# Ethics in Engineering Education 4.0: The Educator's perspective

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# Ethics in Engineering Education 4.0: The Educator's perspective

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*Abstract*— **The advent of the fourth industrial revolution (4IR) has had an all-pervasive influence on virtually every aspect of high-quality manufacturing and associated services. Consequently, it triggered increasing industry demand to drive technological transformation. By implication, this propelled transformation in the requirements of Higher Education (HE) during the process of training engineers, towards more blended or online modes of delivery. A common concern from commentators has been "What are the ethical implications of using technology when teaching engineering students". The objective of this paper is to expand on a previously published literature study which theoretically examined the extent to which ethics has been considered during the process of training engineers in contemporary times. In this follow-up study, a survey research instrument (n= 68) which included eight likert scale questions and ten open-ended questions, was used to empirically explore three ethical dilemmas which emerged during the precursor study. The ethical dilemmas are (1) the unintended negative consequences of using technology; (2) discrimination as a result of the use of technology and (3) educator agency in the Engineering Education 4.0, at a University of Technology (UoT) in South Africa. Ethical clearance to do this research was secured through institutional channels. The findings of this study were consistent with findings of the precursor study and the recommendation of this study is that a series of workshops be held to develop ethics guidelines and establish ethical best practices to assist engineering educators to assure the quality of online engineering education, avoid discrimination, protect the privacy of both students and educators and reinforce the integrity of online engineering assessments**

***Index Terms— 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 [1] 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, an 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, are vital for success. Several researchers [2], [3], [4] referred to this approach to training engineers as Engineering Education 4.0. Moreover, the research of Jeganathan, Khan, Raju and Narayanasamy [3] confirmed 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 [5] 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 [6], including the HE landscape, it is notable that some commentators have raised questions about whether our new technological scenario implies new ethical challenges. Irrespective of the fourth industrial revolution (4IR) progressing at different rates in different parts of the world [7], a common concern from commentators has been "What are the ethical implications of using technology when teaching engineering students?"

## II. Theoretical Framework

To expand the worldview on ethics in Engineering Education 4.0, with particular focus on the examination of complex relationships between stakeholders in engineering faculties and technology, and the implications (good and bad) of those relationships on behavior, a framework proposed by Jasanoff [8] was adopted to perform this study. The framework consists of three primary concepts centered around the idea that 'while it is known that technology has the potential to make life easier, in the context of Engineering Education 4.0, that same technology can be harmful'. These concepts are (1) Unintended negative consequences of Engineering Education 4.0, (2) Discrimination and (3) Agency and digital identity. Jasanoff suggests that these are three main ethical concerns related to the 4IR. The first concern is that technologies that are intended to, and also appear to make our lives easier, could be destructive if

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used with ill-intent or misused intent. This is regarded to be unintended negative consequences or 'hidden costs' associated with the use of technology. Second, assuming that technology is only intended to be used for good, but the technology was not designed to be inclusive and respectful of the essential principle of human dignity, it may not be good. As such, 'good' technology may be discriminatory. Third, technology affects human beings, own perception of ourself and the way we relate to each other. Therefore, technology can also influence our sense of self and agency.

## III. Literature Review

A recent systematic literature review [9] which initiated this study, confirms that there is a dearth of literature on ethical considerations around Engineering Education 4.0, as no publications that have directly addressed this research topic could be identified. An extensive literature search of 12 databases returned only 17 indirectly related publications. Notably, no guiding principles or guidelines are available in literature. Thus, based on a recommendation by the precursor study [9], this study set out to empirically explore the perceptions of the engineering educators at a UoT in South Africa on ethical considerations during the process of training engineers for the global market. To achieve this, literature is presented in this section on the three concepts around which this study is centered.

### *A. Unintended negative consequences of using technology*

It is undisputed that e-Learning has several significant advantages [6], such as having no geographical boundaries or restrictions to contend with. Simultaneously however, with the progression and increasing prominence of the use of technology, some concerns around e-Learning and questions about the behavior of the educators (and by implication, students too) when e-Learning takes place, have arisen. Specific to an Engineering Education, literature presented below outlines examples of the most noteworthy hidden drawbacks of e-Learning. Three key themes emerged from the analysis of literature on this topic, namely (1) ethical dilemmas related to the student training and industry, (2) ethical dilemmas related to the engineering assessments and (3) ethical dilemmas related to privacy and security.

#### *1) Ethical dilemmas related to student training and industry.*

Consistent with studies by Noesgaard and Ørngreen [10] and Tam [11] on the effectiveness of e-Learning, Swartz [9] concluded that despite e-Learning being an effective approach, there are several inherent disadvantages of e-Learning. From a student perspective this includes limited communication skills development and the potential to cause social isolation among students. It is believed that these problems are compounded in periods where global restrictions on movement and social gathering were implemented, due to the COVID19 pandemic.

With specific reference to e-Learning and Industry 4.0, some studies [11], [12] suggested that e-Learning platforms are more suited for theoretical training, thus in certain disciplines such as engineering, where practical work is very important, students may not be adequately prepared for what will be required of them in the industry, if they only receive online training. These authors implied that engineers cannot be completely adequately trained exclusively online [12], since no number of online lessons can substitute hands-on practical experience.

In contrast however, research by Blissit [13] on nursing students showed that blended learning courses achieved similar posttest results as traditional course formats, while simultaneously increasing satisfaction ratings of participating students significantly. This author suggested that prior planning may be a successful approach to overcome this disadvantage. Swartz [9] deduced that it is possible for engineering educators to overcome such challenges through the application of additional strategies to compensate for the lack of hands-on practical contact time with students.

Thus, this empirical study set out to determine if innovative interventions, such as personalized feedback or when personalized feedback is not practically possible, a system of peer feedback should be used to overcome some unintended negative consequences of Engineering Education 4.0.

#### *2) Ethical dilemma related to engineering assessments*

Coulton, Nicholas, Bailey, Arora, King, Taylor, and Durham [14] asserted that protecting the authenticity of an online examination is complicated when compared to traditional assessment methods. They pointed out that there are barriers that hinder successful use of emerging technologies and these include inadequate infrastructure, educator perceptions, educator confidence, educator training and information sharing. The authors specifically highlighted that ethical concerns and issues related to bias and the sharing of data, need special consideration.

From an institutional perspective, protecting the authenticity of online engineering examinations is complicated since students cannot be easily observed during assessments without video feed. Meilleur and Ge [15] advanced 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 these are possible. Against the backdrop of the preceding discussion, one of the objectives of this study is to explore potential mechanisms to overcome ethical challenges associated with online assessments.

#### *3)Ethical dilemmas related to privacy and security*

Although many advances have been made in the mechanics of providing online instruction, Hui-Lien and Chen [16] were of the opinion that it is significant that security and privacy concerns around e-Learning have largely been 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 [17] who averred emerging intelligent solutions for eLearning, as well as commonly used web applications, such as Google Drive, are used by educators to collect, process and store a large array of students' personal data. The authors proposed that in general, educators at HE institutions pay little attention to the type of private data being collected and its relevance for successful learning. Moreover, the authors also raised questions about whether the data is being adequately protected against unauthorized use, and pointed out that this represents an ethical concern involving students' privacy. They suggested that privacy in eLearning could be achieved through a combination of actions from the 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 [18] and the Protection of Personal Information (POPI) Act in South Africa [19]. Notably however, a scoping review performed [9] in 2020, returned no literature on the protection of student data in certain countries, such as South Africa.

Security and privacy concerns around e-Learning is important 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 by Swartz [9] was that engineering educators be given guidance to 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 can distinguish between important concepts like 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. This study set out to explore these concepts.

### *B. Discrimination*

Several researchers [1], [3], [20] agreed that online solutions and educators are becoming more digitally innovative which helps to address the needs of contemporary university students. Gachago and Cupido [21] however raised questions around equal epistemic access and unintended discrimination, due to promotion of and increasing reliance on 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. The authors and Rowe [22] emphasized 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 like the availability of data and an upmarket smartphone.

The views of the above-mentioned authors are aligned to that of Jasanoff [8] who expressed a view that global social environments constantly undergo transformation due to technological change. She argued that societal focus is on the extraneous features of technology and she suggested that society 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 4IR, effort has to be made to understand this evolution and in particular Engineering Education toward Industry 4.0

Directed by this, Swartz [9] suggested that engineering educators could benefit from applying 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 mentioned above. 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. Thus, this study also set out to empirically examine the perceptions of educators at a UoT on these principles.

### *C. Educator agency and digital identity*

To understand 'agency' in the context of Engineering Education 4.0, guidance was sought from Rocchi [6] who proposed that one needs to compare the lives of two similar persons, for example, an educator in current times compared to an educator from 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 2021, compared to 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 [23] and Swartz [9] who agreed that the essential roles of responsibility of educators and students remain unchanged in the digital era. Moreover, agency is also a critical predictor of the field of engineering that students will decide to study. Godwin, Potvin, Hazari and Lock [24] confirmed that the function of engineers is to devise innovative solutions to the world's complex global problems and they assert that agency beliefs are critical to identity development and ultimately the decision to become an engineer.

Thus, this study also set out to empirically determine the perceptions of engineering educators at a UoT on the question of whether the essential roles of responsibility of educators and students remain unchanged in the digital era since Industry 4.0, and 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.

## IV. METHODOLOGICAL APPROACH

This empirical study to probe the perceptions of engineering educators at a UoT took place from December 2020 until March

2021. An online survey (see Table 1) which included eight likert scale questions, was used to collect quantitative data, and ten open-ended questions, used to collect qualitative data (n=68; response rate 36%) from all the lecturing staff in the Engineering Faculty at the UoT. Quantitative and qualitative data analysis took place from February until March 2021. Alpha Cronbach's coefficient was used to ensure internal validity and reliability of the quantitative data. This statistical test measures the strength of that consistency of a set of test items (likert scale survey questions), and the extent to which it is a consistent measure of a concept. The resulting coefficient of reliability ranges from 0 to 1. If all of the scale items are entirely independent from one another (not correlated or share no covariance), then the result will be 0. If all of the items have high covariances, then the result will approach 1 [25]. The Alpha Cronbach result for all sections of the online survey instrument of this study was above 0.7, thus the instrument is considered to be internally valid and reliable.

Thereafter, descriptive statistical analysis was performed on the quantitative data with SPSS statistical software. Following this, qualitative data collected with ten open-ended questions in the survey was thematically coded. The full data set was and analyzed by two researchers who independently used ATLAS.ti software to deductively detect recurring themes in the data set and explore three concepts namely, 1) unintended negative consequences of using technology; 2) discrimination and 3) educator agency and identity. Guided by the view of Saldaña [26], the codes and code families for the thematic analysis were derived from three concepts around which this study is centered. All themes were included however after coding the two researchers had a discussion about the final codebook when deciding what codes to include and what to leave out. Ethical clearance for this study was obtained prior to data collection, through the Faculty of Engineering at the UoT.

TABLE I.
ONLINE SURVEY INSTRUMENT

| Quantitative questions | Question type | Branching to open-ended qualitative questions |
|---|---|---|
| Section 1: Demographic information | | |
| Gender | Demographic | No branching |
| Age | Demographic | No branching |
| Year of Lecturing Experience | Demographic | No branching |
| Years of using technology | Demographic | No branching |
| Types of technology used to teach | Demographic | No branching |
| Section 2: Questions on unintended negative consequences | | |
| Q1. Lack of physical (contact time) with engineering students in lieu of online T&L has a negative impact on their ability to perform as engineers | Likert scale<br>1 – Strongly Agree<br>2 – Agree<br>3 – Neutral<br>4 –Disagree<br>5 – Strongly Disagree | Q1. Agree or Strongly Agree: Do you have ideas of what can be done to overcome lack of contact time?<br><br>Q2. Disagree or Strongly Disagree: Why do you think that lack of contact time with students is not a problem |
| Q2. The integrity of engineering assessments is negatively impacted (or compromised) by using online methods to assess engineering | Likert scale<br>1 – Strongly Agree<br>2 – Agree<br>3 – Neutral<br>4 –Disagree<br>5 – Strongly Disagree | Q3. Agree or Strongly Agree: Do you have ideas of what can be done to mitigate the integrity challenges associated with online assessments? |
| | | Q4. Disagree or Strongly Disagree: Why do you think engineering assessments are not really compromised? |
| Q3. The protection of student and lecturer privacy is a concern when using technology | Likert scale<br>1 – Strongly Agree<br>2 – Agree<br>3 – Neutral<br>4 –Disagree<br>5 – Strongly Disagree | Q5. Agree or Strongly Agree: Do you have any ideas of what can be done to overcome your concerns around the protection of privacy of engineering students and lecturers<br>Q6. Disagree or Strongly Disagree: Why do you think that the protection of student and lecturers is not a concern |
| Section 3: Questions of Discrimination in Engineering Education 4.0 | | |
| Q3. Rate this principle: When using technology, prioritize asynchronous interaction to engage with engineering students | Likert scale<br>1 – Most important<br>5 – Least important | No branching |
| Q4. Rate this principle: Opt for simplicity over complexity | Likert scale<br>1 – Most important<br>5 – Least important | No branching |
| Q5. Rate this principle: Where possible, privilege text over audio or video | Likert scale<br>1 – Most important<br>5 – Least important | No branching |
| Q6. Rate this principle: Adopt contextualized teaching solutions | Likert scale<br>1 – Most important<br>5 – Least important | No branching |
| Q7. Rate this principle: Embrace empathy and co-creation with engineering students | Likert scale<br>1 – Most important<br>5 – Least important | No branching |
| | | Q8. Open ended question: Do you have a comment on the principles or do you have any other principle to add that could help Engineering Educators overcome unintended discrimination? |
| Section 4: Questions on Educator Agency and Digital Identity | | |
| Q8. The essential roles and responsibility of engineering educators remained unchanged in the past decade | Likert scale<br>1 – Strongly Agree<br>2 – Agree<br>3 – Neutral<br>4 –Disagree<br>5 – Strongly Disagree | Q9. Agree or Strongly Agree: Why do you think that the essential role and responsibility of engineering educators remained unchanged the past decade?<br><br>Q10. Disagree or Strongly Disagree: Why do you think that the essential role and responsibility of engineering educators changed over the past decade? |

## V. RESULTS AND DISCUSSION

A census sample was attempted to promote external validity, however of 190 potential participants, despite three separate requests being sent to all lecturing staff to remind them to complete the online survey, only 68 engineering educators completed it, which constituted a response rate of 36%. The UoT where this study took place is the largest university in the Western Cape region of South Africa. It serves a predominantly underprivileged student population from both urban and rural backgrounds. The respondents of this study (lecturers of the student population) may be described in terms of the following demographic characteristics: gender, age, years of teaching experience, years of experience teaching with technology. Respondents were predominantly male (60%) and most respondents (44%) were between the age of 41 to 50 years old. A further 28% were between the ages of 31 to 40 years, 20% were over 51 years and only 8% were between 20 to 30 years old.

In terms of lecturing experience, the responses were more evenly spread across categories with 12% having between 1 to 5 years of experience, 20% having between 6 to 10 years of experience, 28% having between 11 to 15 years of experience, 16% having between 16 to 20 years of experience and 24% having over 20 years of experience. Significantly 36% of all respondents only had between 1 to 5 years of experience teaching using technology, another 36% had between 6 to 10 years of experience and 8%, 8% and 12% of respondents had 11 to 15 years, 16 to 20 years and over 20 years of experience of teaching using technology, respectively. The next section presents the results and a discussion on data analysis on each of the concepts that constitute the theoretical framework of this study.

### *A. Data analysis on Concept 1: Unintended negative consequences of using technology*

#### *1) Lack of face-to-face interaction with students for hands-on laboratory work*

With reference to the lack of practical hands-on time having a negative impact on the ability of engineering graduates to perform the duties of engineers, the results of quantitative data analysis returned 89% of responding engineering educators at the UoT believed that was true to varying degrees. Of this, 20% of respondents believed that this was extremely true, while 12% were undecided and 8% of respondents felt that lack of face-to-face practicals (contact time) with engineering educators has no impact at all on the ability of graduates to perform as engineers.

One participant who believed that that lack of contact time does not have a negative impact wrote "*… simulation labs have a place. For example, if you are dealing with a course like mechanics, a simulation is as good as a physical lab because the students can investigate if you apply this force, a mechanism will move this way".* It is worth noting that the analysis of the qualitative responses of respondents who opined lack of contact time does not have a negative impact suggests that these respondents believe that engineering can be successfully taught as a 'distance learning' offering, as illustrated by one quote stating " … *this* (belief) *flies in the face of what distance learning universities do*".

Conversely, yet equally significant and consistent with the deductions of Swartz [9], Tam [11] and Blissit [13], the analysis of qualitative responses of engineering educators who confirmed that they believe the lack of contact time does indeed have a negative impact, returned innovative suggestions of what could be done to overcome this challenge. These included "*create a contact point with industry for practical exposure for students to learn by doing", "have one on one or small group sessions for better interaction"* and *"invest in simulation software".* From this, it is deduced that different contexts require interventions or solutions that are specific to those contexts.

#### *2) Integrity of assessments*

Aligned with the view of Meilleur and Ge [15] on the integrity of online assessments, 96% of the respondents agreed that the integrity of engineering assessments is compromised as a result of online methods and 4% of respondents were undecided. Significantly, a theme that frequently recurred during the analysis of qualitative responses on integrity of assessments, were challenges associated with the assessment of numbers-based subjects. One respondent noted "*The only way to improve the integrity of maths assessments is with question pools*" A different participant wrote "*Multiple choice and essays are easy for theory subjects, but with maths, students find sketching and drawing difficult and they have to resort to scanned in paper, thus integrity is a problem. Without appropriate hardware students can't be properly assessed.*"

Some participants added observations with their suggestions on how to overcome integrity challenges such as "*The limitation is more on the student side than on the university side. University has the resources – students can't download on their devices. Assumption* [sic] *that all assessments are open book and the questions should be of such a nature that they really test a student's ability to solve problems and then randomize questions to reduce the amount of collaboration – this increases integrity*". Another suggestion to overcome integrity challenges from a different participant was *"use a variety of online assessment methods to support credibility of the final achievement".*

Some other observations were "*If someone can set an open book exam, then integrity is not a problem, it's about understanding – critical thinking – it's an attitude shift. Remote assessments are not a problem"* and *"It's easier to do open book for higher levels rather than lower levels".*

The general consensus among respondents was, to be able to successfully use online assessment, a transition to problem-, project- or case-based assessment methods is required and that the university should invest resources to enable tighter assessment security. Moreover, respondents seem to concur that paying attention to the design of the specific assessment for a particular subject is important as illustrated by these extracts of qualitative data: "*modify the mode of assessment*", "*lecturers need to practice online assessments until they find what works for their subjects*" and *"the manner/nature in which questions are asked… must be revisited and adjusted".*

#### *3) Privacy and security*

The majority of respondents (88%) agreed that educator and student privacy is a concern when using technology for T&L. Nevertheless, 4% of the respondents were uncertain while 8% outrightly disagreed that privacy was a concern. Analysis of qualitative data obtained from the respondents who disagreed that privacy was a concern, generally expressed that view that it would not be a problem if "*… rules of engagement are put in place*". Thus, it is deduced that even the respondents who disagree that privacy and security breaches could be an unintended negative consequence, are aware that the nature of technology for T&L inherently lends itself to privacy and security risks, if preventative measures are not instituted.

The analysis of qualitative data from respondents who agree that privacy and security risks are an unintended negative consequence of using technology for T&L, highlighted some creative suggestions for addressing privacy and security risks such as *"only using a specific device (laptop or tablet) that can be shut down and put away once the work day is complete"*. It is noteworthy that 64% of respondents felt that on an institutional level, heightened cyber awareness and security with associated training is important. One respondent wrote "*Systemic issues affect all students and staff across the board – not just the Engineering Faculty*" From this, this study deduced that engineering educators feel that the role of management for guidance and support should not be understated. Management should act as the first gatekeepers of student and educator privacy, as exemplified by this excerpt from qualitative data *"management needs to sit down, butt heads and come up with solutions to offer us greater protection"*.

Significantly, the analysis of qualitative responses also highlights that some respondents (16%) have completely moved away from sharing private details, or using any private devices for T&L purposes to *"draw boundaries"* as past experience had left them feeling threatened or harassed by students.

*B. Data analysis on Concept 2: Discrimination*

Concerning the recommended universal principles for learning task design [9] to overcome 'discrimination as a result of using technology', 88% of the respondents believe that 'adopting contextual solutions' should be a principle at the UoT. Furthermore, 80% of the respondents believe that 'embrace empathy and co-creation with engineering students' should also be adopted as a universal principle of learning task design, as well as 'opt for simplicity over complexity'. Significantly, all respondents who believe that 'embrace empathy and co-creation with engineering students' should be a principle, also believe that 'adopt contextual solutions' should be a principle. From this it is deduced that these two principles go hand in hand, and that flexibility and being able to adjust as directed by the specifics of the context is important when developing online solutions for engineering students.

Notably 57% of the respondents believe that 'asynchronous interactions should be prioritized' in learning task design and 29% feel that 'text should be privileged over audio and video'. While it is not directly related to this examination of discrimination, a deduction made about this is that these findings coincide with earlier findings on unintended negative consequences due to lack of contact time with engineering students. It is deduced that the respondents in this study believe that to effectively train engineers synchronous engagement and interaction with engineering students in addition to theoretical training is required.

Furthermore, qualitative data analysis also highlighted additional proposed universal design principles such as "*continuous training and development*" and "*clear and open lines of communication with students*" and suggestions such as "*We need ask how can we improve on the delivery, to promote social skills and social justice and transformation (all the social aspects that heavily impact on how we do things) with* [sic] *right from first year level" and "We need to look at broader aspects to improve. Dealing with low pass rates particularly the gatekeeping subjects. These prerequisites have a high failure rate and generally extends the period in which student need to be registered – how do we develop innovative ways to teach in these critical subjects*". Therefore, a further final deduction made in this section of the study is that it would be beneficial for engineering educators at the UoT to engage and brainstorm at a faculty level to develop a set of context-specific principles suited to the UoT.

*C. Data analysis on Concept 3: Educator agency and identity*

The results of the analysis of quantitative data on educator identity and agenda returned that 44% of all the respondents believe that the essential roles and responsibility of engineering educators have remained unchanged in the past decade. Only 24% of the respondents believe that the role of engineering educators has changed and the remaining 32% are undecided.

The analysis of qualitative data obtained from respondents who believed the role has remained unchanged yielded a general standpoint that the graduate attributes of engineering students have generally remained the same over the past decade, however only teaching methods have changed. Significantly however, respondents who believe the role of educators has changed provided several reasons such as "*You are required to provide more support to students related to non-academic matters such as care for the emotional and physical welfare of the student", "The move towards digitalization, internationalization, 3IR and 4IR has brought about the change", "Since I started teaching two decades ago, the role of engineering educator has changed a lot. It changed from chalk and talk to WhatsApp, blackboard etc." and "Students with increasingly less background than what is required are entering the field of engineering, and this requires more responsibility from us than previously".*

A recurring theme that emerged from the qualitative data analysis on this concept is that transformation is essential in Engineering Education 4.0 and has always been an integral part of the essential role and identity of an engineering educator. The theme is captured by one respondent who wrote "*We need to adapt the way we deliver our curriculum to generation Z. We need to renew the way that we do things, teach in the way that our students understand*". Thus, as much as engineering educators are agents for transformation, we are also transformed in the process and that is a fundamental aspect of engineering educator identity and agency.

## VI. LIMITATIONS

A limitation of this study is that the response rate was poor based on the view of Nulty [27] who asserts that 50% is regarded as an acceptable response rate for social research where questionnaires are not physically delivered to and collected from research participants. It must however be noted that a census survey was attempted via the Faculty Management Office at the UoT and three reminders were sent to all (190) the teaching staff in the Faculty via the T&L reps. Regardless of this, 68 responses were received and all these responses were used to do data analysis.

Another limitation of this study is that data was collected from engineering educators in the Engineering Faculty of one UoT, and thus these findings cannot be generalized to all situations at different universities.

## VII. Conclusion

In our modern age, technology and technological choices shape our physical and social world, enabling some things and rendering other things difficult. It is commonly accepted that Industry 4.0, has had a ubiquitous influence on virtually every aspect of high-quality manufacturing and associated services. It triggered an increasing demand to drive technological transformation in Higher Education (HE) during the process of training engineers. Therefore, the advent of Industry 4.0 signifies an important milestone in engineering education as it influences how engineers are trained in South Africa to meet global requirements.

Ultimately this study confirmed and empirically expanded on the findings of precursor study through the examination of the perceptions of selected engineering educators at a UoT. This research showcased the extent to which ethics has been considered at one UoT and influenced behavior during the process of educating engineers in contemporary times. The results of this study presupposes that engineering educators will benefit from engagement in robust discussion around ethical considerations for Engineering Education 4.0. Through this, we, as engineering educators, will have a better understanding of the impact of technology on structures of hierarchy in society and social interaction, and thereby ensure that words like “ethics”, “citizenship”, “equality” and “democracy” do not lose their meaning as cardinal markers for an open society.

## VIII. Implications of this Study and Future Work

Essentially the findings of this study provides a foundation for the development of guiding principles and formulation of a set of best practices. Thus, the recommendation of this study is that a series of workshops be designed and facilitated at the UoT to develop context-specific ethics guidelines and establish ethical best practices to assist engineering educators to assure the quality of online engineering education, avoid discrimination, protect the privacy of both students and educators and reinforce the integrity of online engineering assessments.

Future research should be devoted to the development of a network of safety champions in Engineering Education to improve the quality of teaching and learning in engineering education through adoption of (new) technologies and pedagogical approaches that will enhance safety and sustainability in engineering practice with awareness on sustainability, safety and innovation within local and global society.

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