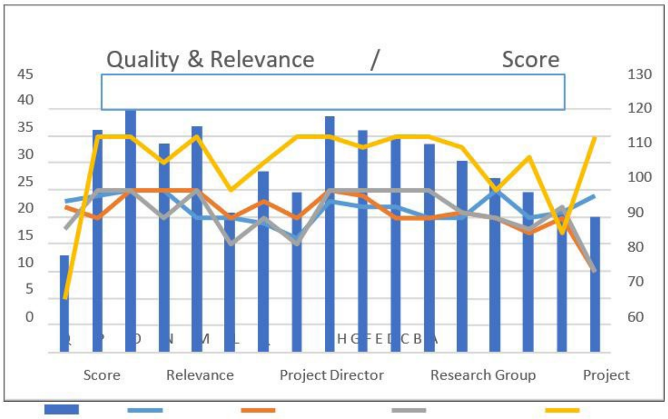

FIGURE 7 Faculty of Engineering quality and relevance vs total score

From the analysis of the quality of the rubric, aspects to be considered in the future are deduced, it is necessary to incorporate in the grid valuation of projects based on new and innovative ideas or expanded on established ideas in accordance with international standards.

Also, registered insufficient participation in financing projects granted by companies, associations or state agencies. Regarding the international standards for the valuation of research projects, most of the skills request by companies are not included in the project application.

In turn, the potentialities of the valued research projects are high, in relation to their social projection due to the requirement to attend humanistic education programs and to encourage the participation of undergraduate students. This is fundamentally reflected in the scores achieved in institutional relevance.

IV. FINDINGS

In relation to the main objectives to be achieved by the research policy of the academic unit, based on this study, the institution registered advances in the training of research teachers and in the participation of teaching staff in research activities.

However, there are still difficulties in achieving the participation of undergraduate and graduate students in research activities, the diffusion of research tasks and their concrete results, the proactive search for financial resources to carry out research activities and to invest in research infrastructure and also in the development of cooperation and exchange interactions with academic institutions and national and international organizations.

Furthermore, the use of Information Systems and access to specialized databases, or the generation of postgraduate courses and careers based on current lines of research, have not been evidenced or evaluated so far.

Based on this research, it is proposed to measure. in this academic unit, the current capacities in science, technology and innovation of the projects, applying the Logical Framework methodology with SWOT analysis (Strengths, Opportunities, Weaknesses, Threats).

In addition, the research lines of the Engineering academic unit are under review which will be modified according to the following conceptual model of Figure 8.

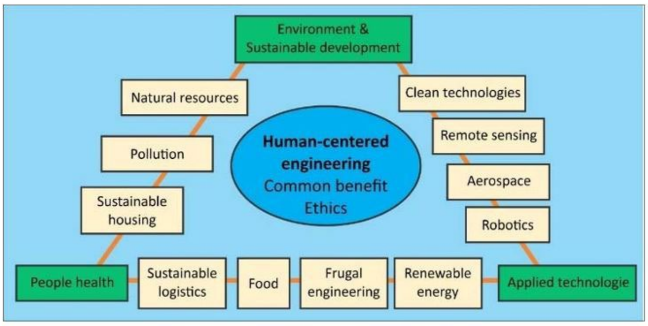

FIGURE 8 Faculty of Engineering conceptual model of research lines 2020

Finally, after presenting a characterization of the general

Finally, after presenting a characterization of the general

problem, a proposal for a research agenda was generated, which will prioritize the need to search for alternative financing mechanisms that involve the national and international private sector, the need for greater clarity in research lines and existing regulations, and the need to further boost the link between higher education, business and the State, in order to achieve a higher level of competitiveness and development.

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REFERENCES

[1] A. Sánchez and R. Gómez. (2013).” Teaching of natural sciences for the development of scientific competences” Amazonia investiga, 2(3), 30-53.G. 2013.

[2] M. Mollis, “The reforms of higher education in Argentina for the new millennium” Las reformas de la educación superior en Argentina para el nuevo milenio. Revista da Avaliação da Educação Superior V 13 (2), 509-532. 2008.

[3] SPU. Anuario 2016. “Argentine University Statistics” Estadísticas Universitarias argentinas. 2017. Buenos Aires: Presidencia de la Nación-Ministerio de Educación.

[4] L. Colina, “Research in higher education and its social applicability.” Laurus, 13(25), 330-353. 2007.

[5] M. Bresciani, M. Oakleaf, F. Kolkhorst, and C. Nebeker, “Examining design and inter-rater reliability of a rubric measuring research quality across multiple disciplines. Practical Assessment, Research, and Evaluation,” Clerk Maxwell, A Treatise on Electricity and Magnetism Vol. 14 , Article 12, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68– 73, May 2009.

[6] D. Burga, “Baseline study methodology.” Pensamiento crítico, 15, 061-082, 2011. https://doi.org/10.15381/pc.v15i0.8994

Technical Papers

The relationship between mindset and academic achievement at university: A quantitative study of South African students

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Abstract—**The majority of studies investigating the social psychology theory of growth and fixed mindsets have taken place in primary and secondary schools outside of Africa. In this study, we investigate the effects of mindset on first-year students' academic achievement at the University of Cape Town, South Africa. The Theories of Intelligence Scale (TIS) questionnaire was used to measure students' mindsets across three first-year courses and the period of several mathematics tests. Both the effect on students' progress across tests and between different courses was studied with respect to mindset. Statistical analysis showed that students in science and engineering programs had higher mindset scores than commerce students. Mindset scores did not significantly predict engineering students' performance in an introductory calculus course. The results of this study will guide future research into the effect of non-cognitive factors such as mindsets on the academic achievement of engineering students.**

Keywords— fixed mindset, implicit theories of intelligence, social psychology, behaviour factors, student success

I. INTRODUCTION

Students need more than just content knowledge and academic skills to succeed academically, particularly in compulsory courses such as mathematics within engineering programmes. Recent literature has explored how student success is affected by various factors such as academic background [1], workload [2], and grit [3]. This research investigates the relationship between the non-cognitive factor called 'mindset' and students' academic achievement both through time and across courses.

Mindsets are beliefs about the nature of intelligence on a spectrum from 'growth' to 'fixed' [4]. Students with a growth mindset tend to enjoy challenges and see them as opportunities to learn and improve their abilities. In contrast, students with a fixed mindset tend to avoid challenges, prefer easier problems that will make them look and feel smart, and when they cannot easily overcome a challenge, they become discouraged and disengaged. While students with a fixed mindset might be just as academically capable as those with a growth mindset, their behaviour in the face of obstacles may affect their academic achievement [5].

While most studies on mindsets have investigated the relationship between mindset and academic achievement in children and adolescents, they tell us little about how mindset influences academic achievement in post-secondary school levels. Although only a few researchers have studied the effects of mindset on academic achievement in South Africa [6], most of these studies were conducted on students based outside of Africa. Thus, in this study, we investigate the effects of mindset on first-year students' academic achievement at the University of Cape Town, South Africa. In addition, we compare mindsets and academic achievement across three different introductory mathematics courses.

A. *Research questions*

In line with previous research on mindset and academic achievement [6, 7], this research explores the relationship between students' mindsets and their academic achievement. The assumption behind the research design is that students with growth mindsets are more likely to use feedback from low performance on a test to improve their performance in the next test, while fixed mindset students may struggle more to overcome academic setbacks and show less improvement.

The research questions are:

1. Does the Theories of Intelligence Scale reliably assess mindset for first year students at the University of Cape Town?
2. Is there a significant difference in the distribution of mindset scores across three different introductory mathematics courses, for commerce, engineering or science students?
3. In an engineering mathematics course, is there a greater improvement between grades for
   a. the first test of the year and the second test;
   b. the first test of the year and the final examination for students with growth mindsets as compared with students with fixed mindsets?

Mindset questionnaires, first year mathematics assessment scores, and statistical analyses were used to address these questions.

II. METHOD

A total of 301, 171 and 241 students at the University of Cape Town from first-year mathematics courses for commerce, engineering and science majors, respectively, participated in this study. The total numbers of enrolled students in these courses were 747, 628 and 723, respectively. Mathematics is a challenging and anxiety-provoking subject [9] taken by engineering students as well as students in many other disciplines. First-year mathematics courses were therefore chosen as appropriate for investigating mindset within and across different majors.

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The Theories of Intelligence Scale (TIS) was used to measure students' mindsets within the first four weeks of first-year courses. The TIS has been found to be reliable and has been used by multiple other researchers as a predictive measure. However, we used Cronbach's alpha test to assess how well the TIS measures the mindset of the current population. The TIS has eight statements, for example, "You can always substantially change how intelligent you are." Students were asked to rate these statements on a 6 point Likert scale (1 = Disagree a lot to 6 = Agree a lot). Weighted scores range from 6 to 48, with scores of 24 and below indicating fixed mindsets and scores of 32 and above indicating growth mindsets [8].

The TIS was distributed to students enrolled in four first-year mathematics courses at the University of Cape Town via the online assessment platform WebAssign, used by students for online homework. This included a consent section. Students were included in the study if they consented to have their TIS results and course grades used.

The TIS responses were loaded into an Excel spreadsheet and the data was cleaned, making sure to (a) remove students who completed the survey but chose not to participate in the study,
(b) remove any duplicates and incomplete entries, and (c) convert the participants' responses to numerical values. The statistical software SPSS was used to validate and analyse the data. The internal consistency of the mindset scale was measured using the Cronbach's alpha test. We used the Kruskal-Wallis test to check for significant differences in mindset distributions, followed by pairwise Mann-Whitney U tests to check where the differences lay. Finally, the main hypothesis, that students' mindset will affect their academic achievement, was tested using a correlation test. We used Kendall's Tau-b test in this study because the data was ordinally measured and was optimal compared with Spearman's coefficient [10].

III. RESULTS

A. Reliability and validity of scale

First, we measured the internal consistency (reliability) of the mindset scale using Cronbach's alpha test. The Cronbach's alpha reliability coefficients ranged between 0.586 and 0.642 (see the table below).

***TABLE 1** Cronbach's alpha values for the mindset scale*

	Cronbach's alpha coefficient	Sample size
Commerce students	0.581	301
Engineering students	0.642	171
Science students	0.586	241

The response rates for commerce, engineering and science students were 40.3%,27.2%, and 33.3% respectively.

B. Mindset scores across different degree programs

The participants of this study mostly had a growth mindset (mindset score above 32 points). The distributions of the mindset scores for the three courses are displayed in the boxplot in Figure 1.

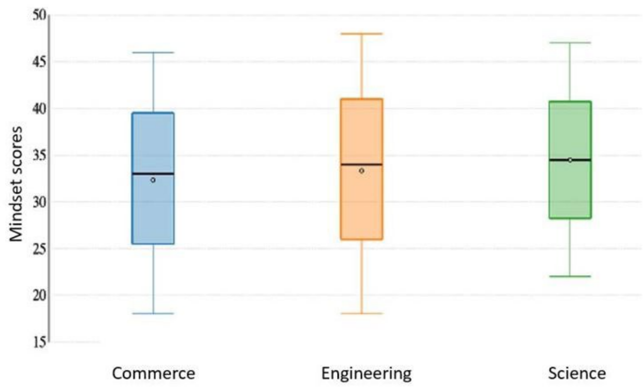

***FIGURE 1** Boxplots of mindset scores of commerce, engineering and science students. The central black line in each box represents the median mindset scores, while the dot represents the mean score.*

Looking at the boxplots above, most of the participants in the study had a growth mindset, represented by weighted scores of 32 and above[8].

On average the commerce students scored slightly lower than science and engineering students. A Kruskal-Wallis test was conducted to determine if there were any differences in the distribution of mindset scores across the three cohorts of students. The test revealed that there are differences in mindset score distribution of the three cohorts of students. However, the test doesn't tell us where the difference lies. Subsequently, a series of pairwise comparisons were performed using the Mann-Whitney U test to determine where the difference lies. To control for Type 1 errors, a Bonferroni adjustment was applied to the alpha values. The alpha level of 0.05 was divided by the total number of the Mann-Whitney U test (6). Therefore, a stricter alpha level of 0.05/6 = 0.008 was used. The results of the Mann-Whitney U tests are presented in Table 2.

***TABLE 2** A summary of the results of the Mann-Whitney U tests*

	Mann- Whitney U test	Z-Score	P-value
Science and Commerce	21166	-4.628	0.000004
Science and Engineering	25520	-0.119	0.905
Commerce and Engineering	16519	-4.048	0.000052

The Mann-Whitney U test revealed statistically significant differences between mindset scores of students enrolled in measure the same thing as the existing items may lead to an inefficient redundancy. He further argues that little additional information will be obtained while the instrument takes longer to administer and analyse. Since the students on these courses come from diverse first language homes, the language used in the questions may need to be adapted for science and engineering programs and those enrolled in commerce programs. The students enrolled in commerce programs had lower mindset scores than students enrolled in science and engineering programs.

C. Mindset and academic performance of engineering students in an introductory calculus course

We calculated the changes between scores in the first and second tests of the year, and the first test and the final exam score for engineering students. We then ran a Kendall Tau-b correlation to assess the relationship between mindset scores and these changes. The results of the correlation are presented in the table below, where 'Students A' are those who failed Test 1 and 'Students B' combines those who failed and passed Test 1.

TABLE 3 *Kendall Tau-b correlation coefficients, and p-values for the correlation between mindset scores and mathematics grade changes, for engineering students who failed Test 1 (Students A) and all engineering students combined (Students B)*

	Test 1 to Test 2 changes			**Test 1 to Exam changes**		
	Kendall Tau-b	Sample size n	p-value	Kendall Tau-b	Sample size n	p-value
Students A	0.000	13	1.00	0.026	13	0.902
Students B	-0.066	149	0.242	0.026	148	0.651

The correlation coefficients indicate that mindset scores did not significantly predict engineering students' performance in an introductory mathematics course.

IV. GENERAL DISCUSSION

A. Research question 1: Reliability of scale

The Cronbach's alpha values calculated for the present study's mindset scale are relatively low but acceptable [11]. Similar studies that use the mindset scale have reported values greater than 0.7 (see [12] and [13] for example). Our findings weakly support that the Theories of Intelligence Scale reliably assesses mindset for first year students at the University of Cape Town. However, it is clear that the reliability of this scale is not ideal and can be improved.

1) Recommendations

The scale can be improved by removing items that decrease the overall alpha values; alternatively, more items can be added to the scale to improve reliability. Although adding more items to the scale may improve the scale's reliability, Cronbach (1951) has noted that adding additional items that this specific cohort. This would be an interesting future research question in terms of test reliability.

B. Research question 2: A comparison of mindset scores for students studying science and engineering versus commerce

The differences in mindset scores that we found were small but significant while almost all mindset scores were positioned far towards the growth mindset end of the spectrum. The finding of overall high growth mindset scores is consistent with findings in other studies [14]. Our data show that students in science and engineering degrees are distributed closer to the growth mindset end of the spectrum than students in the commerce degrees. The reason for this distinction may be that science and engineering are seen as more challenging subjects and therefore more likely to attract students with growth mindsets. This is an hypothesis and remains another interesting question for future research.

1) Recommendations

For any future interventions, it may be most interesting to target commerce students, who are on average more fixed mindset than science and engineering students. Questions to students on why they chose their majors may illuminate the reasons for the differences in mindset scores between disciplines.

C. Research question 3: Mindset scores and academic progress for engineering students

Our data indicate no significant correlation between mindset scores and changes in achievement across multiple mathematics assessments. Although other factors affect students' academic performance in mathematics, we hypothesized that growth mindset oriented students would improve their mathematics grade changes due to their belief in intelligence flexibility. For instance, a student with a growth mindset would seek feedback and look for ways to improve their mathematics grades, rather than attributing their failure to their fixed intelligence.

1) Recommendations

Future research could investigate mindset scores versus academic achievement accounting for other contributing factors such as gender, race, economic status.

V. CONCLUSIONS AND FUTURE WORK

A limitation of the sample is that it only included students in first-year mathematics courses at one tertiary institution. Future studies should investigate whether mindset scores differ depending on year of study, the course in which the questionnaire was administered (mathematics in this study), and institution.

Students self-selected to participate in the study which could lead to self-selection bias. Further, this could lead to a sample that is not representative of the population. Students who self- select to participate in the study show commitment and are more open to expose their thinking to others, which might be a sign of a growth mindset that could lead to a bias towards growth mindsets. For future research, self-selection bias should be off-set by offering an incentive to participate.

Conducting interviews with students may shed light on the reasons for the correlations between mindsets and academic achievement which could only be hypothesised in the current study. Questions regarding the motivation of students for choosing particular majors would help to understand these correlations.

For a study that seeks to make statements about the population such as this one, the lack of probability sampling is a significant limitation. A simple random sampling strategy can be employed in future studies, for example, we can randomly select students whom we wish to participate from the list of students enrolled in first year mathematics courses. This would also allow us to select for specific demographic groups with differing success rates and would allow for specifically targeted interventions in the future.

Results of this work-in-progress study will guide future research in non-cognitive factors of mathematics success at university level in South Africa.

VI. ACKNOWLEDGMENT

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VII. REFERENCES

[1] L. Van den Broeck, T. De Laet, M. Lacante, M. Pinxten, C. Van Soom, G. Langie, Predicting the academic achievement of students bridging to engineering: the role of academic background variables and diagjonostic testing. Journal of Further and Higher Education. 2019 Aug 9;43(7), pp. 989-1007.

[2] R. Kizito, J. Munyakazi and C. Basuayi, Factors affecting student success in a first-year mathematics course: a South African experience, International Journal of Mathematical Education in Science and Technology, 47:1, , 2016, pp. 100-119, DOI: 10.1080/0020739X.2015.1057247.

[3] I. Direito, S. Chance and M. Malik, The study of grit in engineering education research: a systematic literature review. European Journal of Engineering Education. 2019 Nov 9, pp. 1- 25.

[4] C. Dweck, Mindset: The New Psychology of Success. New York: Random House Publishing Group, 2006.

[5] K. Tirri and T. Kujala, Students' mindsets for learning and their neural underpinnings, Psychology, 7, 2016, pp. 1231-1239. http://dx.doi.org/10.4236/psych.2016.79125

[6] T. Porter, A. Martinus, R. Ross, C. F. Cyster and K. Trzesniewski, Changing learner beliefs in South African townships: An evaluation of a growth mindset intervention. Social Psychological and Personality Science, Apr 7, 2020, pp. 1-8.

[7] V. F. Sisk, A. P. Burgoyne, J. Sun, J. L. Butler and B. N. Macnamara, To what extent and under which circumstances are growth mind-sets important to academic achievement? Two meta- analyses. Psychological Science, 29, 2018, pp. 549–571.

[8] C. S. Dweck, C. Y. Chiu and Y. Y. Hong, Implicit theories and their role in judgments and reactions: A word from two perspectives, Psychological inquiry, 6 (4), 1995, pp.267-285.

[9] M. Olango, Mathematics anxiety factors as predictors of mathematics self-Efficacy and achievement among freshmen Science and Engineering students. African Educational Research Journal, 4(3), 2016, pp.109-23.

[10] C. Croux and C. Dehon, Influence functions of the Spearman and Kendall correlation measures, Statistical Methods and Applications, 19, 2010, pp. 497-515.

[11] K. S. Taber, The use of Cronbach's alpha when developing and reporting research instruments in science education. Research in Science Education, 48 (6), 2018, pp. 1273-1296.

[12] L. S. Blackwell, K. H. Trzesniewski and C. S. Dweck, Implicit theories of intelligence predict achievement across an adolescent transition: A longitudinal study and an intervention. Child Development, 78(1), 2007, pp. 246-263.

[13] C. Romero, A. Master, D. Paunesku, C. S. Dweck and J. J. Gross, Academic and emotional functioning in middle school: The role of implicit theories. Emotion, 14(2), 2014, pp. 227–234. https://doi.org/10.1037/a0035490

[14] M. Broda, J. Yun, B. Schneider, D.S. Yeager, G. M. Walton and M. Diemer (2018), Reducing inequality in academic success for incoming college students: A randomized trial of growth mindset and belonging interventions. Journal of Research on Educational Effectiveness, 11, (3), 317-338.

Technical Papers

Female enrolment and persistence in chemical engineering at a Caribbean national university and their employment success after graduation

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***Abstract—*In recent times, there has been a drive to increase the number of engineering graduates in Jamaica as well as to encourage females to pursue professions in science, technology, engineering, and mathematics (STEM). With universities outputting approximately 200 graduates in engineering disciplines annually, the graduates are forced to compete for placement in the island's relatively small manufacturing and processing industries. It is therefore imperative that employment prospects for female STEM graduates be elucidated to better devise strategies to promote and increase the number of females enrolled in STEM degree programs. This study investigates female enrollment and persistence in the chemical engineering (ChE) program at the University of Technology, Jamaica. The method employs a longitudinal cohort analysis to examine gender differences in enrollment, persistence to graduation, and the class of award obtained at graduation. The research focuses on 12 ChE cohorts from 2004 to 2015. The employment profile of female graduates is also assessed. Findings show that although females represent 41% of enrolled students in semester 1, they are more likely to complete their degree in 4 years, obtain better award quality, and less likely to withdraw from the program. Most female graduates receive employment within the first year after graduation with 59.4% in STEM-related occupations and 19% in unrelated fields. This work contributes to the literature on engineering education in the Caribbean and it is the first of its kind to be done for the local university.**

Keywords—chemical engineering, enrollment, graduation outcomes, gender differences, persistence

I. INTRODUCTION

As early as 2012, there was a recognized need for qualified engineers to execute the growing list of projects to be undertaken in Jamaica [1]. Engineers were among the list of professionals considered instrumental in the achievement of the island's Vision 2030 national development plan. In 2017, the Jamaican government specified that at least 1,000 engineering graduates are required each year to meet developmental needs [2]. This charge was placed on the three universities that offer engineering programs: The University of Technology, Jamaica (UTech, Ja.), The University of the West Indies (UWI), and the Caribbean Maritime University (CMU). UTech, Ja. is fundamentally polytechnic but in recent times it has expanded to include courses in Arts, Medical Sciences, and Law. The UWI is a classical research university with a regional focus having campuses in several Caribbean territories. CMU specializes in maritime and logistics education. These three universities and other post-secondary institutions have a share in the approximately 28.5% gross enrollment rate of tertiary age cohort (18 - 24 years) [3]. Combined, the three universities output approximately 200 engineering graduates per year.

In 2010, a charge was given by President Barrack Obama to increase the number of underrepresented groups such as women and minorities in STEM fields within the decade [4]. Even though women represent 50% of the American population and 58% of its college entrants, only 28% of the STEM workforce is female [5]. Although the charge for more females in male-dominated fields has been made almost 10 years now, it has only been within the past three years that there has been a local thrust to have more of the nation's women and girls pursue professions in STEM. To achieve this, more females need to enroll and persist in STEM at the tertiary level.

During the first year of college, typically more men than women venture into STEM degree programs, but the numbers are fewer than those for non-STEM degrees. In the United States of America (U.S.), between 2009 and 2013, students who were enrolled in STEM programs accounted for 22% and 29% of the total female and male college entrants, respectively [6]. However, not all these entrants to STEM programs continue to degree completion. Many colleges and universities have been negatively impacted by high attrition rates. Less than 57% of students continuing to receive degrees have been reported for some institutions [7]. Attrition rates for engineering are higher compared to other professional disciplines [8] with as many as 40% of students switching majors reported [6].

When graduation numbers for engineering are examined, a similar trend to that of enrollment is observed where males exceed females. In 2018, females accounted for approximately 22% of the graduating cohort for both the U.S. and Canada [9]. Specifically, for ChE in the U.S, it was 35.4%. Only females in Environmental Engineering had a slight margin over males with 50.6%. Prior to 2018 (2009 – 2017), the percentage of female graduates ranged from 17.8 to 21.3% while that for males was 78.7 to 85.2% [9]. In a multi-institutional longitudinal study with over 94,000 males and 24,000 females majoring in engineering, Lord et al. [10] found that ChE was the only discipline that had fewer females persisting than males, although by a slight margin. They also found that ChE had the highest attrition rates (greater than 30%) for both genders.
Persistence in the STEM fields is of great importance as it serves to provide graduates with specific skills and knowledge to meet the needs of the largest growing workforce sectors [11]. Persistence involves tracking students enrolled in a program at initial enrollment/matriculation to graduation with a degree in

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the same program. Matriculants at semester 1 are typically the reference for defining the persistence of a cohort [10]. In the U.S., six-year completion or graduation rate is the standard measure of persistence for 4 year or eight-semester degree programs [10, 12]. Approximately 60% of U.S. students persist within 6 years [13]. Eight-semester persistence has also been used [13, 14]. The 4-year mark is a measure of success as it is usually the point when 90% of all students graduate [13]. However, the American Society for Engineering Education (ASEE) [13] reported that for the period 2008 to 2015 the 6-year graduation rates were 20 to 25 % higher than the rates for students who attained a degree in 4 years. When 4-year graduation rates are used, it allows for the inclusion of a larger number of cohorts, as well as more recent cohorts [14]. Studies done on gender-based persistence in engineering include those by [10], [12], and [14 - 17]. Mixed findings relating to whether females persist at better rates than males are evident in these studies.

Scarce is the literature on degree quality awarded to engineering graduates. Madara and Namango [18] found that for all classes of awards in 5 engineering disciplines, including Chemical and Processing Engineering, males outperformed females in every class except for Pass award. Most students received Second Class awards with only 17.8% of graduating females awarded First Class honors. As it relates to employment after graduation, a few studies investigated the job placement of graduates. Smith [19] reported that 60% of the 2007/8 engineering graduates got full-time employment, within the first six years after the participants graduated from UK universities. The outcome might be different for shorter periods after graduation. Corbett and Hill [20] reported that for the year 2009, a total of 84% of all female graduates in the U.S. were employed within their first year of graduating. From the 2016 Canadian census data, 62% of females who studied STEM never worked in a related field; only 20.2% of that group had a STEM occupation [21]. This low involvement of females in STEM occupations threatens the global competitiveness of businesses [22].

This study investigates the number of females enrolled in ChE at UTech, Ja over 12 years, their persistence to degree completion, and the classes of awards obtained compared to their male peers. The employment status of female graduates is also examined.

II. METHODS

This study uses a single-institution longitudinal cohort analysis with a focus on the ChE discipline offered at UTech. ChE was chosen as it was observed to be the most popular program for females in the School of Engineering. As such, is fitting to use this engineering discipline to assess female successes and failures in engineering study and employment over the past 15 years of the life of the program. Only students enrolled in ChE from academic year 2004/2005 to 2015/2016 were considered, with no distinction made between first-time university and transfer students. However, no transfer into the program was recorded for the period under investigation. Academic year 2004/2005 was found to be a suitable entry year to begin the analysis because majority of the students enrolled before that year had advanced placement and completed the 4-year degree in 3 years. The last three cohort entry years had outcomes for all entrants by August 2019.

The main source of data used in the study was the university's Integrated Student Administration System (ISAS), which tracks the academic life of students from enrollment to graduation. Data on employment was derived from the program's Tracer Study, a survey that documents graduates' job placement and responsibility 1 year after graduation and up to 4 years. The Tracer Study is part of a program's re-accreditation process. Only the first year after graduation was considered. With the study having a female focus, the data was compiled then segregated by gender to explore female enrollment, persistence, and employment profile 1 year after graduation.

Persistence was measured in two ways: persistence to complete the degree in prescribed time, 4 years; and persistence to complete within permissible time, up to a maximum of 7 years. Students who did not persist to completion are those who withdrew officially, abandoned, or transferred from the program. No distinction was made between these groups of students who were placed in a single group titled 'withdrawal'. For students who persisted to completion, the award classification of their degree was assessed to determine if a gender difference exists in the class of award received.

Seven categories of job placement were created according to the findings from the Tracer Study. These categories are:

a) *Large Manufacturing/Engineering Companies:* petroleum refinery, power generation, bauxite processing, sugar, and rum distilleries.
b) *Small/Medium Manufacturing Companies:* chemical producing companies to include chemicals and lubricants for local and possible regional distribution.
c) *Small Engineering Consulting Firms:* firms owned and operated by licensed engineers and offer consulting services in a variety of engineering applications.
d) *Government Agencies:* agencies that oversee water and wastewater treatment, and the monitoring of pollution and regulation of its discharge from companies.
e) *Teaching:* placement in the Secondary Education system.
f) *Unrelated/Business Field:* placement in the banking and insurance sectors.
g) *Graduate School:* local and/or overseas study in engineering or any other field.
h) *Unemployed:* unsuccessful to obtain employment.
i) *Unknown:* graduates who have migrated or have returned to their country of origin, for example, other Caribbean islands.

The study employs multivariate descriptive statistics for data analysis.

III. RESULTS AND DISCUSSION

A. Enrollment in Chemical Engineering at UTech, Ja.

Table 1 shows the number of engineering students who matriculated into ChE disaggregated by gender. Yearly enrollment for the UTech ChE program has consistently been low with 44 being the highest number recorded in the 12-year period. The smallest and largest percentage of females at enrollment was approximately 27% and 60%, respectively with a mean of 41% (SD = 9.3%).

The relatively high number of female entrants is comparable to the findings of [10] whereby ChE was found to have the highest percentage of enrolled females at 37%. The less 'macho' nature of the program [8] and physical demands of some courses in the other disciplines, e.g. Engineering Workshop done in Mechanical Engineering, might be contributory factors for females' selection of ChE.

Preference of parents, relatives, and associates employed in an engineering field is a possible contributor to the low number of pre-university students who choose ChE. Employment prospects are also a contributor. Jamaica's processing industry is relatively small. Recent changes in the international market have been impacted negatively industries like Bauxite and Sugar that were once large employers of engineering graduates. Entrants to the School of Engineering are mindful of limited job opportunities and tend to apply to an engineering discipline they believe the job prospects are greater.

B. Persistence to degree completion

Table II shows the graduating demographics – as a percentage of entrants who persisted and completed the degree in either 4 or 7 years. Seven (7) years is the maximum time for degree completion at UTech, Ja. If there were a preferred measure to be used by the university to report graduation rates, it would be the 4-year reference. Although the permissible time to complete undergraduate degrees is 7 years, there is a faculty perception that students who take longer than 4 years, especially those in their sixth or seventh year of the program, are academically inept in their chosen field of study.

However, students who have medical and financial reasons for delayed stay are viewed differently if their grades show competence. Also, institutions such as the Student Loan Bureau and others that offer scholarships have designed financial support for students around the 4-year timeline.

TABLE I *Total number of entrants by cohort and gender*

Entry Year	Entering Cohort				
	Female	Male	Total	% Female	% Male
2004/05	5	12	17	29.4	70.6
2005/06	8	11	19	42.1	57.9
2006/07	4	11	15	26.7	73.3
2007/08	16	28	44	36.4	63.6
2008/09	14	22	36	38.9	61.1
2009/10	12	13	25	48.0	52.0
2010/11	9	6	15	60.0	40.0
2011/12	10	12	22	45.5	54.5
2012/13	13	13	26	50.0	50.0
2013/14	9	18	27	33.3	66.7
2014/15	4	7	11	36.4	63.6
2015/16	8	8	16	50.0	50.0
Total	112	161	273	41.1	58.9

The analysis revealed that 54% (*SD = 16.5%*) of all entrants completed in 4 years. By gender, more females (*M = 65%, SD = 19.7%*) persist to degree completion in 4 years than males (*M = 46%, SD = 20.6%*). Students are mindful of how an extended stay on their résumé might be regarded by prospective employers, hence many start engineering programs with the intent to complete in 4 years. We note that the earlier cohorts had majority of the entrants completing in the prescribed time (4 years), especially for females. This number declined for the more recent cohorts. Financial challenges have forced some students to reduce the number of credits taken each semester while others opted to take leave of absence for a semester or a year. These actions contribute to students staying longer than anticipated.

TABLE II *Persistence of graduating cohort by gender*

Entry Year	4-year graduation (%)		7-year graduation (%)	
	Female	Male	Female	Male
2004/5	80.0	91.7	100.0	100.0
2005/6	62.5	81.8	100.0	100.0
2006/7	100.0	36.4	100.0	90.9
2007/8	62.5	39.3	81.3	67.9
2008/9	71.4	36.4	85.7	63.6
2009/10	66.7	30.8	91.7	84.6
2010/11	77.8	50.0	88.9	100.0
2011/12	80.0	41.7	100.0	66.7
2012/13	46.2	30.8	69.2	84.6
2013/14	40.0	22.2	77.8	77.8
2014/15	25.0	42.9	100.0	85.7
2015/16	62.5	50.0	87.5	75.0
Mean	64.9	46.2	90.2	83.1

The 4-year graduation rates for females compares well with that of ASEE [13] findings where means of 35% and 39% were reported in 2006 and 2013, respectively. We noticed that there is a general decline in graduation rates for males starting with the 2006/7 cohort. Although financial challenges can delay graduation year, another possible reason for this trend is students' participation in the Work and Travel (W&T) program. Students are opting to extend their stay beyond 4 years to have multiple opportunities to work in the U.S. in the summer because active registration in a university program was a requirement. Males were the major participants in W&T, but the number of participating females has increased in recent times. The decline in female 4-year graduation after the 2011/12 cohort supports this view. To allow for comparison with U.S. persistence rates, we also calculated persistence up to the local maximum of 7 years. We found that 90% (*SD =10.4%*) of female entrants persisted compared to 83% (*SD = 13.2%*) for males. This signifies that the attrition rate for females is less than that for males. Brawner et al. [17] had suggested that relationships developed with peers and faculty were among the reasons for females to remain in ChE and we are inclined to accept this viewpoint. Work commitment, poor academic performance, and financial issues are some of the reasons for program withdrawal and/or abandonment for males. For females, migration and financial issues have been noted. Further study is required to identify the underlying reasons for an extended stay in ChE and other engineering programs and attrition of students.

Comparing our findings to the U.S. national average of 55 - 60% for undergraduate degree completion from 2008 to 2015 [13], more of our local ChE students are persisting at a higher percentage (*M = 85.6%, SD = 9.9%*) when the maximum time is used. A higher number of females obtaining an engineering degree compared to males was also reported by [15]. Kamphorst et al. [15] found that 77.3% of females who started an engineering program in 2004 completed within the maximum time, compared to 68.7% of the starting males. Specific to ChE, contradictory findings were reported by [10] and [12] where males in ChE were found to graduate at higher rates than females. We also observed lower attrition rates. We are mindful of the small number of students in the program compared to the large numbers found in U.S. institutions, which limits the making of meaningful comparisons. Future studies on gender demography in other engineering disciplines at UTech Ja. and other universities might provide improved comparisons.

C. *Award classification*

The quality of award obtained according to gender for the 12 cohorts is displayed in Figure 1. Four award classifications are used for undergraduate degrees at the university: First Class, Upper Second Class, Lower Second Class, and Pass, in descending order of GPA. Actual numbers are used instead of percentages. We also found that most of the graduates (80%) obtained Second Class awards, as in [18]. Females performed better academically since they attained a greater number of higher quality awards. As members of faculty, we observe that females take a different approach to their learning. They tend to form study groups early in the semester; attend tutorial sessions frequently; meet with lecturers often for assistance and to query grades. These actions might have had a direct and positive influence on their GPAs. Building relationships with peers and faculty were noted as reasons for females to stay in ChE [16]. We suggest that these relationships also contribute to their success at ChE.

FIGURE 1 *Award classification of graduates*

D. *Employment placement of female graduates*

Table III shows the distribution of female graduates in employment placement within the first year after graduation. The largest placement was in large industries that include bauxite, rum processing, and petroleum refinery where engineering principles are practiced. This shows that hiring potential still exists for these industries, though small. It was viewed as promising that 79% of female graduates obtained employment and 59.4% obtained job placement in a STEM- related field.

TABLE III *Employment placement for female graduates*

Employment Placement	Percentage
Large Manufacturing/Eng. Companies	33.0
Small/Medium Manufacturing Companies	13.8
Small Engineering Consulting Firms	2.1
Government Agencies	10.6
Teaching/Secondary Education	9.6
Unrelated/Business Field	9.6
Graduate School	5.3
Unemployed	7.4
Unknown	8.5

With more than 50% of our female graduates employed within a year of graduation, this finding compares well with that reported by [19]. A higher percentage of our females were in STEM occupations compared to the 20.2% reported for Canada in 2016 [21]. A point to note is that for placement in STEM-related companies, the job description could be either junior engineer or engineering technician. Due to insufficient data on occupations for all graduates, this relevant aspect of job placement was omitted. The ability of graduates to secure employment in business fields suggests that the ChE curriculum is versatile in preparing graduates for multiple roles. Considering that the number of female graduates is small, additional research to investigate the reasons for unemployment and placements in non-STEM occupations is needed.

IV. CONCLUSIONS

This work contributes to the scarce literature on engineering education and occupation in the Caribbean. The results show that ChE has fewer females than males at enrollment but still at a relatively large proportion.; four-year and seven-year graduation rates are higher for females than males, and females are less likely to leave the program before completion. Both genders performed well academically with the majority obtaining Second Class awards; however, females obtained twice the number of First-Class awards while males obtained more Pass awards. Employment placement of females within the first year after graduation shows the majority in STEM companies which is promising but further work is needed to assess their role in these companies. Overall, females in ChE are successful at completing their degrees, getting good GPAs, and securing employment after graduation. The small number of students in the cohorts limited the types of statistical tests employed and the generalization of the findings. Also, lack of regional data on females in STEM occupations restricted the findings to Jamaica.

This study can inform similar research in the Caribbean region where enrollment numbers in engineering/STEM programs are small in general and even smaller for females. Engineering faculties in the Caribbean are encouraged to devise strategies to attract and retain more females in engineering to ensure that females have a place in the STEM workforce and contribute to the development of their respective countries.

REFERENCES

[1] Planning, Research and Monitoring Unit, Ministry of Labour and Social Security, "Labour Market 2012: A Guide to Employment Opportunities,"

[2] N. Wilson-Harris, "Universities joined forces to ease shortage of engineers," 2017, The Gleaner. http://jamaica- gleaner.com/article/news/20171001/universities-join-forces-ease- shortage-engineers, last accessed February 8, 2020.

[3] Jamaica Information Service, "Gov't looking to double tertiary enrolment by 2030" 2017, https://jis.gov.jm/govt-looking-double-tertiary-enrollment-2030/, last accessed February 8, 2020.

[4] H. Blackburn, "The status of women in STEM in higher education: Review of the literature 2007 – 2017," Science & Technology Libraries, vol. 36, no. 3, pp. 235-273, 2017.

[5] N. Dasgupta, M. Scircle, M. Hunsinger, "Female peers in small work groups enhance women's motivation, verbal participation, and career aspirations in engineering," PNAS, vol. 112, no. 16, pp. 4988–4993, 2015.

[6] Jamaica Information Service, "Girls, women have strong place in engineering - technology minister," 2019.http://www.jamaicaobserver.com/career-education/girls-women-have- strong-place-in-engineering-technology-minister_169262, last accessed February 8, 2020.

[7] S. Peuker, "Improving Student Success and Retention Rates in Engineering: A Four-Year Longitudinal Assessment of the DYP Program," American Society for Engineering Education, 2017.

[8] E. Godfrey, T. Aubrey, and R. King, "Who leaves and who stays? Retention and attrition in engineering education," J. Eng. Educ., vol. 5, no. 2, pp. 26-40, 2010.

[9] J. Roy, "Engineering by numbers," 2018, http://www.asee.org/colleges, last accessed May 20, 2020.

[10] S. M. Lord, R. A. Layton, and M. W. Ohland, "Comparing student outcomes for women and men in Electrical Engineering to Civil, Chemical, Industrial and Mechanical Engineering in the USA," Proc. 2017 EAEEIE Annual Conf. Grenoble, FR, June 2017.

[11] O. Almatrafi, A. Johri and H. Rangwala, "Retention and persistence among STEM students: A comparison of direct admit and transfer students across engineering and science," Proc. 2017 ASEE Annual Conference & Exposition, Columbus, Ohio, U.S., June 2017.

[12] S. M. Lord, R. A. Layton, M. W. Ohland, C. E. Brawner, and R. A. Long, "A multi-institution study of student demographics and outcomes in Chemical Engineering," Chem. Eng. Educ., vol. 48, no. 4, pp. 223-230, 2014.

[13] ASEE, "Engineering by the numbers: ASEE retention and time-to-graduation benchmarks for undergraduate engineering schools, departments and programs," 2017, https://ira.asee.org/wp-content/uploads/2017/07/2017-Engineering-by-the-Numbers-3.pdf, last accessed July 10, 2020.

[14] M. W. Ohland, M. M. Camacho, R. A. Layton, R. A. Long, S. M. Lord and M. H. Wasburn, "How we measure success makes a difference: eight-semester persistence and graduation rates for female and male engineering students," Proc. of the ASEE Annual Conf. Austin, TX, USA, June 14-17, 2009.

[15] J. C. Kamphorst, W. H. Adriaan Hofman, E. P. W. A. Jansen, and C. Terlouw, "Explainng academic success in engineering degree programs: Do female and male students differ?," J. Eng. Educ., vol. 104, no. 2, pp. 189-211, 2015.

[16] B. D. Jones, C. Ruff, and M. C. Paretti, "The impact of engineering identification and stereotypes on undergraduate women's achievement and persistence in engineering," Soc Psychol. Educ., vol. 16, no. 3, pp. 471-493, 2013.

[17] C. E. Brawner, S. M. Lord, R. A. Layton, M. W. Ohland, and R. A. Long, "Factors affecting women's persistence in Chemical Engineering," International J. Eng. Educ., vol. 31, no. 6A, pp. 1431- 1447, 2015.

[18] D. S. Madara and S. S. Namango, "Longitudinal comparative study: Females' vs males' graduation outcomes in undergraduate engineering," J. Educ. and Pract., vol. 7, no. 30, pp. 9-23, 2016.

[19] E. Smith, "Women into Science and Engineering? Gendered participation in higher education STEM subjects". British Educational Research Journal, vol. 37, no. 6, pp. 993–1014, 2011.

[20] C. Corbett and C. Hill, "Graduating to a Pay Gap The Earnings of Women and Men One Year after College Graduation" 2012, https://files.eric.ed.gov/fulltext/ED536572.pdf, last accessed May 20, 2020.

[21] K. Frank, "A gender analysis of occupational pathways of stem graduates in Canada. Social Analysis and Modeling Division, Statistics Canada", 2019 www150.statcan.gc.ca/n1/pub/11f0019m/11f0019m2019017-eng.htm, last accessed June 20, 2020.

[22] S. Greenfield, J. Peters, N. Lane, T. Rees, and G. Samuels, "A report on women in science, engineering and technology for the Secretary of State for Trade and Industry" 2002, https://extra.shu.ac.uk/nrc/section_2/publications/reports/R1182_SET_Fair_Report.pdf, last accessed July 11, 2020.

Technical Papers

The validity of international instruments for assessing South African engineering students

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Abstract—**This study examines the validity of three international instruments for assessing South African first-year engineering students. The Grit-S, Dweck's Implicit Theories of Intelligence Scale (ITIS), and the Revised Purdue Spatial Visualization Test: Visualisation of Rotations (PSVT:R) were assessed for internal functioning and usefulness in predicting engineering drawing subject marks. Grit-S and ITIS were chosen as they may offer potential areas for intervention to enhance psycho-social adjustment to university. The PSVT: R was administered as it was expected to have a relationship with engineering drawing, and spatial reasoning is a skill that can be taught, which will assist first-year engineering students. The study found that Grit-S was not internally reliable and valid for assessing our engineering students. Both Grit-S and ITIS had low discrimination, with most students strongly agreeing with the statements. The overly positive responses to the instruments led to no predictive power. The PSVT:R had a small but significant relationship to the engineering drawing semester mark as well as evidence for internal reliability and validity. Constructs such as Grit and mindset may need to be recontextualised for the African setting, or the instruments would need to be redesigned to offer greater discrimination power. Only the PSVT:R showed some potential for predicting first-year engineering achievement in the graphics module.**

Keywords—First year engineering; South Africa; Grit; Dweck's Implicit Theories of Intelligence Scale (ITIS); Revised Purdue Spatial Visualization Test: Visualisation of Rotations (PSVT: R); Rasch measurement models

I. INTRODUCTION

Many internationally validated instruments exist to interrogate aspects of student functioning. Instruments, such as the ones examined in the current paper, may be used in engineering programs to classify or to assess first year engineering students. This information should theoretically identify shortcomings in teaching and learning, allowing for appropriate interventions, with the long-term goal of improving achievement.

However, when instruments are utilized without first investigating their usefulness for the context, misleading inferences can be derived. This is especially true when instruments were developed for a different population than eventual usage. An African perspective requires that instruments be contextualised and constructs be investigated for their local applicability.

Instruments are designed to measure underlying constructs. A *construct* is a trait which you cannot observe directly, and hence attempt to measure indirectly. An example of a construct in engineering is problem-solving ability. The validity of an instrument is the extent to which it measures the construct it claims to measure. For example, if you attempt to measure problem-solving, but the questions are too similar to problems students are familiar with, then the students rely on their memory during the assessment, and the assessment measures recall instead of problem-solving. Therefore the instrument is not a valid measure of the construct of problem- solving. The *reliability* of an instrument is a measure of how consistently the construct is measured. Reliability is established when students consistently reach the correct answers for questions of equivalent difficulty. To assess *internal* validity and reliability, we consider only the results from the instrument. For *external* validity, we compare results from the instrument to other assessments to which it should have a relationship.

The current study examines three international instruments. The instruments measure underlying constructs which have been shown to have a relationship with achievement in engineering or a student's ability to adapt to first-year social and academic demands. Two questionnaires are related to psycho-social characteristics: mindset and Grit. The third instrument is a frequently utilised spatial reasoning test. These instruments are investigated for their internal validity and reliability. The predictive validity of the instruments is assessed in relation to results of the first year engineering drawing course. Based on the statistical analysis, we critique the usefulness of the constructs for our South African context.

Mindset was defined by Dweck [1] as a set of beliefs about how the human mind functions, specifically whether a person believes that intelligence and talents are inborn and unchanging (fixed mindset) or that acumen and aptitudes can be developed and changed (growth/malleable mindset). Studies have found that when engineering students hold a growth mindset, they are more likely to employ active learning strategies, collaborate with classmates and report higher self-efficacy [2, 3, 4]. Campbell, Craig and Collier- Reed [5] found that teaching a growth mindset helped approximately half of the engineering students from minority groups and low socioeconomic backgrounds shift their mindset, but the small sample size makes drawing conclusions from the study difficult. Teaching mindset as a way to negate the effects of poverty has shown some potential [6]. A growth mindset in first-year engineering students has been found to be positively correlated to engineering identity, and consequently, higher retention rates [7]. The Dweck Implicit Theories of Intelligence Scale (ITIS) has shown high internal reliability (>.80) as well as predictive validity for mastery of skills in European and United

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States of America (US) settings [8, 9]. Despite the popularity of the mindset construct, Dweck [10] warns that it is not a magic bullet that can address all aspect of teaching and learning and that researchers need to contextualise mindset.

Grit was defined by Duckworth as a personality trait in which a person shows passion and persistence to achieve goals [11]. Duckworth and colleagues conducted studies to demonstrate that Grit could be a better predictor of achievement than factors such as talent or inherent ability [12]. Duckworth also has a Grit Formula, in which aspects of the trait such as prioritisation, precision and effort can be taught [11]. Direito, Chance and Malik [13] found that most of the Grit studies in engineering were conducted in the US, and with first-year students as the sample. Some of the studies showed correlations between high Grit scores and increased first-year achievement as well as retention rates [14, 15]. In contrast, other studies could not detect such relationships [16]. Inconsistent conceptualisations of the Grit construct as well as unreliable reporting of analysis makes it difficult to draw conclusions about the role of Grit in engineering success, further research is needed [13]. The Grit-S had high internal reliabilities when used with adults in the US, the reliabilities between self-reported and informant versions were consistently above .80 [17]. The Grit-S had higher correlations with external factors and was more internally reliable and valid compared to the longer version [17].

Spatial reasoning and mental rotation skills are crucial for most types of engineering programmes and are assessed in the first-year programmes by many institutions [18]. The Revised Purdue Spatial Visualization Test: Visualisation of Rotations (PSVT:R) was designed to assess three-dimensional reasoning and the ability to mentally manipulate objects [19]. The PSVT:R is a widely recognised standardised test of spatial ability and has shown moderate correlations with engineering graphics courses [20]. It is used in many engineering programmes and has shown internal validity in a variety of studies, as well as moderate correlations with engineering subjects [21, 18]. The PSVT:R had high internal reliability (.84) when used to assess first-year engineering students in the US [22]. There were weak to moderate correlations between the PSVT:R scores and aptitude scores for the US first-year engineering students [23].

II. RESEARCH QUESTIONS AND THEORETICAL APPROACH

In this paper, we address the following research question: *"Do the chosen international instruments have sufficient internal and external reliability and validity to assess South African Engineering students?"*

The theoretical approach is grounded in measurement theory, specifically Rasch models and philosophy. The Danish mathematician Georg Rasch [24], designed a logistic model to assess the reliability and validity of social and educational instruments. The family of Rasch models are applied and interpreted through the philosophical lens of objective measurement [25]. Rasch models have the unique property of sufficient statistic and measurement invariance. The Rasch models assess how well social science instruments meet the criteria of measurement in the physical sciences. Rasch theory was used to guide the study and obtain evidence of accurate and useful assessment. The Rasch models are both practical and philosophical, assessing the items and instrument functionality with statistical evidence as well as providing the theoretical structure to interpret and confirm/refute the attainment of objective measurement.

III. METHOD

The current study was conducted in a South African university which recruits most of its engineering students from Quintile 5 and IEB/Cambridge schools. The South African public schooling system is classified according to socioeconomic categories, wherein schools from low resourced communities are classified as Quintile 1 to 3 (non- fee paying). Public schools in more affluent communities are Quintile 4 and 5 (fee-paying). Independent schools are mostly private schools with high school fees, such as schools falling in the category of the Independent Examinations Board (IEB) or Cambridge systems.

Engineering drawing is a compulsory subject in the first semester at university for a range of engineering disciplines. The subject includes a large component of technical drawing, performed by hand as well as using software. Students also learn some theory about manufacturing processes. Three- dimensional visualisation is a critical skill for achievement in this course, while psycho-social aspects of adjustment to university should reflect in any of the first semester courses. We, therefore, focused our predictive analysis on results in the engineering drawing course.

A. Sample

During orientation week, 541 first-year students in the School of Engineering participated in the study. Permission to conduct the study was obtained from the Engineering faculty's Ethics committee, and students provided informed consent for their results to be used for further research purposes. There were more men (68%) than women in the study. The majority of students (85%) attended schools classified as affluent, such as Quintile 5 or IEB/Cambridge schools. Merely 37% spoke English as a home language, whereas the rest of the students spoke languages other than English. English is the medium of instruction at our institution.

B. Instruments and administration

Three international instruments were administered:

- **Revised Purdue Spatial Visualization Test: Visualisation of Rotations (PSVT: R)**, which consists of 30 items.
- **Dweck's Implicit Theories of Intelligence Scale (ITIS)** which consists of 8 items for *mindset talent* and 8 items for *mindset intelligence*.
- **Short Grit Scale (Grit-S)** which consists of 4 items for *the perseverance of effort* and 4 items for *consistency of interest.*

C. Data Analysis

The construct validity (internal), as well as the predictive validity (external), were assessed to gauge the usefulness of the constructs and instruments for assessing South African engineering students. Rasch models were used to assess the construct reliability and validity of the instruments. Winsteps 4.5.0 software was utilised to conduct the analysis [26, 27].

The Rasch statistics we examined include item fit, reliability coefficients, ordered categories, unidimensionality of constructs and measurement invariance. Item fit is characterised by the MNSQ, which should have a value smaller than 1.5. Reliability coefficients, denoted ŧ, should have a value above .70 for acceptable internal consistency. Categories should be ordered and increase monotonically with person location. Unidimensionality is measured by principal component analysis and should result in Eigenvalues smaller than 2.0. Measurement invariance should be non-significant between groups, as assessed by Differential Item Functioning (DIF). More details of the Rasch analysis and interpretation are available as supplementary material [28].

Multiple linear regression analysis was used to assess the predictive validity of the instruments. We used the marks from the practical drawing and Semester 1 engineering drawing attainment as the outcome variables. Standardised coefficients were calculated with IBM Amos software [29]. Predictors in the regression model included background characteristics (gender, race, home language and school attended), academic history (physical science, mathematics and English language achievement) and the mindset as well as PSVT:R scores.

IV. RESULTS AND DISCUSSION

The results are presented by first investigating the internal reliability and validity, i.e. the construct validity. Thereafter, we present the predictive validity findings from a multiple linear regression analysis. Data tables are available as supplementary material [28].

A. Construct reliability and validity: Results

Good reliability coefficients for persons (70. > ŧ) and items (90. > ŧ) were present for the Mindset and PSVT constructs. Grit, Mindset and PSVT had constructs which were unidimensional (Eigenvalues < 2.00). Mindset and PSVT had items that fit the Rasch model (MNSQ < 1.50). The PSVT had a lower than acceptable person separation index (below 2), which could indicate that the sample may not be diverse enough in ability to establish item hierarchy.

The Grit-S questionnaire had a misfitting item, *Q2 Setbacks do not discourage me*, which had an MNSQ of 1.51. The Grit-S instrument had unacceptably low person reliability (59 = .ŧ) as well as poorly functioning categories. The categories: Not like me at all (1); *Not much like me (2)* and ***Somewhat like me (3)*** were problematic, due to few persons choosing the categories and the first three categories not increasing with higher person endorsement of the construct. The Grit-S showed differential item functioning (DIF) for 4 of the 8 items between women and men who answered the questionnaire. For example, *Q4 I am a hard worker*, men were significantly more likely to endorse the question when compared to women (00. = ŧ), even when they had the same overall agreement with Grit-S statements. The opposite pattern is observed for *Q2 Setbacks don't discourage me*, where women were significantly more likely to endorse the item.

The mindset constructs of *talent* and *intelligence* showed significant DIF for the type of school attended, with Quintile 1-3 and Quintile 4 (lower socioeconomic) students being more likely to endorse items than the Quintile 5 or IEB/Cambridge students. The DIF for Race in the PSVT results vary across groups, some items African students are significantly more likely to answer correctly, other items White or Indian/Coloured students are more likely to answer correctly despite the same underlying ability. The same was observed for languages, not giving a clear indication as to why some of the items may be easier for one group and not for another. Based on the number of items in the PSVT that display DIF (6 items out of 30), we would argue that there is sufficient evidence for measurement invariance overall. Generally, we would prefer to see no DIF in instruments; however, 6 out of 30 items displaying DIF is not likely to cause differential test functioning (DTF), and indeed Maeda and Yoon [30] found that DIF for gender in the PSVT:R had a negligible impact on the total score. The same cannot be applied to Grit-S and the Mindset constructs, since out of a small number of items as many as half displayed DIF for Quintile.

All of the constructs fit the Rasch model globally (o[illegible] non-significant), but this is the least important aspect of examining internal reliability and validity. More important is that items function well to provide evidence of consistent and accurate measurement of one construct.

The Grit-S and Mindset questionnaires also had low overall discrimination, with the majority of students highly endorsing the constructs. For all three constructs, students highly endorsed the constructs. More than 87% of students said they endorse a growth mindset, and 92% of students could be classified as "gritty".

B. Construct reliability and validity: Discussion

The PSVT:R and Mindset (ITIS) instruments had items that fit the Rasch model, had acceptable coefficients for persons and items as well as unidimensional constructs. The PSVT:R did not have a sample diverse enough in ability to establish item hierarchy; the assessment may be too easy for most of the students.

Grit-S was problematic in many aspects, including a misfitting item, poor category functioning and an unacceptably low person reliability coefficient. Across all person factors (gender, race, home language, school quintile), the Grit-S showed a lack of measurement invariance for as many as half of the items. This could indicate problems with the design of the items, or the construct meaning is not invariant across groups.

Category functioning was also problematic for both *mindset intelligence* and *mindset talent*, where one category was chosen by less than 10% of the sample and for some items no-one chose the option of *strongly disagree*. Problems with the way the categories functioned for Grit and the Mindset constructs are linked to the lack of discrimination found for both instruments. Most of the respondents *agreed* or *strongly agreed* with the statements, offering virtually no range of agreeability and not providing much useful information.

C. Predictive reliability and validity: Results

A multiple linear regression model was built to investigate the association of PSVT:R and the mindset constructs with attainment in the engineering drawing module while holding background variables constant. Grit was not included in the model because of the weak internal reliability and validity.

Table 1 shows the standardised regression coefficients (β) per predictor, as well as the standard error (SE). Results which were statistically significant (0.05 < ŧ) are indicated with an asterisk (*). In the multiple linear regression model, the PSVT:R score emerges as small and significant only for the semester mark. The mindset scores do not have a relationship with either the drawing mark or the semester mark.

The practical drawing model had an R2 of 0.17, and the semester mark for engineering drawing had an R2 of 0.24, indicating that the models explained only a small amount of the observed variance in practical drawing and the semester mark.

TABLE I *Multiple linear regression model predicting practical drawing and the semester mark*

	Practical β	SE.	Semester β	SE.
Gender (M/F)	0.12*	-0.13	-0.04	-0.01
White	0.32*	0.16	0.17	0.05
Indian/Coloured	0.19*	0.20	0.06	0.02
Quintile 4	-0.09	0.12	-0.04	0.02
Quintile 5	0.10	0.07	0.13	0.15
IEB/ Cambridge	0.06	0.04	0.14	0.25
Afrikaans spoken at home	-0.11	-0.16	0.07	-0.07
English spoken at home	-0.10	-0.10	0.09	-0.08
Other language spoken at home	-0.06	-0.10	0.04	-0.04
Physical Science Gr12	0.13*	0.05	0.14*	0.06
Mathematics Gr12	0.06	0.03	0.11	0.10
English Gr12	0.06	0.03	0.10*	0.08
English taken in school as home langague	0.13*	0.10	0.08	0.04
Mindset Intelligence	0.02	-0.01	-0.04	-0.12
Mindset Talent	0.03	0.00	-0.05	0.28
PSVT:R	0.05	0.47	0.11*	0.00

D. Predictive reliability and validity: Discussion

Both *mindset intelligence* and *mindset talent* had no relationship with either the *practical drawing* or the *engineering drawing semester mark*. This is unsurprising as both variables had very low discrimination and students generally just agreed with most statements. The spatial visualisation (PSVT:R) score was a small but significant predictor for the *engineering drawing semester mark.*

In our preliminary analysis, in which we investigated the correlation with the marks in the first practical assignment and the first semester test, the PSVT:R had stronger correlations than in this final analysis. We expect that the predictive validity of the PSVT:R would decrease over the semester, since spatial dimensional learning has taken place throughout the course.

V. CONCLUSIONS AND IMPLICATIONS

The social sciences, much like the natural sciences, are often geared towards finding neat, simplified answers to the complexity of human nature. Our current study leads us to critique and question two underlying assumptions: that the constructs we measured are co-constructed in our contexts ('real for us'), and that the constructs can be measured quantitatively by the questionnaires ('reduced through statements and numbers'). Social constructs are inherently qualitative, frameworks created by us to understand aspects of experiences and observations [31]. Constructs are not objective reality, and they are created within certain contexts and are likely to have deeply embedded biases.

> *If educators teaching "growth mindset" do not take young people's environment into account, particularly, youth experiencing white supremacy, anti-Blackness poverty, patriarchy, and ableism, then they are engaged in glorified victim blaming.* [32]

When we measure constructs, we both affirm their "existence" as well as the principal implications embedded within those constructs. Our findings showed that the Grit-S and the ITIS are blunt tools when applied to our specific first- year engineering students. Possible reasons include applying the constructs too broadly and not linking them to specific tasks or activities, ignoring how the traits are co-constructed in diverse groups and creating instruments that lead to social desirability responding. We summarise our conclusions and the implications below.

A. Critique of the constructs

Language and constructs: Thinking critically about the constructs we measured, we acknowledge that within the field of resilience, constructs such as Grit and mindset may be used to place the onus on the individual to overcome unfair circumstances. The use of coded language such as Grit and mindset, could imply that an individual must have certain personal abilities in place in order to succeed without considering the context in which development happened [33].

Constructs in the African milieu: The constructs may not 'exist' or function in the African context as they were defined in a Western context. Constructs are socially created frameworks, and ideas such as Grit and mindset could either manifest in a different way in a developing context or not be applicable at all for some groups.

B. Critique of the instruments

The constructs should be domain and task-specific: Latent-traits such as Grit and mindset, if co-constructed in our context, could be specific to domains and tasks [13]. A potential solution to this problem would be to apply items to more specific contexts to gain refined insight. A person may have a growth mindset for one type of domain (for example mathematics) but a fixed mindset for a different domain (for example, writing). A person may be gritty in dealing with their studying, but less gritty when faced with interpersonal problems. Assuming mindset and Grit are globally applicable to all contexts and at all times is problematic and inaccurate.

Generic phrasing of questions: The items in both the Grit-S and the Mindset Questionnaire are phrased in general ways, and it is unclear to which specific aspect or task they apply. This could be the reason the instruments fail to discriminate between those of different mindsets or grittiness. An example is item 8 of the Grit-S: *I finish whatever I begin.* Completing all tasks is nonsensical, especially as one may begin a task that is later not required or no longer useful. A possible improvement could be: *I finish work required for my class on time.*

Construct meaning varies among groups: An assumption of questionnaires is that the constructs function in the same way for all homogenous populations (measurement invariance). But our first-year engineering students are very diverse, and it may be that the constructs have different meanings for different populations. This, coupled with potentially problematic or vague phrasing, will lead to more inaccurate measurement.

Social desirability responding: Our students are intelligent people who have a good idea of who they are supposed to be, or how they should present themselves. This could have led to overly positive responding to satisfy perceived researcher expectations.

C. Overall conclusions

The PSVT:R is judged to have sufficient evidence that it is internally reliable and valid for assessing first-year engineering students in

South Africa. The Grit-S showed too many problems to be used in its current format for assessing engineering students. The Mindset constructs are generally reliable, but revision may be needed for construct validity to be confirmed, especially considering the overly positive endorsement of the items.

The Grit-S and Dweck's Implicit Theories of Intelligence Scale (ITIS) may not be useful for predicting first-year engineering achievement, but the PSVT:R could be used as a predictor and provide some useful information, especially at the beginning of the semester.

D. The way forward

Our main recommendation is that researchers who want to use psycho-social constructs such as Grit and mindset in a unique context, first pilot the instruments before use, or explore the constructs qualitatively. This, in turn, may lead to the redevelopment of the instruments if the constructs are found to be reconstructed by participants in a different way than represented in the existing instruments. The shortcomings of the selected instruments provide an opportunity for engineering educators. The challenge is not to create "standardized" assessments which rigidly classify students. Rather, engineering educators need assessment tasks which gauge student functioning holistically and give indications for supporting students.

REFERENCES

[1] C. S. Dweck, "Developing talent through a growth mindset," Soccer Journal -Binghamton- National Soccer Coaches Association of America, vol. 56, no. 5, pp. 8-13, 2011.

[2] M. Frary, "Encouraging a growth mindset in engineering students," in Proceedings of the ASEE Annual Conference & Exposition, Salt Lake City, UT, 2018.

[3] E. Silva and T. White, Pathways to improvement: Using psychological strategies to help college students master developmental math, Carnegie Foundation for the Advancement of Teaching, 2013.

[4] G. S. Stump, J. Husman and M. Corby, "Engineering students' intelligence beliefs and learning," Journal of Engineering Education, vol. 103, no. 3, p. 369–387, 2014.

[5] A. Campbell, T. Craig and B. I. Collier-Reed, "A framework for using learning theories to inform 'growth mindset' activities," International Journal of Mathematical Education, vol. 51, no. 1, pp. 26-43, 2019.

[6] S. Claro, D. Paunesku and C. S. Dweck, "Growth mindset tempers the effects of poverty on academic achievement," Proceedings of the National Academy of Sciences of the United States of America, vol. 113, no. 31, pp. 8664-8, 2016

[7] H. L. Henderson, K. E. Rambo-Hernandez, C. Paguyo and R. A. Atadero, "What is the Relationship between Mindset and Engineering Identity for First Year Male and Female Students? An Exploratory Longitudinal Study," in Proceedings of the ASEE Annual Conference & Exposition, Columbus, OH, 2017.

[8] D. Corradi, J. Nicolaï and F. Levrau, "Growth mindset and its predictive validity—do migration background and academic validation matter?" Higher Education: The International Journal of Higher Education Research, vol. 77, no. 3, pp. 491–504, 2019.

[9] D. A. Cook, R. M. Castillo, B. Gas and A. R. J. Artino, "Measuring achievement goal motivation, mindsets and cognitive load: validation of three instruments' scores," Medical Education, vol. 51, no. 10, p. 1061–1074, 2017.

[10] C. S. Dweck, "Growth mindset doesn't promise pupils the world," Tes: Times Educational Supplement, 5187, 2016.

[11] A. Duckworth, Grit: the power of passion and perseverance, London: Vermilion, 2016.

[12] A. L. Duckworth, T. A. Kirby, E. Tsukayama, H. Berstein and K. A. Ericsson, "Deliberate Practice Spells Success: Why Grittier Competitors Triumph at the National Spelling Bee," Social Psychological and Personality Science, vol. 2, no. 2, p. 174–181, 2011.

[13] I. Direito, S. Chance and M. Malik, "The study of grit in engineering education research: a systematic literature review," European Journal of Engineering Education, 2019, https://doi.org/10.1080/03043797.2019.1688256.

[14] J. Bracey, G. D. Jones, N. Bracey and K. Sadeghipour, "Chasing the Holy Grail: Pushing the Academic Persistence of Highly Motivated, Underprepared URM Students Pursuing Engineering," in Proceedings of the 2016 ASEE Annual Conference & Exposition, New Orleans, LA, 2016.

[15] R. McDermott, M. Daniels and Å. Cajander, "Perseverance Measures and Attainment in First Year Computing Science Students," in Proceedings of 2015 ACM Conference on Innovation and Technology in Computer Science Education, Vilnius, Lithuania, 2015.

[16] D. S. Choi, "Engineering Survivors: Students Who Persist in Engineering Through an Academic Setback," in Proceedings of the 2016 ASEE Annual Conference & Exposition, New Orleans, LA, 2016.

[17] A. L. Duckworth and P. D. Quinn, "Development and validation of the short grit scale (GRIT-S)," Journal of Personality Assessment, vol. 91, no. 2, p. 166–74, 2009.

[18] J. Rodriguez and L. G. Rodriguez-Velazquez, "Data analytics on improvement of spatial visualisation skills," Procedia Computer Science, vol. 172, p. 106–111, 2020.

[19] S. Y. Yoon, Revised Purdue Spatial Visualization Test: Visualisation of Rotations (Revised PSVT:R) [Psychometric Instrument], 2011.

[20] S. A. Asmaa, L. F. Daghestani and L. F. Ibrahim, "Techniques used to Improve Spatial Visualisation Skills of Students in Engineering Graphics Course," International Journal of Advanced Computer Science and Applications, vol. 8, no. 3, pp. 91-100, 2017.

[21] C. Charyton, R. J. Jagacinski, J. A. Merrill, W. Clifton and S. DeDios, "Assessing creativity specific to engineering with the revised creative engineering design assessment," Journal of Engineering Education, vol. 100, no. 4, pp. 778-799, 2011.

[22] Y. Maeda and S. Y. Yoon, "A meta-analysis on gender differences in mental rotation ability measured by the Purdue spatial visualisation tests: visualisation of rotations (PSVT:R).," Educational Psychology Review, vol. 25, no. 1, pp. 69-94, 2013.

[23] Y. Maeda, S. Y. Yoon, , G. Kim-Kang and P. K. Imbrie, "Psychometric Properties of the Revised PSVT: R for Measuring First Year Engineering Students' Spatial Ability," International Journal of Engineering Education, vol. 29, no. 3, p. 763–776, 2013.

[24] G. Rasch, Probabilistic models for some intelligence and attainment tests, Chicago: Institute for Objective Measurement, 1980.

[25] D. Andrich and I. Marais, A Course in Rasch Measurement Theory: Measuring in the Educational, Social and Health Sciences, Singapore: Springer, 2019.

[26] J. M. Linacre, Winsteps® (Version 4.5.0) [Computer Software], Beaverton, OR: Winsteps.com, 2020.

[27] J. M. Linacre, Winsteps® Rasch measurement computer program User's Guide, Beaverton, OR: Winsteps.com, 2019.

[28] C. Combrinck and H. M. Inglis, "Supplementary data tables," 2020. [Online]. Available: https://drive.google.com/drive/folders/1RAshJTBiqiPYWHAzuBlOI WIiaaKeVj_m.

[29] J. L. Arbuckle, Amos (Version 26.0) [Computer Program], Chicago, IL : IBM SPSS, 2019.

[30] Y. Maeda and S. Y. Yoon, "Are gender differences in spatial ability real or an artifact? evaluation of measurement invariance on the revised PSVT:R," Journal of Psychoeducational Assessment, vol. 34, no. 4, p. 397– 403, 2016.

[31] J. Michell, "Is psychometrics pathological science?," Measurement: Interdisciplinary Research and Perspectives, vol. 6, no. 1-2, pp. 7-24, 2008.

[32] Class Trouble, "A Guide to Coded Language in Education Vol. I & II," 2020. [Online]. Available: https://classtrouble.club/blogs/resonance- archives/a-guide-to-coded-language-in-education-vol-i.

[33] L. Ebersohn , "Collective resilience to global challenge: a collective wellbeing agenda to transform towards sustained equitable education," Práxis Educativa, vol. 15, pp. 1-14, 2020.

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