“More than learning”: Teaching and learning ethics within an electrical engineering undergraduate capstone course

Alison J. Gwynne-Evans

Abstract— **How learning is conceptualized and negotiated within the engineering undergraduate curriculum is affected by the theory of learning implicit in the design of the curriculum. The shift to online learning due to restrictions brought about by the COVID-19 pandemic provides the opportunity to make visible aspects of the curriculum that were previously hidden. The paper presents evidence of student learning relating to ethics found in student assignments submitted in partial fulfillment of a capstone course that forms part of the undergraduate program for Electrical Engineering at the University of Cape Town. Evidence of student learning will be linked to three distinct theories of learning that are presented and contrasted as metaphors: 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 will be linked to particular teaching approaches and assessment strategies. The learning theories provide a frame to examine evidence of student learning relating to ethics in a particular context. This process justifies an expanded conception of learning relating to ethics in engineering.**

Index Terms—**ethics in engineering, online learning, teaching and learning ethics, graduate attributes, engineering identity**

I. Introduction

THIS paper investigates the teaching and learning of ethics within a capstone electrical engineering course in the context of the sudden shift to online learning caused by the COVID-19 pandemic. In this situation, online learning provides a fully virtual learning environment to connect students in diverse contexts. The material is consequently available to be evaluated.

The paper lays out strategic differences in approaching the teaching of ethics within engineering and connects these to theoretical differences in conception of theories of learning. It proceeds to engage critically with online artefacts relating to the teaching and learning of ethics within a particular undergraduate engineering course at the University of Cape Town.

The capstone course is presented as a case study where key elements of the teaching and learning interface are described, discussed and connected to the process of curriculum construction relating to the *intent*, the *implementation* and to what is *attained* in the curriculum. The analysis will use qualitative data and interpretive method based on an analysis of student responses submitted in course assignments to build new understanding and insight about how learning theory affects the development of curriculum and assessment relating to the teaching and learning of ethics within an engineering undergraduate degree.

II. Background and Context

The prevalent shift in higher education towards online and blended learning provides examples of a graded analysis of student perspectives in relation to blended learning [1]. Contrasted with this is research which urges caution as regards the readiness of students to transition to online learning, particularly in contexts with a diverse student body [2]. Whereas the focus of earlier studies has, to a large extent, been on student success within the online environment, this paper will focus on a case study detailing student learning in the online context. In this context, students’ developing understanding of ethics within engineering will be examined in relation to different theories of learning. The case study analysis will demonstrate how student responses relate to distinct theories of learning and to the requirements of the accreditation process.

The process of accrediting engineering programs entails defining of broad areas of knowledge where competence is required [3], rather than detailing how the curriculum is to be constituted. In this process, graduate attributes are typically expressed in terms of a combination of generic attributes common to or required of all or most graduates [4]. Gutiérrez, Fitzpatrick & Byrne identify these as combining core knowledge, transferable skills and professional values and attitudes [5] 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

A. J. Gwynne-Evans is a lecturer within the Professional Communications Studies Department within the Engineering and the Built Environment Faculty at the University of Cape Town, Cape Town, South Africa, 7700 (email: alison.gwynne-evans@uct.ac.za).

Based on “A journey to visibility: Making explicit the teaching and learning of ethics within the engineering undergraduate programme” by Alison Gwynne-Evans which appeared in the Proceedings of 2020 IFEES World Engineering Education Forum - Global Engineering Deans Council (WEEF-GEDC), virtual conference, 16 - 19 November 2020.

design, knowledge profile and a set of graduate attributes (GAs) [6]. Ethics is addressed explicitly in one of the eleven ECSA graduate attributes, that of Engineering Professionalism (GA10), defined as requiring the demonstration of "critical awareness of the need to act professionally and ethically and to exercise judgment and take responsibility within own limits of competence". Teaching of ethics within the engineering curriculum is thus required in order to enable final year undergraduate students to be assessed as competent in terms of the specific range of graduate attributes.

Gwynne-Evans, Chetty and Junaid [7] distinguish five facets of teaching ethics within engineering, where ethics can be seen to operate as a "threshold concept" that forms a conceptual gateway to understanding [8]. These include teaching ethics as a concept distinct from other familiar concepts, as knowledge, skill, values and/or attitudes. These distinct approaches to teaching ethics require the utilization of diverse educational strategies within the engineering curriculum and will necessarily impact the way assessment is planned and implemented. The five elements represent a range of possible approaches, where the way in which ethics is formulated in the graduate attributes impacts how ethics is assessed. Previous research by the author into how ethics can be taught and learned conceptualizes knowledge in multiple ways, as:

- objective knowledge of content external to the learner
- individual skill – consisting of the knowledge of how to do something
- self-knowledge relating to attitudes and values and
- conceptual knowledge [9].

These different types of knowledge may in turn be related to the specific forms of knowledge associated with different learning theories. Learning theory potentially impacts the way ethics is translated in the curriculum. This research explores the effect of the learning theory on the development of curriculum and assessment.

In their research into the quality of ethics education within engineering, Bombaerts, Doulougeri and Nievien [10] point to the necessity of enabling a more nuanced understanding of quality relating to the teaching and learning of ethics within the engineering curriculum. They distinguish ethics education quality in terms of 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 distinguishes the standards promulgated by the accreditor, the vision for the curriculum and that which is operationalized. As an example of this, Stappelbelt distinguishes the intent to "teach ethics" from "engendering and enabling" positive ethical development [11]. Different approaches will require different curriculum strategies. In this context, the study by Balakrishnan, Tochinai and Kanemitsu [12] on student attainment of the objectives of ethics education recommend "well-structured, integrated, and innovative ethics pedagogy to help students… develop positive attitudes toward ethical issues." This perspective similarly connects student learning regarding ethics with curriculum planning and implementation and with the pedagogy associated with this.

Herkert's [13] contrast of two approaches to teaching ethics: the approach that positions individual moral dilemmas as 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. He sees a danger in teaching ethics as if problems can easily be solved as is possible in some technical design problem. Mitcham [14] similarly cautions engineering educators that the focus on problem-solving within engineering does not provide engineers with the tools to reflect on themselves and their world-transforming enterprise. He sees self-reflection as vitally important to counter the power of engineers and recommends building self-reflection and critical thinking into the engineering curriculum, thus enabling reflection on engineering identity and the mandate of engineering in a broader social and environmental context [14]. How this can be done effectively has challenged educators within engineering.

Out of this overview emerges the following research question:

> How does the shift to online learning enable an analysis of the artefacts of teaching and learning ethics in terms of how they embody different theories of learning?

III. METHODOLOGY

Theory provides a frame for looking at and interpreting evidence and data but can become indistinguishable from the formulation of what is described. In this research, 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 articulated as metaphors of learning by Sfard [15] while the third emerges from activity theory and is formulated by Engeström and Sannino [16]. Positioning three theories of learning as alternative frames within one analysis highlights the researcher's role and responsibility in terms of purposefully structuring the research process.

This paper will examine evidence of the teaching and learning of ethics within a particular undergraduate course, a fourth-year capstone electrical engineering course, where ethics is assessed as a graduate outcome. The paper will present an overview of the course, highlighting examples of curriculum innovation introduced as a result of the sudden shift to online learning, connecting these strategies to learning theory. Subsequently, it will examine examples from student assignments that illustrate how the different theories of learning influence what is construed as learning. The data profiled will be selected to illustrate a range of elements, rather than the frequency with which these elements occur.

The distinctions between *intention*, *implementation* and *attainment* made by Bombaerts *et al*. as regards curriculum design is translated into an integrated conception of curriculum, see Fig. 1.

Here the process of defining the *intent* of the curriculum may be seen in the formulation of learning outcomes that are

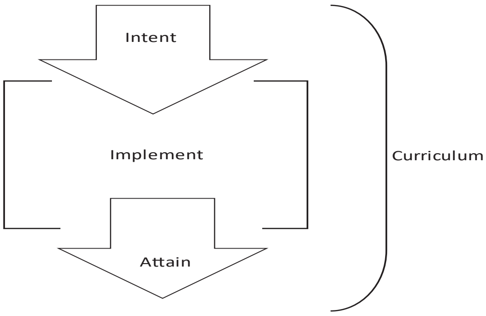

Figure 1. Depiction of Curriculum as an integrated process involving the action and interaction of both educator and student*

*Visual translation of Bombaerts, Doulougeiri and Nievien's (2019) use of Goodlad's theory

developed as part of the curriculum process rather than as prior to the process. The *intent* thus feeds into, and is part of, the *implementation* of the curriculum, where evidence of what is *attained* is actioned throughout the implementation process rather than in a separate assessment process at the end. How this is carried out relates to the theory of learning that is drawn on. As such, artefacts from the online management system are examined as data providing evidence of pedagogy and student learning. The data is then discussed in terms of how it manifests facets of the different learning theories. Conclusions are drawn as to possible affordances of the different approaches to teaching ethics.

In exploring what is possible in terms of teaching input, Kloot and le Roux [17] investigated the use of a range of language modes to model a "broad, rich and holistic" learning experience for the student within a face-to-face technically oriented course. In contrast, this paper will look for evidence of a broad, rich similarly and holistic learning experience within the online context of the teaching and learning of ethics. Kloot and le Roux utilized a social semiotic multimodality to investigate the way in which an experienced lecturer used "purposeful" and "contextual" language choices to communicate complex material in the face-to-face lecture situation. In the face-to-face situation, the lecturer used a range of language modes, including gesture, tone and visual emphasis in addition to words to mediate learning in a flexible and intentional way.

In the online environment, the modes available to be used by the lecturer are very different to what is possible in the face-to-face environment. The interactions between lecturer and student are translated into artefacts by the affordances of the online management system. The analysis will thus use interpretive method to examine online material from the course and assessment process to build new understanding of the way the teaching and learning of ethics emerges from underlying theoretical understandings of what learning entails.

IV. The Role of Learning Theory

Sfard [15] 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* [15]. 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 characterizing 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 [16] 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* [16]. 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 [16]. This opens the possibility of transformative learning beyond the intended consequences of the instruction. Engeström 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" [16]. 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" [16] 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 [18]. 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.

The case study that follows presents key elements of the capstone undergraduate course, depicting the teaching and learning interface as artefacts that exemplify aspects of the curriculum.

V. Overview of the 4th year electrical engineering course in Professional Communication Studies

The 8-credit, fourth year electrical engineering capstone course in Professional Communication, takes the equivalence of 80 student hours and is run in tandem with another 8-credit capstone course in New Venture Planning. Students had previously completed a second-year course in professional communication with a focus on the formal requirements of report writing. In the tandem courses, students are required to work in groups on a common entrepreneurial project with multiple outputs across both courses. In the professional communication course students engage critically with their understanding of professional identity [19] and develop confidence and assurance in effective communication. This course builds on previous learning and is designed to provide 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. This provides a good foundation for students' professional careers.

Instead of the usual lecture and workshop format, the transition of the course to online learning resulted in the course being presented as a set of six integrated 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. Co-ordinating and operating as a team during the COVID-19 pandemic, over extended distance, with very varied access to internet, became a significant test of professional skills and attitude for the students. Technology was key to enabling effective teamwork and students were required to use and become proficient with the use of Google documents, Zoom and/or Microsoft Teams and video packages such as PowerPoint and Screencast-o-matic.

The course assessed three graduate attributes, seen in Table I.

The course was assessed in twelve 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. Assessment needed to provide clear evidence of learning relating to the three graduate attributes. New formative assessments were introduced, particularly as regards groupwork and reflection, to ensure students planned and implemented strategies to enhance teamwork, as well as developed the ability to critically evaluate these processes.

TABLE I
ECSA Graduate Attributes Assessed in the 4th Year Capstone Course

Graduate Attribute (GA)	Where GA is assessed
GA 6: Professional and technical communication	Business summary, eportfolio and individual/group business presentation
GA 8: Individual, team and multidisciplinary working	Teamwork planning, reflection and peer assessment
GA 10: Engineering Professionalism	Ethics essay and annotated ECSA Code

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 roles played by team members in terms of Belbin personality types [20] and
- as regards their prospective role as an engineer in Africa.

These assignments required students to formulate and articulate coherent views on topics related to their practicing as an engineer in the future. This contributed to the students' 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. The three reflective pieces provided 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 part of developing awareness of how students' personal achievements and accomplishments contributed to building up their sense of professional identity and integrity.

Teamwork was recognized as a particular challenge in the lockdown situation resulting from the COVID-19 pandemic, where groups could not meet face-to-face. As such, it required strategy and planning. Success in this was crucial for the group assignments, both in this course and in the co-requisite course, New Venture Planning. Because of this, additional assessment tasks were incorporated that required the students to engage proactively with working in a team, developing and implementing a plan and reflecting on how the plan was carried out. The section on ethics built explicitly on the preceding weeks' focus on professional identity 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 skillset of tools for making ethical decisions was 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* [21], 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 their ability to perform as part of a professional team: able to anticipate and to avoid problems, demonstrating professional and ethical judgment. Students were encouraged to explore topics outside of the assessed curriculum, including the consequences of engineering decisions in history and in their own context to apply ethical problem-solving in these situations. Students contributed to online polls and forums where their responses relative to their peers were visible, challenging one another as to how professional identity is formed and how this identity in turn 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 of the business idea from 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.

The following section provides evidence of the implementation of the teaching process in the online environment.

VI. Evidence of Teaching as Evidenced in the Online Management Tool

The enforced transition to online learning, combined with a keen awareness of the reality of restricted internet access, resulted in contact between lecturers and students being mediated through the online management system. Lectures and class interactions thus transitioned into a series of independent online lessons, consisting of short online videos, stitched together by the lecturer and interspersed with activities that engaged the students on various levels.

In line with *activity theory*, this fits the model that requires continuous, collective interaction of the individual subject within their context to produce a learning artefact. The triangular depiction thus positions the *learner* as subject, *learning ethics* as the object and *the course content in the online management system, including the student assignments* as the artefact. As such, evidence from the online management system will be presented in line with Bombaerts *et al.* [10] use of three main distinctions between the *intended*, *implemented* and the *attained* aspects of the curriculum. Here, the content of the online learning management system relating to the particular course is examined as an artefact demonstrating the three aspects that are identified to influence the quality of the ethics education.

The *intent* of the lesson formally constructed around ethics within engineering was encapsulated in the learning outcomes for the lesson [22]. These were:

1. Identify different ways of making choices, both as an individual and as an engineer.
2. Show awareness that the application of engineering judgment often has an ethical component.
3. Demonstrate the ability to analyse a situation so as to make clear the ethical dilemma or conflict of interest.
4. Apply ethical decision-making strategies to your personal experience of engineering work experience and to ethical case studies.
5. Demonstrate your ability to reflect critically on your own experiences and choices and to constructively analyse what is required in the situation to make a decision that correlates with your professional responsibilities.

The following provides glimpses of different modes of communication that were utilized to recreate the interactions of an in-person classroom. In terms of the analysis by Bombaerts *et al.,* this is identified as the *implementation* phase:

A. Class polls

As a way of connecting with students and of engaging their active response, questions were set up that required them to submit an answer and then to see their answer measured against their peers' responses. Fig. 2 shows two examples of questions posed with the associated students' response poll:

Figure 2. Sample class poll of ethics questions

There is a measure of risk in this activity as it is not certain how students will respond. It is evident that the act of answering the poll and measuring this against peers can potentially both reinforce and undermine ethical conduct. The community is effectively the measure of the individual response. In this case it is encouraging (instructive?) to find that no one identifies themselves as "not at all" ethical!

B. Peer marking of self-reflection essays

The activity of marking peer's self-reflection ensured each student engaged reflectively and critically with their own and two other students' perspectives on topics relating to engineering identity. It also encouraged students to engage critically with formatting and critiquing written work.

C. Student forums

The use of online forum discussions by the lecturer required trial and error to get students to respond. What was found to be effective was to set up an open-ended question that would evoke a significant response where students could take initiative as regards how the response was developed. In the following exchanges, the original question set by the lecturer, together with any further lecturer input, is in *italics* and the sub-heading and text below is that of the students:

> *"Why is ethics important for engineers?"* "Engineers have a unique physical effect on the world."

> "Scientists, researchers, accountants all have their own moral codes and guides and have their own impact on the world. However, as Engineers, where our identity is about creation, we have a unique opportunity to put science into action where it can affect others. It's one thing to discover the possibility of harnessing the Atom, It's quite another to build an atomic bomb."

> "Ethics is important to guide the impacts our creations will have on the world."

> *"Wish you had posted this one earlier in the week! It is quite a topic - do we have ethical responsibility for the way in which the things (products/processes) we create are used?"*

> "I think this is a really good point to be bringing into context…. A lot of us are going to end up making things that people hugely depend on, or things with a lot of potential for harm if not properly handled until completion."

And then:

> *"Why is ethics important for engineers?"* "It mitigates the damage caused by power."

> "Ethics …[is] important in engineering because our specialized knowledge grants us power and influence over others. Acting ethically and with integrity involves using your power in a way that does not disadvantage those over whom you hold power."

> "I agree - engineers has a big responsibility as their work affects/impacts other individuals (in various levels of risk) - and it is expected that an engineer's ethics and integrity aligns with the codes of conduct set by ECSA."

> *"Wow, this discussion is getting really deep…. A certain amount of risk will be involved... aligning yourself with a bunch of ethical and committed engineers will give you confidence and a mandate to make a difference."*

There were times when the lecturer did insert a comment, but it was important that these comments did not try to speak for everyone – or try to cap the conversation with the expert view. If they were perceived in this way, it was likely to cut the exchange short! The implicit rule for the lecturer was to get involved only if necessary – to trust students to draw on their developing sense of professional identity to respond. It was necessary, however, to be prepared to step in if the discussion seemed in danger of moving students into opposing camps.

There were other ways of bringing additional resources into the course by posting links to materials or films that opened topics beyond the scope of the formal learning outcomes. It was envisaged that these resources would generate interest and emotion beyond the constraints of the online management system – and this made their impact more difficult to assess.

The following section presents examples of extracts from student assignments that provide evidence of learning in terms of the three theories of learning identified.

VII. Evidence of the Different Forms of Learning as Demonstrated in Extracts from Student Assignments

In the text that follows, examples relating to what is *attained* in the curriculum are presented from student assignments. These demonstrate the way in which student learning illustrates complementary theoretical perspectives in terms of what and how learning has taken place.

Learning as acquisition

The quotations below are taken from student assignments and are selected for the way they demonstrate the student's ability to access objective knowledge from a relevant source and to refer to it in building their argument:

> "The IEEE Code of Conduct states…"

Or, in the context of referring to the relevant clause in the ECSA Code, the student is able to paraphrase the document they are quoting so as to demonstrate understanding of the specific formulation:

> "It is the duty of the registered person to give priority to health, safety and best interests of the public [3(3) a & b]. Also, it is this person's duty to report any acts against the professional advice provided, that may be detrimental to the health, safety and interests of the public [(2)(3)]."

The following quotation shows the ability of a student to select information from a source of choice and to apply it to the task at hand – in this case identifying an ethical dilemma that the student themselves might have experienced in their work environment:

> "An ethical dilemma is one that occurs when two (or more) ethical standards apply to a situation but are in conflict with each other (Allen, 2014)."

In all three extracts, the student demonstrates both their ability to access knowledge available in documents and their ability to apply that knowledge in a particular context, to a particular task. It also provides evidence of the transfer of knowledge from an external source to the student. This is learning as acquisition – taking ownership of knowledge from another source and being able to use this information.

Learning as participation

The extracts below show evidence of the students identifying themselves with a particular group, where learning takes place in relationship to this community.

The first extract shows the student consciously adopting the identity of an *engineering student* in contrast to that of *work colleagues*. This identification as part of the community of students does not reflect a sense of the student being less qualified than their work colleagues. In contrast, the student sees themselves as being at an advantage because of their ability to learn quickly and be adaptable. They position themselves as sharing this advantage:

> "Being an engineering student gave me an edge over the technicians who worked at the company as I learned and adapted very quickly and was soon teaching and pointing out proper procedure to those who were tasked with catching me up to speed."

In the second extract, the student consciously takes on a professional identity to deal with a situation where a fellow professional appears to be conducting themselves in a way that goes against the professional code:

> "We might not agree with the other person's moral viewpoints, …. but it will help us understand where the other party is coming from. It is through understanding, not necessarily agreeing, that resolutions can arise. This is in line with the responsibility of peers of a profession to engage with one another and share feedback and comments on views and opinions (McMullan, 2020)."

In both extracts there is a sense of personal identification with a community and, associated with the taking on of the identity of the group, there is the sense of having learned how to "be" or to behave in a particular situation. This shows the student experiences learning by *participation* within a community and in relationship to other communities.

Learning as transformation

The following extracts show a third sort of knowledge: there is the awareness of knowledge of the self and an accompanying self-reflectiveness that generates a sense of agency, of the ability to *act* in a situation. This self-knowledge connects a sense of personal identity in relationship to a particular community (in this case that of engineering professionals):

> "If I had known of the codes of conduct highlighted by ECSA – I would have approached this challenging situation differently."

The second extract shows a shift from self-knowledge to an awareness of potential power – and of associated responsibility:

> "However, reflecting on the situation, I realize that regardless of my position, I have the responsibility to raise concerns and advise on ethical courses of action."

The third extract shows the student's appreciation of the journey of self-discovery – of "learning-what-it-is-to-be-a professional" – that they have been on. Self-knowledge thus creates the space to exercise judgment and choice in a particular situation, and this agency makes transformation possible:

> "I have learned a lot about myself from that experience and I feel as though I am ready to take on employment as a responsible and qualified professional."

This transformation has the potential to change the relationship of the individual relative to their profession. It also has the potential to impact the profession through the way in which it opens alternatives in which the individual or others can act.

VIII. Evidence of Reflection on the Learning Evidenced in the Assignments

The following extracts are taken from personal correspondence with one of the students who had demonstrated reflective engagement with a particularly challenging work situation:

> "I have had further thoughts and resorted to keeping my integrity intact by not taking part in unethical activities or anything seeming to be on the fence. In addition, instead of turning a blind eye, whistleblowing in an anonymous and clever way that doesn't bite me in the back."

The student was then asked how he thought ethics and professional responsibility would best be taught and/or learned during an engineering undergraduate experience:

> "This course is unlike any course I have had so far, very engaging and learning through reflection and considering how you could have acted differently, with new knowledge is amazing."

This response indicated a high level of engagement and reflection on the course. It prompted asking the student if they were prepared to respond to additional questions to develop into an additional phase to the research. The questions were as follows:

> *"What did you appreciate about the way in which the course was presented that contributed to developing your understanding of your professional and ethical responsibilities?"*

> "I liked the way we initially primed our brains in the beginning by discussing as a team through the ECSA document, picking each others perspectives. It is definitely a different and more

engaging pedagogical approach as compared to reading on your own. Weeks later engaging with a document we were familiar with and reflecting on a past event each person could relate to, gave it more depth. *It was more than learning* – learning, reflecting on a past event, hindsight analysis and how to approach a similar event in the future." *(Italics added by the author.)*

"What else would you have liked to see included as regards strengthening your understanding as regards your professional and ethical responsibilities (either in fourth year or earlier in your undergraduate program)".

"At least a week of each year of engaging with ethical issues, or just an earlier introduction to issues to do with ethics within my degree. The ECSA doc isn't too long, that would give a foundation for all my engineering principles *as I learn* as opposed to just before I'm done. First read the ECSA doc last semester when I was doing Law." *(Italics added by the author.)*

"You mention "new knowledge" that is developed through engagement in the course. What do you understand this to be?"

"Firstly a deeper engagement with the ECSA doc from an ethical perspective as opposed to a legal one. Secondly an engagement with the IEEE code of conduct I did not know of. Lastly, gaining insights from a past experience I did not know involved ethical issues, and being able to identify and analyze them. The new knowledge also helps me to better spot ethical issues and deal with them should they arise."

This response gives evidence of significant reflection on the goals and strategies for strengthening ethics education during the undergraduate program.

IX. Discussion

The extracts from student assignments demonstrated distinct differences in the way that learning occurred and in the way that student responses were formulated, reflecting the different approaches to learning in the different theories. 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 [23]. Developing a sense of identity as belonging to a particular group or profession is part of what enables participation in the profession. It affects the development of ethical identity and choice. In addition, the student is required to *transfer* general objective principles about the content of professional codes and of case studies 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*, the analysis portrays students as able to contribute actively to the professional ethos rather than as passive receivers of an already established culture and ethos.

In terms of the wider course, the overarching goal was 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. For this, the student needed to develop 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 were assessed in the capstone course, there was scope and flexibility in the curriculum to incorporate innovative pedagogic approaches and assessment. This shifted the learning from a model where knowledge and skill are transferred from expert to student in a one directional approach to a constructivist model where learning is built in collaboration with peers. Here learning is modelled in the interactions between participants, where learning takes place horizontally (between peers) as well as vertically (involving the expert or authority and the student). This process required space for the student to explore and own their personal journey as aspirant engineers, providing opportunities to identify significant incidents which built up this sense of identity, and to collate artefacts that demonstrated students' 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. This process is necessary and distinct from other areas of the engineering program.

These general interactions and learning opportunities aimed at developing the professional identity of the engineering student contributed to building the student's sense of professional responsibility, aligning in important ways with the student's sense of ethical responsibility. In addition, building in opportunities to reflect on engineering identity provided the space for students to claim aspects of that identity in a more personal way, simultaneously developing their sense of professional responsibility. The reflection on work experience required students to reflect critically on previous decisions and to apply the 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.

Competence in a learning outcome requires engagement with the different levels of learning taking place relative to the various forms of knowledge that have been identified. The way ECSA's GA 10 is formulated tends to focus attention on the assessment of objective knowledge and skill rather than on attitude or values. This has kept the focus of teaching engineering ethics on objective fact, with a resultant emphasis on input relating to knowledge of an engineer's responsibility, such as the requirements of the ECSA Code of Conduct [22] and the details of various case studies involving wrong-doing or disasters.

Most significantly, prior formulations of ECSA's GA 10 [6] made it possible for the student to avoid reflecting on their personal positions on ethical matters, and not be required to account for, or to engage critically with, attitudes or values. This missed important opportunities to engage with professional and engineering identity. Recent changes to ECSA documentation for degree accreditation [24] replace the word "show" [6] with "demonstrate" for GA 7 and 10 as in "demonstrate awareness of…". This may be seen to open up opportunities to engage more explicitly with attitudes and values in the future.

X. Conclusion

The sudden shift to online teaching and learning created opportunities for the teaching and learning process relating to ethics to be made more explicit and more visible. As a result of the expanded recognition that knowledge about ethics could be understood as objective, as conceptual, as skill, or as self-knowledge [7], course planning, teaching and assessment needs to reflect these different aspects.

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 optimally in the teaching and learning of ethics as the knowledge connects with identity and attitudes and values. Teaching ethics within engineering needs to be approached from a variety of angles, in complementary ways, where ethical responsibility and identity are both an individual and a social issue. It can be difficult to ensure both students and staff shift gear to appreciate and profile the value of different types of knowledge. Intentionally drawing on the insights of different learning theories can ensure flexibility and space for innovation in the curriculum.

Because of the professional requirement for engineers to act with integrity and responsibility [25], it is important that formative assessment requires the student to engage with their personal value system. Students need the opportunity to develop the skills to relate personal 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 important. This will require the development of a discourse relating to values and attitudes that is broader than efficiency or technical proficiency. This challenges the role and responsibility of the course convener or lecturer in facilitating the students' shift from neutral observer to active upholder of behavior that is ethical and professional.

This analysis has implications for curriculum and course designers in that it suggests the assessment of competence and graduate attributes 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 sustained engagement with the teaching and learning process relating to professionalism and ethics. Learning is thus experienced as objective, yet context-bound and personal. This highlights the role of research to profile the agency and critical awareness of both teaching staff and students involved in a course. It points towards the potential transformative impact of research concerning the teaching of ethics on the research participants, including the students, academics responsible for planning and organizing the course and the researcher.

References

[1] R. Kandakatla, E Berger, J. Rhoads, J. DeBoer, "Student Perspectives on the Learning Resources in an Active, Blended, and Collaborative (ABC) Pedagogical Environment," *International Journal of Engineering Pedagogy*, vol.10, no. 2, pp.7-31, 2020.

[2] M. Basitere; E. Ivalo, "Implementation of Blended Learning: The Experiences of Students in the Chemical Engineering Extended Curriculum Program Physics Course, International Conference on e-Learning, June 2017, pp.23-30.

[3] International Engineering Alliance (IEA), *Graduate attributes and professional competencies*, Version 3, Washington: International Engineering Alliance, 2013.

[4] S. Palmer, D. Holt, W. Hall, & C. Ferguson, "An Evaluation of an Online Student Portfolio for the Development of Engineering Graduate Attributes," *Computer Applied Engineering Education,* vol. 19, pp. 447-456, 2011. DOI 10.1002/cae.20324.

[5] F. Gutiérrez Ortiz, J. Fitzpatrick & E. Byrne, "Development of contemporary engineering graduate attributes through open-ended problems and activities," *European Journal of Engineering Education*, vol.46, no. 3, pp. 441-456, 2020. DOI: 10.1080/03043797.2020.1803216.

[6] 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.

[7] 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", Proceedings of the Eighth Research into Engineering Education Symposium (REES), Cape Town, 10-12 July 2019.

[8] 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, pp. 373-388, 2005.

[9] A. Gwynne-Evans, "Student Learning at the Interface of University & Industry Relating to Engineering Professionalism" *Critical Studies in Teaching and Learning*, vol. 6, no. 2, pp. 1-20, 2018. https://journals.co.za/doi/abs/10.14426/cristal.v6i2.153

[10] 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.

[11] B. Stappenbelt, "Ethics in engineering: Student perceptions and their professional identity development," *Journal of Technology and Science Education*, issue 3, vol.1 pp. 3–10, 2013. https://doi.org/10.3926/jotse.51

[12] B. Balakrishnan, F. Tochinai & H. Kanemitsu, "Engineering Ethics Education: A Comparative Study of Japan & Malaysia," *Science and Engineering Ethics*, vol. 25, pp.1069–1083, 2019. https://doi.org/10.1007/s11948-018-0051-3. .

[13] J. R. Herkert, "Future Directions in Engineering Ethics Research: Microethics, Macroethics and the role of Professional Societies" *Science and Engineering Ethics*, issue 7, vol.3, pp. 403-414, 2001.

[14] C. Mitcham, "The true grand challenge for engineering: Self-knowledge," *Issues in Science and Technology*, vol. 3, no. 1, pp. 19–22, 2014.

[15] A. Sfard, "On Two Metaphors for Learning & the Dangers of Choosing Just One," *Educational Researcher*, vol. 27, no. 2, pp. 4-13, 1998.

[16] Y. Engeström & A. Sannino, "Studies of expansive learning: Foundations, findings and future challenges," *Educational Research Review*, vol. 5, pp. 1–24, 2010.

[17] B. Kloot and K. le Roux, "Pedagogy for modelling problem solving in engineering dynamics: a social semiotic analysis of a lecturer's multimodal language use," *European Journal of Engineering Education*, vol. 45 no. 4, pp. 631-652,2020. DOI: 10.1080/03043797.2019.1657068.

[18] Y. Engeström, "Expansive Visibilization of Work: An Activity-Theoretical Perspective," *Computer Supported Cooperative Work* vol. 8, pp. 63–93, 1999.

[19] 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.

[20] M. Belbin, *Team roles at Work*, Oxford: Butterworth-Heineman, 2010.

[21] I. van der Poel and L. Royakkers, "The Ethical Cycle," *Journal of Business Ethics*, vol.71 pp. 1-13, 2007. DOI 10.1007/s10551-006-9121-6

[22] S. Junaid, A. Gwynne-Evans, Y. Serreau, P. Granholm and G. Bombaerts, "Global Citizens and Ethical Engineers within our CDIO Programs" workshop run by as part of the CDIO 2021 Bangkok International Conference. This included re-working learning outcomes to do with the ethics curriculum.

[23] 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," *European Journal of Engineering Education*, issue 34, vol. 4, pp. 359-367, 2009.

[24] 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 6 Sep 2020. [Accessed online Oct 2021] Available at https://www.ecsa.co.za.

[25] Engineering Council of South Africa (ECSA), Code of Conduct, *Engineering Professions Act No 46 of 2000*. Government Gazette, 142 (40691). 17 March 2017. Government Notice 41. Cape Town: Government Printer. [Accessed online 20 Feb 2021]. Available at: https://www.ecsa.co.za/regulation/RegulationDocs/Code_of_Conduct.pdf.

Alison J. Gwynne-Evans is South African and holds an Honors' Degree (Cum Laude) in Philosophy and English Literature from the University of Stellenbosch in 1991, where she was awarded the Benjamin Boshoff Prize for the top student in English during her undergraduate degree, a Higher Education Diploma from the University of South Africa in 1994 and a Masters' Degree in Education and Development (Curriculum Planning) from the Institute of Education at the University of London in 1996. She is currently working towards a PhD in Engineering Ethics at the University of Cape Town.

She has taught Professional Communication Studies at the University of Cape Town since 2008. Her research has a cross-disciplinary focus, including a strong practical focus on teaching and learning ethics within engineering. In 2020 she was a co-recipient of the US-based Transport Research Board's Charley V. Wooten Prize for the best paper in Transport Policy and Organization. In her professional capacity, she is a member of the South African Institute of Civil Engineers' Ethics Committee, the University of Cape Town's Faculty of Engineering and the Built Environment Ethics in Research Committee and also serves as Western Cape Chairperson of the South African Council for English Education.

CONTENTS PAGE