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ARTICLE

Repositioning ethics at the heart of engineering graduate attributes

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ABSTRACT

The integration of ethics in engineering education has largely been focused at the curriculum design level. The authors posit that this integration be done at the accreditation level and investigate how ethics may be more extensively incorporated in the documentation of a particular engineering accreditation body's qualification standards. The paper proceeds, by means of a narrative review, to justify an expanded conception of the teaching of ethics within engineering education. It builds a synthesis of contrasting conceptual approaches to the teaching of ethics within engineering and proposes a conceptual framework to guide both regulators and educators to identify and engage with different elements of the ethics across the curriculum within an engineering programme. The South African case study provides a context to engage with existing policy formulation around programme accreditation and to demonstrate the application of the proposed conceptual framework across the graduate attributes so to indicate how ethics might be more comprehensively integrated within a programme. This demonstrates that ethics needs to be repositioned at the centre of the preparation of engineers, rather than at the periphery. The expected consequence of this integration is the more extensive incorporation of ethics within and across accredited engineering programmes.

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1. Introduction

The challenge of engineering is negotiating complexity: applying 'complex problem-solving' to address 'complex engineering problems' (International Engineering Alliance (IEA) 2013, Engineering Council of South Africa (ECSA) 2017) in contexts that are recognised as increasingly multifaceted and regulated. Engineering problem-solving requires balancing the 'purposeful application of engineering knowledge, technology and techniques' (International Engineering Alliance (IEA) 2013) with innovation and judgment (Conlon, 2008) for the benefit of humanity, where project specific risk is balanced with project context risks (Galloway 2008). The need to deal with complexity in engineering requires a fresh look at how to balance the power of technical engineering skill and proficiency – 'powerful knowledge' (Young and Muller 2013) – with vision and purpose in the preparation of graduate engineers. Engaging with vision and purpose requires a critical engagement with how ethics is conceptualised within engineering and how this can be translated into the curriculum.

Engineering is positioned to be 'carried out responsibly and ethically and use available resources efficiently, be economic, safeguard health and safety, be environmentally sound and sustainable and generally manage risks throughout the entire lifecycle of a system', recognising, anticipating and dealing with 'potential adverse risk' (International Engineering Alliance (IEA) 2013). Identifying risk potentially involves more than technical challenges (Lui and Chen 2015) and requires the knowledge, skill and commitment to apply tools and strategies to anticipate, avoid and manage risk. This widens the scope of the role of the engineer. It requires an engineer to recognise their role as extending beyond protecting today's public to commit to protecting future generations who will inherit this environment (Galloway 2008). Engineers are thus expected to apply professional skill and knowledge to problems in a sustainable and ethical way. Ethics is thus an integral part of the vision of engineering, addressing diverse priorities.

Unavoidably, engineering has been defined within specific political, geographical and socioeconomic contexts. Although contrasting these contexts is beyond the scope of this paper, this has influenced the way ethics has been defined within engineering and the space it has been allocated in engineering programmes. As such, ethics is frequently positioned as an individual and personal matter rather than a corporate or social concern. Even where ethics is prioritised, there is the tendency to emphasise

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compliance with regulations and codes, rather than profiling judgment and process as distinct from technical elements.

At a global level, the Washington Accord is a multilateral agreement between bodies responsible for the accreditation of tertiary-level engineering qualifications that positions the accreditation of engineering academic programmes as a key foundation for the practice of engineering at the professional level (IEA 2013). The graduate attributes adopted by the Washington Accord signatories are thus generic across all engineering disciplines. Each signatory of the Washington Accord defines the standards for the relevant level against which engineering educational programmes are accredited (International Engineering Alliance (IEA) 2013). A focus on compliance with the standards of professional conduct within the practice of engineering is recognised as necessary, but insufficient (Davis 1991), to ensure the development of judgment and decision-making suited to deal with the complexity of problems facing engineers, in particular, those operating within developing economies with complicated historical relationships between industry, society and the environment.

There is a need to provide an explicit link between the existing standards for engineering programmes as prescribed by the accreditation regulator and the measure of professional conduct portrayed in the same regulator's code of conduct. Identifying and strengthening the connection between the technical and non-technical criteria set out in the standards and the required code of ethical conduct requires an expanded understanding of how ethics can be approached in engineering programmes.

This gap is highlighted by Bombaerts, Doulougeri, and Nievien (2019) who distinguish between what is *intended* in the curriculum (formulated in the vision and formal intentions), what is *implemented* (demonstrated through what is perceived and experienced by the participants) and what is *attained* (what can be measured). This highlights potential discrepancies between the standards promulgated by the accreditor, the vision for the curriculum and that which is operationalised in teaching practices.

This paper sets out to examine how ethics is positioned within the engineering programme criteria of an accreditation body, the Engineering Council of South Africa (ECSA), and uses this as a proxy for evidence of intent. The aim of this paper is to investigate how ethics may be more extensively incorporated in the documentation of an engineering accreditation body. The hypothesis is that ethics is relevant across all the graduate attributes, instead of only where ethics is explicitly mentioned. It recognises that there is currently limited evidence of the application of ethics across the range of graduate attributes and proposes a thought experiment to articulate what addressing this gap might look like.

The paper develops a narrative review of approaches to the teaching of ethics, consolidating these in a conceptual framework for the teaching of ethics. This will provide a visual scaffold to be used to position different approaches to ethics. The conceptual framework is then creatively applied in a thought experiment to a case study to indicate how ethics might be incorporated across the range of graduate attributes.

A conceptual framework may be defined as an 'interconnected set of ideas (theories) about how a particular phenomenon functions or is related to its parts' (Svinkini 2010). The conceptual framework does not set out to be unique in that the individual elements are grounded in existing scholarship and literature. Instead, by deductive reasoning, the conceptual framework 'makes explicit … knowledge already contained implicitly in the premises from which the deductions are made", where 'what is implicit in premises is not always apparent until it has been made explicit' (Salkind 2010). This conceptual framework is consequently deduced from existing theory and assembled in a visual format that invites the practitioner to engage with it and to extend its reference and meaning.

Sorensen brought thought experiments to popular attention as a potential methodology when he argued for their inclusion as a research method (Sorensen 1995). Although thought experiments had mixed reception, their value was recognised (and has endured (Sorensen 2019)). Sorensen argued that thought experiments followed a similar pattern to regular experiments: organising data, making subtle connections, grounding hypotheses into tests, leading to fresh information and insight through the execution of the experiment (Sorensen 1995).

In this stage of the research, where the graduate attributes are interrogated and creatively translated, the hypothesis is tested that ethics is relevant across all eleven graduate attributes. The conceptual framework is thus applied as an analytical tool to the graduate attributes in order to identify facets of the graduate attribute that can potentially demonstrate ethics in one of the five ways identified by the conceptual framework. Redefining these graduate attributes will have an impact on how the curriculum is formed, delivered and assessed.

This analysis contends that the criteria by which the ECSA currently evaluates standards for engineering programmes in South Africa, inadvertently neglects ethics. The profiling of ethics in the criteria is seen to be necessary in order to make the link between undergraduate engineering educational preparation and the professional registration of engineers.

This paper will therefore engage with a critical analysis of literature and the ECSA policy documents relating to programme standards in undergraduate degrees at South African universities as a case study to identify specific examples where the explicit inclusion of ethics would enhance the scope and reference of the documents.

2. Methodology of Investigation

The research builds on a range of sources, to investigate how ethics may be more extensively incorporated in the documentation of a particular engineering accreditation body. The first objective is to use a narrative review to build and describe a conceptual framework to engage with how ethics can be positioned in the documentation of accrediting regulators. The second objective is to engage critically with a particular case study of engineering programme accreditation: that of the South African Engineering Council, where the programme standards are critiqued alongside an analysis of the ambit of the ECSA Code of Conduct. The third objective is to test the hypothesis that ethics is relevant across the graduate attributes by applying the elements of the conceptual framework across the range of graduate attributes. This approach provides a contextual platform to profile South Africa as a case study for applying the conceptual framework.

Borrego, Foster, and Froyd (2014) distinguish between quantitative meta-analyses and qualitative systematic reviews that follow transparent, methodical, and reproducible procedures involving the selection of appropriate studies and the identification of trends, patterns and relationships from the material. While procedures for selecting studies have become more formalised and may focus on specific geographic areas (Hess and Fore 2018) or range of publications, for example Haws' 2001 synthesis from the American Society for Engineering Education (ASEE) conference proceedings), qualitative reviews aiming at meaning making tend towards incorporating an element of subjectivity as regards the choice of texts and the themes which are identified. Consequently, the process of developing a cohesive narrative may be affected by the researcher's own priorities and values.

This narrative literature review avoids privileging particular orthodoxies as regards which sources to include and has intentionally profiled texts from multidisciplinary sources that give evidence of the variety of different possible approaches, in order to build a more nuanced understanding of approaches to teaching ethics within engineering. For details of the spread of texts referenced in this paper, see Appendix A. The first sources used include review studies in engineering ethics education, followed by texts on research method. The third group covers scholarly work that has engaged with conceptual approaches to the teaching of ethics. These texts are used to support the development of a conceptual framework to define possible approaches to the teaching and learning of ethics that can be used to enhance curriculum decisions. Studies that did not address the bridging of ethical conduct with regulatory requirements and curriculum design were not included, as were studies that did not reference learning theory in the context of teaching engineering ethics. The remaining sources represent regulatory and South Africa texts that provide contextual detail. In the selection of texts there is the recognition of the way that research and teaching practice in engineering education are interlinked and potentially influence the practice of engineering in that context (Gardner et al. 2019).

The conceptual framework for teaching ethics was thus developed as a heuristic tool to supplement and enhance existing practical descriptions of possible interventions and to enable practitioners to expand their understanding and options as regards how ethics can be incorporated in the curriculum. This aims to supplement specific curriculum interventions, with a simple and accessible visual depiction of the range of approaches to teaching ethics, to assist the practitioner identify different aspects of ethics to be addressed in the implemented curriculum. Consequently, in the development of the conceptual framework, authors are profiled whose work illustrates different possible approaches to how ethics can be understood and taught. These conceptual approaches are critiqued and consolidated to form a conceptual framework with five components that provide a tool to interpret practice or specific interventions for integrating ethics within engineering – both at policy and curriculum level. Alternative examples of each approach are included (data sourced from Gwynne-Evans, Chetty, and Junaid 2019).

To demonstrate the application of the proposed conceptual framework at a policy level, the ECSA policy documents are examined as a case study. These documents include ECSA's qualification standards pertaining to the Bachelor of Science of Engineering and the Bachelor of Engineering. The accreditation standard is outlined, detailing the key constituents so as to identify the extent to which the standards address ethics explicitly in their wording. A similar semantic examination of the specific graduate attributes and the associated code of conduct is undertaken. The conceptual framework is subsequently applied to the graduate attributes to identify potential opportunities to engage with ethics across the range of graduate attributes (GAs). The conceptual framework provides a scaffold to identify and assess opportunities in the curriculum for practitioners to engage in teaching practice relating to ethics within the engineering curriculum.

3. Results

3.1 A narrative review of different conceptual approaches to ethics within engineering

Gwynne-Evans, Chetty, and Junaid (2019) identified 'ethics' as one of Meyer and Land's (2005) '*threshold concepts*' that operates both within and across disciplines and, as such, forms a 'conceptual gateway' to understanding. This identification of ethics as a threshold concept provides a bridge to justify the rationale of repositioning ethics at the centre of the practice of engineering. Meyer and Land (2005) recognise important ways in which a 'shift in perspective' is often associated with an 'extension in the use of language' and a 'shift in subjectivity [involving] a repositioning of the self' (Meyer and Land 2005). This is particularly important as regards the relationship of ethics to engineering and signals a space for ethics to shift from its position related to external norms of conduct into a space linking professional and individual identity.

Educational outcomes are implicit in the assessment of the ECSA Graduate Attributes (Engineering Council and Royal Academy of Engineers 2014; Engineering Council of South Africa (ECSA)) and stem from Bloom's seminal theory (1956) identifying educational outcomes, from *recall, comprehension, analysis, application, synthesis* and the *creation* of knowledge. His taxonomy was expanded and revised to include a second level of description which engaged with four areas of knowledge, that of factual, conceptual, procedural and meta-cognition (Krathwohl 2002). His theory, although abidingly influential for outcomes-based education, has been criticised for its assumption of learning as a linear process and its inability to account for learner agency, attitudes or values (Amer 2006).

Several systematic literature reviews have surveyed parts of the literature relating to the teaching of ethics within engineering, tracing trends and identifying common practice or approaches (Haws 2001; Hamad et al. 2013; Hess and Fore 2018). While several of these reviews focused on specific teaching interventions and styles in practice, there is very little evidence of engaging conceptually with wider learning theory. The emphasis of these reviews has been on identifying and describing similarities and trends in particular constituencies without articulating or engaging with conceptual reasons for potential differences of approach. In their overviews, Hess and Fore (2018), and Hamad et al. (2013) focus on specifying and detailing potential teaching interventions.

In a similar way, Haws' meta-analysis of ethics instruction (2001) is based in an uncritical acceptance of learning as the transference of existing knowledge. Haws' contribution to establishing a separate assessment criterion conflating ethics and professionalism may be seen to be founded in an understanding of ethics as knowledge which can be transferred. Current understandings of knowledge as socially constructed and influenced both by context and knowers (Behari-Leak and Mokou 2019) require a much more nuanced examination of what teaching and learning ethics involves. In contrast, this research focuses on grounding and developing a simple and accessible conceptual framework to depict the different facets of what teaching ethics involves.

Fink's (2003) theory of significant learning builds on the strengths of Bloom's theories and extends areas Bloom did not incorporate. Fink's theory is useful in modelling how learning takes place in relation to ethics in that it seeks to define learning beyond understanding and application, to incorporate the human dimension, including values and attitude. Fink (2003) builds *relationship, caring* and *learning-to-learn* onto the more traditional elements of learning theory of *foundational knowledge, application of knowledge* and the *integration of concepts*. This theory of learning is valuable because it achieves two things: it sets out a vision where learning is significant and neither arbitrary nor incidental, and incorporates aspects that connect easily with traditional approaches to organising engineering programmes, where foundational knowledge provides the base for the application of knowledge. Noteworthy is Fink's inclusion of concept integration. This aspect gives impetus to ensuring the concept of ethics is more explicitly addressed and extensively profiled – both in ECSA documentation and in the undergraduate curriculum design.

Fink's recognition of the importance of concept integration in making meaning and in assessing significance, dovetails well with the research goal of developing a conceptual framework to scaffold different approaches to teaching ethics into one frame. This will allow practitioners to assess what has been achieved and what is still to be achieved, as well as the significance of this for the engineering undergraduate.

Rest's early analysis of the teaching of ethics (1984), distinguishes four outcomes comprising:

- ethical sensitivity
- knowledge of relevant standards of conduct
- ethical judgement and
- ethical willpower (that is, a greater ability to act ethically when one wants to).

These outcomes usefully introduce the distinction between awareness-raising of an issue and the inclination to act on the awareness or knowledge. In this, Rest pre-empts the focus of ethics as a skill that can be taught, learned, and practiced, that is inherently associated with the outcomes approach, where learning ethics involves *practice* and *doing* in a way that is fundamentally implicit in the everyday practice of engineering.

Wright's 1995 literature study on whether moral judgement and ethical behaviour can be learned as a result of the education process is situated in the behaviourist tradition and thus does not engage with the complexity of ethical judgment that is required in social and political contexts. His contribution anticipated the focus on learning communities and the role of discourse in teaching and modelling ethical conduct.

Harris, Pritchard and Rabin's (2000; 2008) expand the definition of engineering ethics beyond knowledge and skill to include attitude and values: where engineering ethics is part of 'thinking like an engineer' (Davis 1991). Harris et al. (2014)), expands its authorship to include a more obvious diversity of approach, subtly affirming the importance of expanding engineering identity in a visible way.

Davis' argues that the complexity of the envisaged context requires the incorporation of ethics within the curriculum (Davis 2006). He goes on to endorse Rest's four categories and emphasises the impact of a shared discourse and the regular profiling of ethical issues and standards of conduct in developing a sense of professional identity. This speaks to the importance of ethics being a thread binding the curriculum together, rather than being a single competence assessed at the exit level. Davis underlines the importance of this sense of common identity in forming the perspective of engineering students, building on a sense of shared commitment to a standard of conduct. In highlighting the relationship between professional group identity and individual conviction in persuading others and winning support and commitment to act ethically (Davis 2006), Davis's emphasis of advocacy through persuasion and argument, highlights the importance of professional communication as an area of the preparation of engineers that requires ethical engagement. While Davis recognises the value of enabling consensus, it is noteworthy that he does not make the skill of persuasion an explicit outcome.

In contrast to Davis's broad endorsement of the project of teaching ethics, Pfatteicher (2001) is more critical and poses the question: 'What is ethics instruction supposed to do?' in a way that deliberately defines learning to exclude attitude or values. Pfatteicher (2001) limits the responsibility of teaching ethics by defining that, 'strictly speaking, the criterion does not require programs to demonstrate that graduates *are* ethical; it requires that they *understand* professional and ethical responsibilities'. This shifts the focus of ethics education so that ethical behaviour becomes the *object of study* rather than its *objective*. This approach parallels the approach of ECSA Graduate Attribute 10 that requires students 'to demonstrate *critical awareness* of the need to act professionally and ethically', rather than 'to be professional and ethical'. Pfatteicher's (2001) perspective conceptualises the learning process as an objective and neutral process that does not engage with *meaning* (Fink 2003). The problem with this perspective is it omits the demonstration of ethics in the face of power and persuasion – of distinguishing conflicting interests and moral dilemmas (Gorman et al. 2000). These situations, where power and influence are involved, are precisely the sorts of situations that engineering graduates need to have encountered and developed confidence in about how to respond – how to act and the courage to act – as both an individual and as part of a professional body and peer group. Students require encouragement to rehearse ways of choosing and acting that are related to *personal values* and *belief*s and that affect *attitude* and *motivation*. Gorman et al. (2000) describe the need for students to exercise 'moral imagination' through evaluating different perspectives, courses of actions and the emotions/feelings that may come while faced with difficult ethical choices. Here, students develop confidence in their rehearsed responses so they can extrapolate these in more challenging situations and have the *commitment* and the *confidence* to make difficult decisions. Students need to explore and understand *personal values* and *beliefs* (Sayer 2011) and how these connect with their *professional values* and *peer values*.

Van Der Poel (2015) emphasises the importance of teaching a range of individual *skills* including the ability to identify and analyse an ethical issue and to form judgements. He also positions communication and teamwork as skills to be learned in a course in engineering ethics. He profiles the ethical dilemma and presents an ethical problem-solving model (Van Der Poel and Royakkers 2007), which focuses on the process of identifying and selecting alternatives. This model provides a bridge to enable the exploration of the *reasons* and *values* that *legitimate choice*. Using this, or a similar model, undergraduate engineers can explore potential alternatives, roles and understandings of their responsibilities. Bowden's empirical study into the skills and ethical requirements for engineers usefully identified the following aspects to include within the curriculum: case study teaching; ethical theory; acting in the public interest (or whistleblowing); codes of ethics and the role of the professional in society (Bowden 2010). These topics correlate with the detail of ECSA graduate attributes that relate to ethics (Engineering Council and Royal Academy of Engineers 2014). Although these aspects can be approached in a personal and relational manner, Bowden's emphasis on *knowledge* as objective makes it difficult to engage critically and creatively with the canon of ethical knowledge in order to ensure it represents the diversity of engineers and engages the multiplicity of engineering students experiences as engineers.

Teaching ethics within engineering needs to go beyond celebrating the role of the individual to act on and to transform systems and situations (Conlon and Zandvoort 2011) and to recognise instead the effect of systematic factors such as power and inequality. Herkert (2001) usefully distinguishes between microethics (emphasising the actions of individuals) and macroethics (looking at the wider implications to society). It is here that the ethics of care, social responsibility (Herkert 2001) and feminist ethics (Whitbeck, 1996 and Riley 2013) provide important alternative approaches to teaching ethics that emphasise the relational and invite engagement with the identity of the engineer and with social transformation. Fore and Hesse's recent contribution of 'ethical becoming' as a conceptual framework for teaching ethics in engineering ''insists" on the 'complementarity of pragmatism, care and virtue' (Fore and Hess 2020) and recognises relationality as central to all aspects of 'becoming', anticipating the transformative possibilities (Lillis et al. 2015) that are opened up by the relational.

This transition connects graduates' developing identity as engineers with their sense of professional and ethical responsibility in a way that is necessarily exploratory and transformative. Meyer and Land's contribution juxtaposes the requirements of professional bodies and other stakeholders with vested and pragmatic interests, with the exploratory nature of learning that is characteristic of the development of professional identity (Meyer and Land 2005). This contrasts the achievement of defined professional outcomes with a more tentative reaching for meaning that is characteristic of the journey of incremental understanding that characterises learning beyond the conceptual portal. This recognition of the interrelatedness of the learner's identity with thinking and language (Meyer and Land 2005) reinforces the recognition of the importance of community and discourse in establishing consensus and norms (Davis 2006).

The above analysis demonstrates the breadth of understandings of what is involved in the teaching of ethics within engineering. This points to the value and significance of a conceptual framework for the teaching of ethics to engineers, allowing engineering educators from different disciplinary backgrounds and with different goals to engage with teaching ethics. The following section draws together the various aspects of teaching ethics that have been identified in this examination of the literature and combines them into a conceptual framework to be used to engage with the challenge of teaching and assessing ethics within the engineering curriculum.

3.2. Deducing a conceptual framework for ethics within engineering

The narrative review provides evidence of different possible approaches to the teaching and learning of ethics within engineering. In line with Fink's theory of significant learning, this section synthesises conclusions that are logically implicit in the claims from which they are drawn into a conceptual framework for the teaching of ethics.

From the approaches identified in the review, five alternate understandings of ethics are posited:

- ethics as a *concept* that operates within the boundary of language (Meyer and Land 2005; Pfatteicher 2001; Davis 2006)
- ethics *as knowledg***e** of existing legislation, of case studies and of theory (Colby and Sullivan 2008; Harris et al. 2014; Davis 1991; Bowden 2010)
- ethics *as a skill* that can be acquired or owned or developed (Harris et al. 2014; Van Der Poel 2015; Pfatteicher 2001; Galloway 2008)
- ethics as a set of *values* by which to make decisions, (Whitbeck, 1996; Van Der Poel 2015; Conlon and Zandvoort 2011; Sayer 2011)
- ethics as an *attitude* affecting action (Harris et al. 2008/2014; Riley 2013; Wright 1995; Davis 2006; Conlon and Zandvoort 2011; Fore and Hess 2020; Sayer 2011).

Figure 1 distinguishes five core, interrelated elements of ethics and illustrates the alternative approaches that have been identified. These elements are able to be combined (shown overlapped) so as to shape particular pedagogical approaches to the teaching of ethics in engineering. These enable the teaching of ethics to be approached flexibly. Examples of each option are incorporated that illustrate the different facets. These are not intended to be all-inclusive, but to be illustrative of the range of possible alternatives.

The first, ethics as a *concept*, relates to the way the word 'ethics' is used within the teaching and learning process and within documents relating to professional responsibility. This identification of ethics as a concept that needs to be clarified, explored and used in order to have meaning relative to other concepts, emphasises that a concept such as ethics is not obvious and self-defining but acquires significance within a context (distinguishing the cultural, societal and environmental) and within the established relationships of stakeholders. Ethics as a concept thus gains meaning within a community where meaning is developed in discourse and through use.

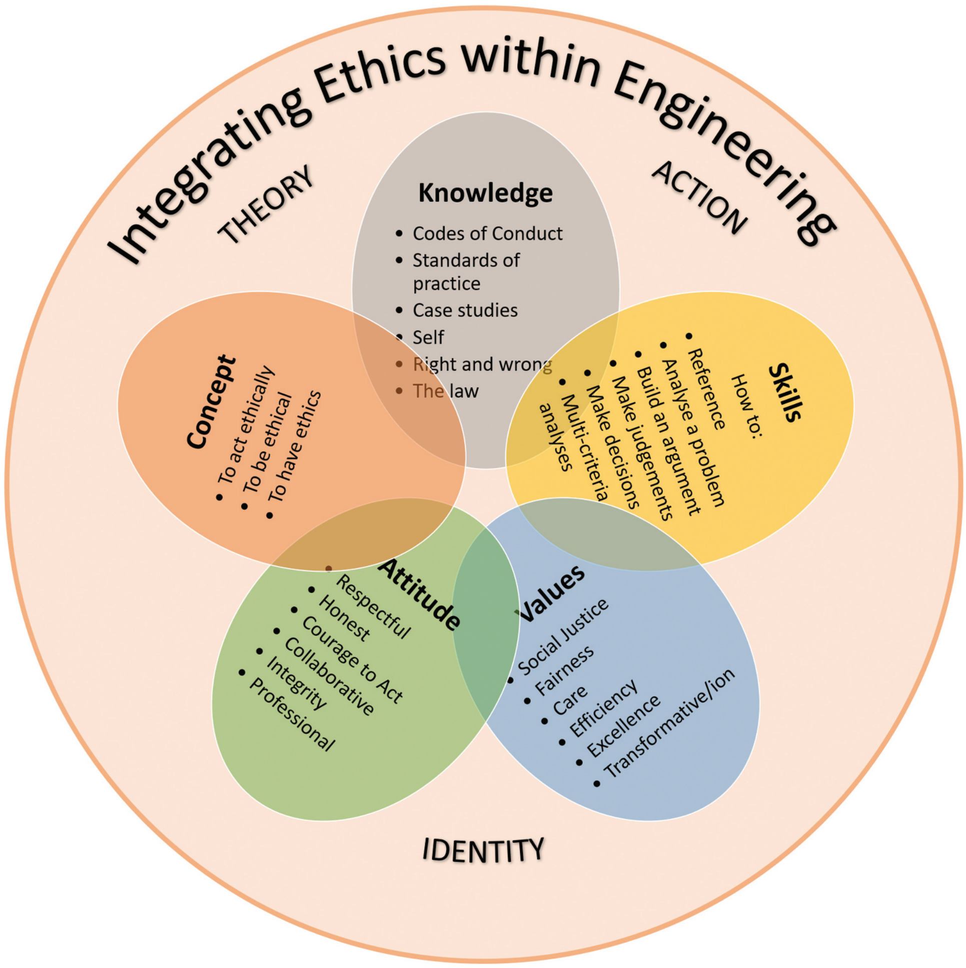

Figure 1. Conceptual Framework identifying five elements of ethics with complementary teaching approaches.

Ethics as *knowledge* incorporates a range of different knowledge forms from objective content including case studies, policy and regulation, knowledge of how to perform skills, self-knowledge and conceptual knowledge (Gwynne-Evans 2018). Ethics as a *skill* refers to the ability to do and to act: to apply the different forms of knowledge in practice. Developing a skill is recognised to take place over time, requiring practice and the opportunity to perform. Knowledge and skill can be acquired both for their own value and as commodities that have value in the marketplace, to be traded or passed on. This suggests that the teaching of ethics is something that can build *value* in an individual, a company or a society. By extrapolation, this suggests that the teaching of ethics warrants effort and attention and justifies investment.

Values are seen to motivate purposeful action. Values matter to people (Sayer 2011), and affect the choice and action of individuals and companies in significant ways and, as such, need to be identified and examined. Values, such as 'efficiency' or 'cost effectiveness' can operate in a subtle way to drive a technical agenda, in contrast to values such as 'care' or 'justice' that require the recognition of the needs of people or the environment in decision-making.

Knowledge and *skill*, combined with *values*, constitute *strategy*. This puts the emphasis on ethics as a means to an end – as scaffolding – to make decisions and to act 'on the world' and 'in the world'. This sees value in what is enabled by the application of ethics, in particular, within decision-making. This is of key importance to engineers as decision-makers and requires significantly different approaches from the technical knowledge and skill transfer associated with mainstream engineering qualifications. Strategy can include advocacy, which extends personal conviction beyond the individual to include action within community.

Ethics as *attitude* requires a shift from the passive commendation or endorsement of a value to a more active internalisation of the particular value: so that this affects how the person engages with the world. Attitudes may be seen to practically demonstrate values in action.

The focus on the *development of* personal, social or corporate *identity*, where the articulation of values is closely aligned to ethos and attitude, distinguishes goals as values that exist outside of individual persons from attitudes which are inherent to individuals, but which can, in turn, be shared. It is important to recognise identity as developing within a specific context within multiple sets of relationships that make up the professional or corporate environment. There is a *power* in being able to motivate action based on *personal* and *professional identity* that is difficult to sway.

Operationalising these alternatives has implications for the way in which curricula are designed: what is taught and learned, how teaching takes place and how learning is assessed. This will be demonstrated in the next section.

3.3. South Africa as a case study

The context for this research is South Africa, a developing country with high levels of unemployment and inequality (Statistics South Africa (STATS SA) 2019) with a premium on professional qualifications, including engineering, as a means to secure employment (Case et al. 2018; Martin et al. 2005; Bhorat, Mayet, and Visser 2012). In South Africa, the challenges of dealing with complexity are particularly stark due to the transition from an Apartheid society favouring overly simplistic political and economic solutions, to one that seeks to recognise the full value and aspirations of its diverse citizens and to incorporate an ethos that places social justice and environmental sustainability as key criteria of a well-functioning society (National Planning Commission 2011). Post-Apartheid legislation and regulation in South Africa has increasingly recognised the importance of ethics and ethical conduct (see the four versions of the King Committee's King Code, 1994/2002/2009/2016; National Planning Commission 2011 and the Companies Act, 2008). Through this legislation, government, industry and professional bodies are encouraged to apply ethical principles and standards within their practices and processes.

In South Africa, the practice and qualification of engineers is regulated at a national level by the Engineering Council of South Africa (ECSA) in terms of the Engineering Professions Act, No. 46 of 2000. In line with international accreditation patterns, there are three levels of qualification, distinguishing qualifications that result in a Bachelor of Science (Engineering) and Bachelor of Engineering from degrees prioritising technical competence (Engineering technologists) or diplomas (Engineering technicians). ECSA has the responsibility for registering engineers as professionals for industry as well as regulating the professional conduct and the professional development of registered engineers. Professional engineering conduct is generally assessed in terms of the ECSA Code of Conduct (Engineering Council of South Africa (ECSA) 2017) and by codes of conduct promulgated by the specific industry bodies. In addition, ECSA is responsible to set standards for, and to accredit, the training providers. The ECSA vision statement is 'Engineering excellence, transforming the nation' (Engineering Council of South Africa (ECSA) 2015). For this vision of transformation to be realised, ECSA needs to ensure the practice of preparing graduate engineers equips graduates with more than technical skills and knowledge.

ECSA is responsible for accrediting engineering qualifications by assessing the qualification programme offered by approved institutions every five years in terms of qualification standards. This quality assurance process is based on international best practice in line with the Washington Accord and leads to the accreditation of engineering education programmes worldwide in terms of purpose and process (Engineering Council of South Africa (ECSA)). The process is dynamic such that academic developments affect the accreditation process. An example of this is Haws' 2001 meta-analysis of ethics instruction in engineering, which can be seen (Hess and Fore, 2018) to have resulted in the United States' Accreditation Board of Engineering and Technology (ABET) system incorporating an 'understanding of professional and ethical responsibility' as one of the criteria of engineering programme accreditation. This, in turn, had repercussions on global accreditation and resulted in South Africa including a separate criterion (exit level outcome/GA 10: Engineering Professionalism) in the ECSA accreditation system.

This process of accrediting engineering programmes includes specifying the educational requirements for the qualification, independent of the curriculum. In this process, ECSA defines the standard for engineering programmes in terms of three sets of criteria positioned at different levels depending on the qualification. The criteria include:

- programme design and credits
- knowledge profile and
- a set of graduate attributes (Engineering Council of South Africa (ECSA)).

It is noteworthy that there is no mention of the word 'ethics' in the general descriptors of the first two criteria: the course credits and knowledge areas. In the South African environment, ECSA prescribes eleven graduate attributes to be achieved as "competencies that may be demonstrated in a university-based, simulated workplace context" (Engineering Council of South Africa (ECSA) 2018: 10). The terminology of 'graduate attributes' has replaced that of 'exit level outcomes' to define competence (contrast Engineering Council and Royal Academy of Engineers 2014 with Engineering Council of South

Table 1. The eleven ECSA graduate attributes and descriptors that collectively depict the requirements for a graduate engineer in South Africa.

Graduate attribute	Descriptor
GA1: Problem solving	Demonstrate competence to identify, assess, formulate and solve convergent and divergent engineering problems creatively and innovatively.
GA2: Application of scientific and engineering knowledge	Demonstrate competence to apply knowledge of mathematics, basic science and engineering sciences from first principles to solve engineering problems.
GA3: Engineering Design	Demonstrate competence to perform creative, procedural and non-procedural design and synthesis of components, systems, engineering works, products or processes.
GA4: Investigations, experiments and data analysis	Demonstrate competence to design and conduct investigations and experiments.
GA5: Engineering methods, skills and tools, including Information Technology	Demonstrate competence to use appropriate engineering methods, skills and tools, including those based on information technology.
GA6: Professional and technical communication	Demonstrate competence to communicate effectively, both orally and in writing, with engineering audiences and the community at large.
GA7: Impact of Engineering activity	Demonstrate critical awareness of the impact of engineering activity on the social, industrial and physical environment.
GA8: Individual, team and multidisciplinary working	Demonstrate competence to work effectively as an individual, in teams and in multidisciplinary environments.
GA9: Independent learning ability	Demonstrate competence to engage in independent learning through well-developed learning skills.
GA10: Engineering Professionalism	Demonstrate critical awareness of the need to act professionally and ethically and to exercise judgement and take responsibility within own limits of competence.
GA11: Engineering management	Demonstrate knowledge and understanding of engineering management principles and economic decision-making.

Source: ECSA E-02-PE Revision No. 5: 17 April 2019

Africa (ECSA)). Whereas formulating competencies to be measured as outcomes tended to prioritise the assessment system rather than the student, the term 'graduate attribute' potentially expands the focus to measuring the full range of competencies appropriate to a graduate. This is in line with ECSA's definition of competencies to include knowledge, skills and attitude (Engineering Council of South Africa (ECSA) 2018). Table 1 details the eleven graduate attributes to be assessed in the engineering programmes.

Although 'ethics' is not explicitly mentioned in any of the 11 graduate attributes, it is mentioned in a single descriptor (see GA 10: Engineering Professionalism), where students are required to demonstrate critical awareness of the need to act professionally and ethically, and in two of the associated range statements (GA 9 and GA 10) where students are required to '**be aware of** social and ethical implications' (GA 9) and where '[e] thics and the professional responsibility of an engineer . . . **is generally applicable**' (GA 10) (bold emphases added by the authors). One of the consequences of this formulation is that ethics is conflated with professionalism and positioned as an aspect of the curriculum independent of technical engineering design or problem-solving. It is thus evident that ECSA's formulation of graduate attributes does not explicitly identify ethics as a key constituent of the knowledge, understanding, abilities and skills required in support of a competent practicing engineer. The failure to address ethics more explicitly in the graduate attributes invites an engagement exploring opportunities to incorporate ethics more obviously within these graduate attributes.

South African engineering programmes aim to produce high calibre graduates with the knowledge, skill and values to operate within their level of competence in contexts that are complex. In this context of complexity, engineering programmes need to ensure that the focus on knowledge and skill is imbued with a similar emphasis on ethics, enabling the development of judgement and decision-making aligned to an understanding of future professional responsibilities. Nine of the graduate attributes are formulated as requiring the demonstration of competence, whilst the two graduate attributes most closely associated with ethics, GA 7 and GA10, require only that students 'demonstrate critical awareness of' the particular aspect of ethics (see Table 1). Taking ECSA's own definition of competence as 'possession of the necessary *knowledge, skills* and *attitudes* to perform the [required] activities' (Engineering Council of South Africa (ECSA) 2018), it might be expected that a range statement would go further than require 'critical awareness of' ethics, to require that students demonstrate evidence of values and attitude.

Nudelman's (2020) analysis of the relationships between the engineering industry, higher education and the professional regulator (ECSA) in South Africa, draws attention to the way in which the dominance of ECSA in the policy environment of engineering regulation and accreditation in South Africa results in ECSA having consolidated considerable power relative to both higher education and industry. In this context, Mutereko (2018) highlights the way in which the accreditation processes are 'never neutral or apolitical; rather they emerge from a complex interaction of power relations'. Nudelman's analysis concludes that the South African engineering education and training system 'exhibits a tendency towards the maintenance of the *status quo* and that system transformation is therefore unlikely' (Nudelman 2020). This emphasises the potential role the regulator could play in the invigoration of engineering education.

3.3.1. The ECSA Code of conduct as a base for professional and ethical conduct of engineers

Colby and Sullivan's 2008 review on teaching ethics in undergraduate engineering, sets out the code of ethics as a way to frame the goals of education for ethical development. They trace this in the American ABET accreditation criteria, where the codes are seen to 'usefully elaborate' professional and ethical responsibility. Colby and Sullivan warn that over-reliance on detailed codes of conduct can make decisions difficult, where constituent formulations may be seen to oppose or contradict one another. This analysis provides a platform to approach the South African context, where the ECSA Code of Conduct (2017) is the base for professional and ethical conduct as an engineer. It is interesting that the ECSA Code of Conduct, while providing clear guidance as to professional conduct, uses the word 'ethics' only once as a frame for a section, without elucidating the term further or relating it explicitly to the content – despite clarifying other, more prosaic, terminology.

The ECSA Code of Conduct (Engineering Council of South Africa (ECSA) 2017) covers the responsibilities of engineers in general from an individual and professional perspective and is intended to regulate the conduct of engineers. It is divided into sections with different functions: objectives that underlie specific rules of conduct, then definitions of terms, followed by the rules of conduct and a section of administrative detail. The structure of this document may be compared to documents produced by engineering councils across countries that are co–signatories of the Washington Accord (see Engineering Council and Royal Academy of Engineers 2014; Engineers Australia 2019).

The ECSA Code of Conduct starts by formulating objectives. These objectives include that registered persons (i.e. engineers), in the execution of their engineering work, are obligated to:

- Apply their knowledge and skill in the interests of the **public** and of the **environment**;
- Execute their work with integrity and in accordance with generally accepted norms of professional conduct;
- Respect the interests of the **public** and honour the standing of the **profession**;
- Strive to improve their professional skills and those of their **subordinates**;
- Encourage excellence within the engineering profession and
- Safeguard **public** health and safety (see Engineering Council of South Africa (ECSA) 2017, 1.1-1.6, emphases the authors).

The objectives serve to identify different stakeholder groups, highlighted in bold, whose interests need to be considered in the practice of engineering: the general public, the environment, the engineering profession, the engineers themselves and their teams (colleagues and subordinates). The objectives of the Code of Conduct impose normative expectations on professional conduct within engineering, without detailing what is required or how this is to be achieved.

In the section that follows, terms are defined. It is notable that words such as 'ethics', 'conflict of interest', 'competence' and 'integrity' are not included in the definitions of key terms. In fact, it is noteworthy that 'ethics' is referred to only once in the entire document as a sub-heading/annotation to the Rules of Conduct. While 'competence', 'integrity' and 'dignity of the profession' form headings of sections of the Rules and thus gain content and meaning, 'ethics' forms an invisible frame for the document without specific reference or content.

In the ECSA Code, the objectives are followed by the rules of conduct, relating to ethics, that are mandatory for the registered engineer and cover competency, integrity, public interest, the environment and the dignity of the profession (Engineering Council of South Africa (ECSA) 2017). The code operates on two levels: it plays an *aspirational* role where the objectives set out a vision for the role and practice of engineers and a *regulatory* role (sections 3 and 4) where specific rules and administrative details require compliance and execution and can be enforced.

As it is, ECSA does not explicitly identify ethics as a key constituent of the knowledge, understanding, abilities and skills required in support of a competent practicing engineer. This is where the authors posit the application of an ethical framework across ECSA's graduate attributes. Although articulated in the Code of Conduct and referred to in the descriptors of two graduate attributes, there is at present very little conceptual detail as to what is required in the implementation and assessment of ethics within the curriculum.

3.3.2. Applying the conceptual framework to integrate the teaching of ethics within the particular engineering qualification standard

The previous sections justified the expansion of the concept of ethics within engineering so that it is seen to include a spectrum of distinct elements that may be evident across the outcomes specified by the programme accreditor. The following section aligns the conceptual framework for the teaching of ethics in relationship to the ECSA graduate attributes (Engineering Council of South Africa (ECSA)), as seen in Figure 2 below.

This juxtaposition prompts the execution of a thought experiment to recreate each graduate attribute so as to incorporate opportunities to engage with ethics.

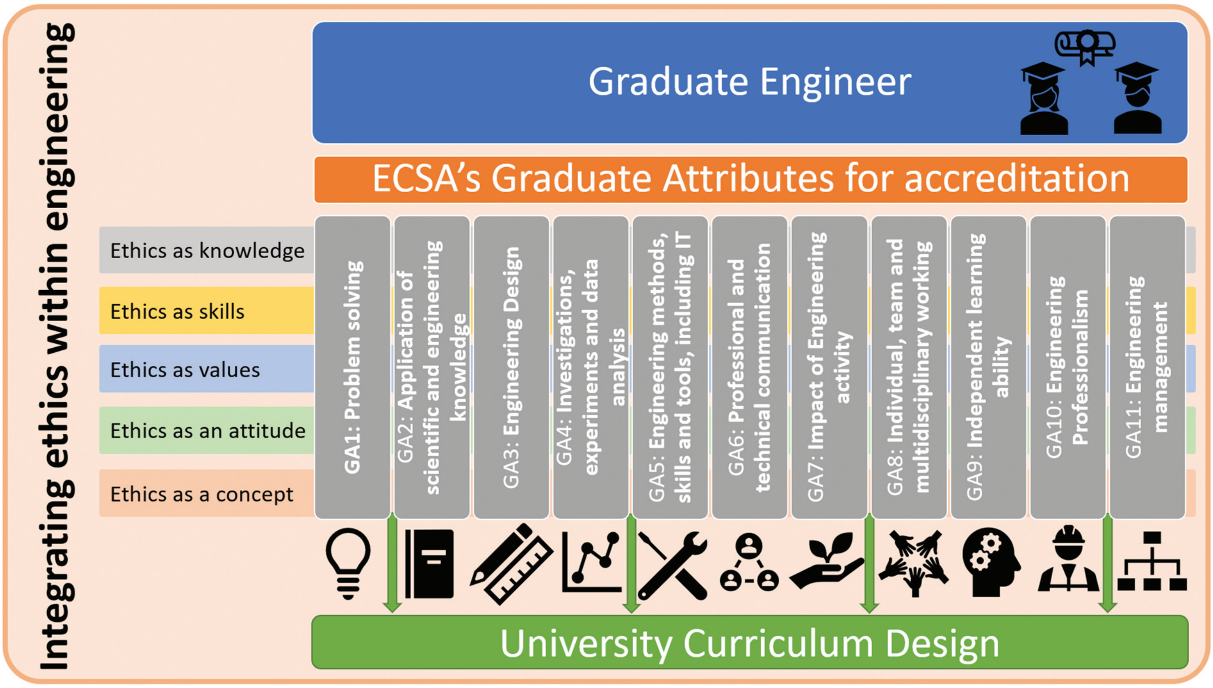

Figure 2. A schematic demonstrating the integration of ethics within the Graduate Attributes requirements filtering into curriculum design.

The first graduate attribute **(GA 1)**, is that of *problem-solving* and requires that students demonstrate the competence to identify, formulate, analyse and solve complex engineering problems creatively and innovatively. The recognition of ethics as a threshold concept transforms further engagement with problem-solving from a technical or efficiency process to a complex context-related challenge. Although not explicitly articulated within this graduate attribute, this may be understood to position ethics at the core of the process of problem-solving. Problem-solving is recognised as inherently an ethical challenge where ethics becomes key to both the application and design of systems.

Following from this assertion of problem-solving as inherently ethical, the second graduate attribute **(GA 2)**, covers the *application of scientific and engineering knowledge*. GA 2 prioritises the ability to know and to do rather than the rationale for choice. This falls in line with the decisions that are already made (GA 1) as regards how to approach the problem.

In contrast, the third graduate attribute **(GA 3)**, that of *engineering design*, places a dual emphasis on innovation and on utilising systematic procedure within design, requiring the exercising of ethical judgment within a specific context. There is a strategic element to the exercise of ethical judgment, balancing the emphasis on acquiring or applying knowledge with that of innovating and creating potential new systems.

The fourth graduate attribute **(GA 4)**, covers *investigations, experiments and data analysis* and requires the student to demonstrate the competence to design and conduct investigations and experiments. With the fundamental shift in engineering research to involve inter-disciplinary research, the increasing prominence of research ethics recognises that ethical considerations in the research process itself are significant. Here the emphasis on ethical *process* must be distinguished from the ethical *goals* for research.

Together with the previous three graduate attributes, the fifth graduate attribute **(GA 5)**, *engineering methods, skills and tools*, includes the use of information technology, and again places the emphasis on the competence to use a range of technical skills, methods and tools rather than on how to measure or assess the appropriateness of the skills, methods and tools. This is reasonable in that it occurs within a disciplinary environment where those methods, skills and tools have established their legitimacy within the boundaries of the particular discipline, which may be seen to have already vetted the selection of methods, skills and tools from a disciplinary perspective.

It is evident that the first five graduate attributes cover a range of skills and knowledge that defines the particular engineering discipline and are thus seen to be core to the discipline. These graduate attributes are seen to be distinct from the graduate attributes that include complementary and cross-disciplinary skills and knowledge.

The sixth graduate attribute **(GA 6)**, that of *professional and technical communication*, requires students to demonstrate competence to communicate effectively, both orally and in writing, with engineering audiences and the community at large. Because of the power of persuasion to effect action, this requires engagement with both the legitimate, and illegitimate, use of persuasion and argument. This becomes an ethical concern challenging both the use of language and the reach of the communication.

The seventh graduate attribute **(GA 7)**, termed the *impact of engineering activity*, requires students to demonstrate critical awareness of sustainability and the impact of engineering activity on the social, industrial and physical environment. This graduate attribute clearly signals a shift to critique established engineering practice beyond the disciplinary boundaries and to consider engineering as situated within the world of experience and consequence. This may be seen to encourage a shift from a narrow focus on technical engineering processes to contextual and time-bound solutions.

Graduate attribute eight **(GA 8)**, together with that of graduate attribute nine **(GA 9)**, requires students to demonstrate the *ability to work and learn as individuals, within teams and across disciplines* and *within a multidisciplinary* working environment as well as independently. The process of developing professional and respectful relationships with stakeholders is core to ethical practice and links ECSA outcomes with requirements for professional practice within industry and society more widely. ECSA's requirement to assess this competence, is to be recognised as this area of competence has historically fallen outside of traditional assessment practices and its inclusion requires innovative pedagogy.

It is the tenth graduate attribute **(GA 10)**, that of *engineering professionalism*, that engages explicitly with ethics and professionalism, and requires students to comprehend, apply and commit to ethical principles, professional ethics, responsibilities and the norms of engineering within their level of competence. This graduate attribute is commonly identified as the exclusive area of the curriculum where ethics and professionalism are primarily assessed. In an earlier study based on version three of the ECSA programme criteria, Gwynne-Evans (2018) defined four distinct areas of student learning that can be deduced from the criteria demonstrating competence:

- objective knowledge of systems and procedures and content;
- knowledge demonstrating skill, such as how to build an argument;
- self-understanding and an engagement with personal values and choices;
- and conceptual knowledge and engagement with the way one concept relates to another (Gwynne-Evans 2018).

The final graduate attribute, **(GA 11)**, is that of *engineering management* and requires students to demonstrate knowledge and understanding of engineering management principles and economic decision-making. This brings to light numerous areas of management that relate to ethics from both a relationship and process perspective and that link with values such as efficiency as an ethical prerogative in both industry and society. It opens multiple opportunities for assessing understanding and application of tools and strategies that relate to both efficiency and contrasting ethical values such as care and respect.

This analysis can be summarised in Table 2, where the first column lists the particular graduate attribute, the middle column gives the descriptor and the third column presents an innovative re-construction of the specific descriptor so as to more clearly articulate the ethics component.

From the table above, it is evident that ethics can be engaged with throughout the under-graduate engineering curriculum at different points, in ways that complement the definition of the graduate attributes.

4. Discussion

Globally, engineering education sets out to ensure the graduate is equipped with 'a knowledge base and attributes to enable the graduate to continue learning' so as to 'develop the competencies required for independent practice' (International Engineering Alliance (IEA) 2013). The focus on technical knowledge and skills in engineering programmes can result in the marginalisation of other aspects of the programme, because of differences in understanding as regards how knowledge is developed within the disciplines.

The research set out to distil significance from the range of theories relating to teaching ethics in engineering. This narrative is synthesised into a framework that is visually accessible and simple to use, and that can be applied by engineering educators and technical engineering experts, to their own areas of expertise, to make teaching ethics possible and inviting across a range of areas. This conceptual framework melds together different approaches as complementary, rather than disparate, and is intended to provide a way for engineering educators to engage with ethics within their specific disciplinary expertise. The value of this conceptual framework is that it provides a model that sees the different approaches to teaching ethics within engineering as complementary rather than alternative. Its intention is to provide a broad rather than deep analysis and to provide space to include different voices. This demonstrates that ethics needs to be repositioned at the centre of the preparation of engineers, rather than at the periphery. It recognises that many of the voices contributing to the discussion on teaching ethics have historically emerged from a particular tradition of western philosophical thought and

Table 2. Application of the Conceptual Framework for the teaching of ethics to the Graduate Attributes of the ECSA Qualification Standard Framework.

Graduate attribute	Descriptor	Application of the expanded conceptual framework for ethics to the GA descriptors
GA1: Problem solving	Demonstrate competence to identify, assess, formulate and solve convergent and divergent engineering problems creatively and innovatively.	Solving problems ethically is a necessary criterion to add alongside creativity and innovation. Ethical problem-solving to be defined distinct from technical problem-solving: relates to the application and design of systems.
GA2: Application of scientific and engineering knowledge	Demonstrate competence to apply knowledge of mathematics, basic science and engineering sciences from first principles to solve engineering problems.	Rationale of choice and application of knowledge requires application of ethical responsibility. Assessment of risk in terms of 'risk to what/who?' Requirement of care has ethical implications.
GA3: Engineering Design	Demonstrate competence to perform creative, procedural and non-procedural design and synthesis of components, systems, engineering works, products or processes.	Develop and use ethical judgment alongside technical engineering judgment in designing and innovating for sustainable systems and procedures.
GA4: Investigations, experiments and data analysis	Demonstrate competence to design and conduct investigations and experiments.	Demonstrate competence, ethical goals & ethical process in research and experimentation. Demonstrate awareness of the ethical implications of the choice and use of method.
GA5: Engineering methods, skills and tools, including Information Technology	Demonstrate competence to use appropriate engineering methods, skills and tools, including those based on information technology.	Demonstrate competence and integrity to select and use appropriate engineering methods, skills and tools, including those based on information technology.
GA6: Professional and technical communication	Demonstrate competence to communicate effectively, both orally and in writing, with engineering audiences and the community at large.	Develop skills of oral and written communication relating to purpose, language, tone and positionality. Engage with the legitimate use of persuasion and argument and the potential misuse of persuasion.
GA7: Impact of Engineering activity	Demonstrate critical awareness of the impact of engineering activity on the social, industrial and physical environment.	Develop critical and ethical awareness of the impact of engineering activity on the social, industrial and physical environment.
GA8: Individual, team and multidisciplinary working	Demonstrate competence to work effectively as an individual, in teams and in multidisciplinary environments	Ability to create, value and sustain professional and respectful relationships with stakeholders. Develop the willingness to take and share responsibility and to act with purpose.
GA9: Independent learning ability	Demonstrate competence to engage in independent learning through well-developed learning skills.	Demonstrate competence to engage in independent learning through well-developed learning skills. Demonstrate awareness of social and ethical implications of applying knowledge in particular contexts*
GA10: Engineering Professionalism	Demonstrate critical awareness of the need to act professionally and ethically and to exercise judgement and take responsibility within own limits of competence.	Demonstrate critical awareness of the need to act professionally and ethically and to exercise judgement and take responsibility within own limits of competence. Demonstrate the ability to draw on personal experience in relation to values, principles and attitudes.
GA11: Engineering management	Demonstrate knowledge and understanding of engineering management principles and economic decision-making.	Demonstrate the ability to apply skills and knowledge in an ethical manner to manage relationships and make strategic economic decisions. Show awareness of the way ethical choice influences process.

Source: Adapted from ECSA E-02-PE Revision No. 5:17 April 2019 * from associated ECSA GA 9 range statement

recognises that there is space for new approaches, and that their contributions are potentially important. Furthermore, this recognises the power of theory to influence what is framed and what is excluded (Dastile and Ndlovu-Gatsheni 2013).

In this connection, the research highlighted the incongruity of ECSA's own assumption of the clarity of conceptual understanding of words such as 'ethics', 'competence' and 'integrity', where ECSA does not explicitly engage with the meaning of these words. It is significant that conceptual understanding is assumed in both the graduate attributes and the ECSA Code of Conduct. The earlier description of elements of the ECSA Code of Conduct and the graduate attributes provides some evidence of intent to position ethics as part of the engineering accreditation programme but provides very little conceptual detail as to what is meant by this. A consequence of this is that there are insufficient signposts to guide educators in the implementation and assessment of ethics within the engineering programme. The hypothesis that ethics is relevant across all the graduate attributes, instead of only where ethics is explicitly mentioned, has been demonstrated by the application of the thought experiment across the full eleven graduate attributes.

A cumulative consequence of the facts that the ECSA Code of Conduct mentions ethics only once, that the accreditation documents neglect to profile ethics in the programme standards and that ethics is mentioned in only one graduate attribute (GA 10), is that ethics is relatively invisible. Despite this, the ethical conduct and responsibility of engineers remains a key concern of engineering regulators, globally and in South Africa. Ethics is an area of the engineering curriculum that should cut across disciplines and levels of qualification. It is therefore to be expected that the requirements for the preparation of engineering undergraduates explicitly addresses ethics in distinct ways at specific points in the curriculum. This correlates with what has been proposed in this paper, where the outcomes of the thought experiment (Table 2) demonstrate a set of graduate attributes from which to develop a curriculum that imbues ethics in engineering programmes by addressing ethics through theory, action and identity (Figure 1).

Ensuring that engineering serves the needs of society is presented as both an objective and a rationale of the ECSA Code of Conduct (see Engineering Council of South Africa (ECSA) 2017). From the outset, the ECSA Code of Conduct sets out to challenge: the diverse interests of the stakeholders are presented in a way that allows the engineer to see these as complementary rather than competitive to their own interests. The vision incorporates an improved industry benefitting different stakeholders. This vision combines the challenge of problem-solving in its complexity: as how best to maximise potential benefits for the full range of stakeholders within a specific situation.

As the graduate attributes stand, the two GAs most obviously connected to ethics, GA 7 and GA 10, do not require students to engage their sense of identity, attitudes or values, but portray ethics as involving objective knowledge and skill. In particular, the current version of ECSA's Graduate Attribute 10 stops short of requiring that students bring their own sense of who they are – their sense of professional identity – into the assessment process. This is precisely the space to require students to engage with their sense of *identity* and *meaning* in relation to their professional role. This misses an important opportunity to engage the students in formulating their developing sense of what it is to be an engineer, thus critically constraining the way students engage with ethics at a formal level.

Ethics thus needs to be positioned as a transdisciplinary area in the curriculum for engineering students that provides a context to, and rationale for, the selection and practice of technical skills and knowledge developed in the discipline. All the technical, mechanical and process choices that are made by engineers can be seen to proceed from an understanding of their professional and ethical responsibilities and obligations.

The main drawback of this study is the narrative approach to exploring ethical frameworks, which opens the paper to criticism in opting for an approach that may lack repeatability. However, the authors consciously used texts from multidisciplinary sources, firstly to contextualise and ground the work in a case study, in this case, the South African context, and secondly to provide a practical way that invites practitioners to appropriate and build onto the conceptual model, working in and interpreting examples from their own readings and context. This approach recognises the effect of education, socioeconomic and socio-political context on the process of interpreting and implementing accreditation policy and programme design. A more formulaic study on implementing engineering ethics in higher education could risk conflating these distinctions that require articulation.

An additional limitation of the study is that competence was not explored in more detail. In particular, it would be possible to explore how ethics could be defined as a competence. Although relevant, the discussion was beyond the scope of the paper and warrants further exploration.

5. Conclusion

A range of approaches to teaching ethics have been consolidated in a conceptual framework to inform and critique different strategies and approaches to the teaching of ethics within engineering (Figure 1). Understanding these as different lenses allows an appreciation of the variety of approaches and the distinct purposes that are possible.

This paper demonstrates how ethics can be repositioned at the centre of the preparation of engineers, rather than at the periphery. To date, the integration of ethics in engineering education has largely been focused at the curriculum design level. While several conceptual frameworks have been developed and implemented at this level, the authors posit that this integration be done at the accreditation level, to be more effective in permeating ethics within curriculum design. Although competence is defined by ECSA to include skills, knowledge and attitudes, current graduate attributes define areas of competence in terms of skill and knowledge rather than engaging with attitude or values.

The authors present a conceptual framework for teaching ethics in engineering and demonstrate integration at the accreditation level by rewording the descriptors of ECSA's eleven graduate attributes. The expected consequence of this is a more comprehensive incorporation of ethics within the curricula of accredited engineering programmes.

6. Implications for future research

This study demonstrates ways in which ethics underpins the professional engineering code of conduct and is at the heart of engineering education as defined in the graduate attributes of a particular engineering regulatory accreditation body. Extending the analysis to other engineering regulatory bodies may provide additional perspectives on the ability of the graduate attributes to incorporate ethics across the engineering curriculum.

Further research can apply the conceptual framework to a range of specific examples of implementation and assessment, as evidenced by Bombaerts, Doulougeri, and Nievien (2019). This will include auditing the tools and strategies that engineering educators use to teach ethics and examining how these tools and strategies address different elements of the conceptual framework. These additional areas of research and analyses may further influence the approach to teaching ethics across different institutions and engineering disciplines.

The value of the conceptual framework needs to be tested through research in different contexts as to its ability to highlight differences in pedagogic approaches and to facilitate a more nuanced engagement with implementing and assessing ethics within the curriculum.

7. Implications for practice

This research highlights that regulation relating to the qualification of engineering graduates is key, both to affecting and effecting the delivery of engineering education. The way in which ethics is articulated in these standards and criteria informs and influences the profile of ethics in the engineering curriculum. The definition of competencies and graduate attributes is malleable and evolves alongside developments in scholarship and practice relating to engineering education.

Consequently, if ethics is seen to be an integral part of the curriculum, this research argues the need for integrating ethics at the accreditation level, where, instead of being one of eleven graduate attributes, ethics permeates all eleven attributes, causing ethics to be more visible in the curriculum.

This research justifies a much higher premium on the teaching of ethics within engineering – without ethics, training is reduced to commodified skills and knowledge– with ethics, vision, responsibility and attitude is developed in a way that augments technical skill and knowledge.

In contrast to the bold scope of the vision encapsulated in the ECSA Code of Conduct, there are aspects of the broad objectives that need further clarification: words such as 'generally accepted', 'integrity', 'norms of the profession' and what it means to 'respect the interests of the public' or to 'honour the profession'. In order for the Code of Conduct to be useful and to inspire in the way that is intended, these terms need to be explored and articulated within a document that provides the scaffolding to engage in an accessible way with the potential meaning of the terms.

With regards to the wider issue of students' developing sense of professional identity, it is important that where the dominant ethos contrasts with students' lived experience and values, engineering programmes make space for robust engagement with values so that students develop a sense of their professional identity that is integrated with their personal values. This sense of integrity forms a significant part of students' confidence to exercise judgment and to act decisively.

Educators necessarily engage with ethics at multiple places in their execution of the undergraduate engineering curriculum. Engineering educators therefore need to be equipped to identify opportunities to include ethics in their material, starting with articulating the learning outcomes or graduate attributes relating to ethics, and to have confidence in their own skill and competence to do so.

Redefining the graduate attributes so that ethics is positioned at the heart of the undergraduate engineering programme will have an impact on how the curriculum is formulated, delivered and assessed.

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Appendix A: Range of resources ordered according to subject area

Subject Area	Reference
Reviews:	Borrego, Foster, and Froyd 2014.
Systematic literature reviews	Hamad et al. 2013.
Literature reviews	Haws 2001.
Meta-analysis of ethics instruction	Hess and Fore 2018.
	Wright 1995.
Research Methods:	Borrego, Foster, and Froyd 2014.
Engineering education research	Gardner et al. 2019.
Qualitative research design	Maxwell 2013.
Research method	Salkind 2010.
Thought experiment	Sorensen 1995, 2019.
Conceptual frameworks for research	Svinkini 2010.
Potential conceptual frameworks for teaching	Bowden 2010.
ethics within engineering:	Bombaerts, Doulougeri, and Nievien 2019.
Teaching ethics – theory and practice	Colby and Sullivan 2008.
Curriculum typology	Conlon and Zandvoort 2011.
Micro-insertion	Davis 1991, 2006.
Integrating ethics in engineering	Fore and Hess 2020.
Collaborative research strategy	Galloway 2008.
Microethics & Macroethics	Gorman et al. 2000.
	Gwynne-Evans 2018.
	Gwynne-Evans, Chetty, and Junaid 2019.
	Harris et al. 2000, 2008, 2014.
	Herkert 2001.
	Hess and Fore 2018.
	Pfatteicher 2001.
	Rest 1984.
	Riley 2013.
	Sayer 2011.
	Van Der Poel and Royakkers 2007.
	Van Der Poel 2015.
	Whitbeck 2011.
Learning theory:	Amer 2006.
Origins of outcomes-based learning theory	Bloom et al. 1956.
Transformative practice	Fink 2003.
Threshold concepts	Krathwohl 2002.
Powerful knowledge	Lillis et al. 2015.
	Meyer and Land 2005.
	Young and Muller 2013.
Accreditation documentation and policy:	Engineering Council of South Africa (ECSA). 2019 Qualification Standard for Bachelor of Science in Engineering (BSc (Eng))/Bachelor of Engineering (BEng). NQF Level 08.
Graduate competencies	Engineering Council of South Africa (ECSA) 2014. Qualification Standard for Bachelor of Science in Engineering (BSc(Eng))/Bachelor of Engineering (BEng). NQF Level 08.
Professional competencies	Engineering Council of South Africa (ECSA) 2018 Guide to the Competency Standards for Registration as a Professional Engineer R-08-PE.
Codes of Conduct	Engineering Council of South Africa (ECSA) 2017. Code of Conduct.
International Ethical Codes	Engineering Council of South Africa (ECSA) 2015. The Strategic Plan.
	International Engineering Alliance (IEA) 2013. Graduate attributes and professional competencies Version 3.
	International Engineering Alliance (IEA) 2014 Washington Accord.
	Engineers Australia 2019 Code of Ethics and Guidelines on Professional Conduct
	UK Engineering Council, Statement of Ethical Principles, 2014.
South African Context:	Behari-Leak and Mokou 2019.
Development policy research	Bhorat, Mayet, and Visser 2012.
The influence of higher education on South African accreditation	Case et al. 2018.
	Dastile and Ndlovu-Gatsheni 2013
South African legislation	Martin et al. 2005.
	Mutereko 2018.
	Nudelman 2020.
	Companies Act, No. 71, 2008.
	Statistics South Africa (STATS SA) 2019.
	King Committee on Corporate Governance in South Africa. 1994, 2002, 2009, 2016. King Code (versions 1, 2, 3, 4).
	National Planning Commission 2011. National Development Plan: Vision for 2030.