

A research ethics framework for training engineers in doctoral degree studies

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Abstract. Both the South African Qualifications Authority (SAQA) and the Engineering Council of South Africa (ECSA) have specific expectations for the learning outcomes of engineering students. SAQA defines level descriptors that define the expected academic and professional competencies, with ethics and professional practice being key cross-cutting descriptors. ECSA expects graduates to demonstrate critical awareness of professional and ethical responsibilities, exercising judgment within their competence. This paper proposes a research ethics framework for training engineers in doctoral degree studies. This research follows a qualitative approach. This proposal was initiated by the Council on Higher Education's (CHE) national review of South African Doctoral Qualifications from 2020 to 2021, and the CIRP (The International Academy for Production Engineers) Ethics in Manufacturing questionnaire, presented in August 2024. The CHE Report confirms that ethical awareness in research and professional conduct is an essential graduate attribute that students should master. The CIRP questionnaire included 18 questions designed to draft an Ethical Code of Practice. Two key questions focus on ethical concerns in manufacturing and confidence in ethical decision-making related to technology. The matters raised by this report and questionnaire are important for designing a research ethics framework for doctoral degree studies. Additionally, Drolet et al. (2023) examined ethical issues in research through a triangulated approach, identifying ten key ethical concerns such as research integrity, conflicts of interest, and social injustices. These insights and perspectives from SAQA and ECSA were used as the basis for this framework.

1 Introduction

The integration of ethics into higher education and training is not new. Both the South African Qualifications Authority (SAQA) and the Engineering Council of South Africa (ECSA) focus on the learning outcomes of engineering students. SAQA [1] identifies level descriptors defining the expected learning outcomes for academic and occupational qualifications. Ethics and professional practice are included among the cross-cutting level descriptors. One of ECSA's [2] expected graduate attributes (GA) is a demonstrated critical awareness of the

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necessity to act professionally and ethically, exercising judgement and taking responsibility within one's limits of competence. ECSA identified 11 Graduate Attributes (GAs) [3] which are aligned with the Washington Accord [4].

ECSA GA10 emphasises engineering professionalism, including ethics, as outlined in the following statement: "Apply ethical principles and commit to professional ethics and norms of engineering practice and adhere to relevant national and international laws" [3]. The Washington Accord Graduate Attribute Profile has 12 elements, with WA 8 referring to: "Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice (WK7)" [4]. Knowledge profile WK 7 requires: "Comprehension of the role of engineering in society and identified issues in engineering practice in the discipline: ethics and the professional responsibility of an engineer to public safety; and the impacts of engineering activity – economic, social, cultural, environmental and sustainability".

The Council on Higher Education (CHE) conducted a national review of South African Doctoral Qualifications from 2020 to 2021. This review led to the "Doctoral Degrees National Report" published in 2022 [5]. The report recorded that ethical awareness in research and professional conduct is an essential graduate attribute that students should master. Being ethical in research is important as research (results) influences people and their environment. This attribute should be evident in the learning programmes of doctoral degrees.

The need to accommodate ethical and professional behaviour within higher education has become more apparent due to several factors, of which two are specifically important. Firstly, the emerging influence of Artificial Intelligence (AI) on higher education and subsequently on the world of work. Secondly, the professional preparedness of new graduates is essential for the global workplace [6-7]. It is predicted that job preparedness now is more important than ever before. Following this is the growing need for ethics in the workplace. This need entails much more than choosing between right and wrong. Additionally, it is expected that employees will bring fairness and integrity to the workplace. This comment can be shown in, for example, the context of the manufacturing value chain. Here, leading ethical questions are on technology (new products and abilities) and the impact manufacturing has on people (health, safety, and security) and the environment (pollution, water, energy, sustainable livelihoods, and more) [8].

Stern and Castell [9] add another perspective on the role of ethics in training by examining graduate studies through a quality lens. According to them, quality is a fundamental value in higher education, evidenced by the benefits provided to individuals, governments and society. Furthermore, higher education promotes equitable opportunities for all. Another important value they identify is productivity, which enables individuals to progress to various job opportunities, which they reported as "beyond the graduate premium".

To address the needs listed, this paper proposes a research ethics framework designed to prepare doctoral engineering students for a future workplace that will be AI-driven and shaped by emerging ideologies. The new world of work will require new ethical skills and competencies. The paper's focus is purposefully targeted to doctoral degree studies, given the absence of clear expectations from ECSA on this GA for this qualification level [3], and the recommendation from the CHE's Report on Doctoral Standards [5]. This paper aims to contribute to the discussion on doctoral standards from the perspectives of ethics and professional behaviour.

The research question for this paper is "How can ethical and professional behaviour be included in a research ethics framework for doctoral studies?" The outcome is to present a research ethics framework for the training of engineers in doctoral degree studies based on existing guidelines, requirements and practices. This framework is generic because a specific framework addressing ethical and professional behaviour in engineering doctoral studies

could not be found in the public domain. This does not imply that training in these areas is absent in doctoral studies at South African universities. Rather, it suggests that a systematic approach to ethics and professional behaviour could enhance the expected learning outcomes at this qualification level.

2 Methodology

The methodology followed a *qualitative approach*, informed by a thematic literature review and *document analysis*, considering practices at South African universities' training for doctoral degree engineering students. Hecker and Kalpokas [10] comment that the primary objective of *thematic research* is to furnish scholars and practitioners with a comprehensive and succinct overview that captures the key developments and discourse surrounding a particular theme. Doctor Degree® [11] emphasises that thematic literature reviews stand apart from general literature reviews, focusing on analysing patterns and trends that emerge within specific themes of inquiry. In contrast to traditional literature reviews, which often adhere to a chronological organisation of the subject matter, thematic reviews systematically arrange content around these identified themes. This method not only facilitates a clearer understanding of the predominant issues pertinent to the research area but also aids in illuminating connections between various studies and highlighting gaps in the literature, thus guiding future research directions effectively.

Document analysis, as a qualitative research method, involves systematically reviewing and interpreting institutional documents to understand meaning, gain insights, and develop empirical knowledge. Morgan [12] comments that bias and misinterpretation can be avoided by using reflexive thematic analysis.

The approach in this article was first to attend to the results from the thematic research and then identify the policy and professional council requirements and expectations for ethical and professional training at the doctoral degree level based on document analysis.

2.1 Thematic observations

From the thematic research, four important matters were identified:

- Ethics is a learning outcome relevant to educating and training engineering students.
- Ethics in the curriculum is no add-on, but an integral part of engineering studies.
- The engineering profession depends on ethical and respectful behaviour.
- Engineering ethics embodies the care for society.

These themes can be unpacked with the following comments:

- Ethics as a learning outcome: The South African Qualifications Authority (SAQA) defines level descriptors as expected learning outcomes. Ethics and professional practice are one of the cross-cutting level descriptors identified by SAQA [1]. For postgraduate engineering students, research ethics is particularly important. The landscape of research ethics has undergone a profound transformation, expanding far beyond the traditional focus areas that once dominated the field. Historically, the primary concerns of doctoral supervisors revolved around the ethical treatment of research participants, the integrity of data reporting, and vigilant monitoring for instances of plagiarism. However, in the contemporary research milieu, the scope of research ethics has broadened significantly to encompass a diverse array of critical issues. Today, ethical considerations extend into vital realms such as environmental sustainability, where researchers are increasingly called to evaluate the ecological impact of their work. Budget management also plays a crucial role,

necessitating a careful balance between financial constraints and ethical responsibilities in conducting research. Furthermore, data governance has emerged as a concern, with the need to safeguard data integrity and ensure compliance with legal and ethical standards. Additionally, publication ethics has gained prominence, emphasising the importance of transparency and accountability in disseminating research findings. The supervisor-student relationships are now recognised as an essential component of ethical research practices, demonstrating the need for open communication, mentorship, and support. This comprehensive and multifaceted approach to research ethics mirrors the increasing complexity of the academic landscape, revealing the heightened responsibilities that students and their supervisors must navigate in pursuing knowledge and innovation.

- Ethics is no add-on: Gwynne-Evans, Chetty and Junaid [13] argue that integrating ethics in engineering education is not limited to the curriculum design level. This should be evident in graduate attributes. The relevance of ethics for engineering education and research is identified by Gwynne-Evans et al. [13], referring to ethics as the “heart of engineering attribute”. From another corner, Drolet et al. [14] published research triangulating different perspectives from researchers, Research Ethics Board members and ethics experts. Using this research, emerging ethical issues were grouped into ten units of meaning. These units are (a) research integrity, (b) conflict of interest, (c) respect for research participants, (d) lack of supervision and power imbalances, (e) individualism and performance, (f) inadequate ethical guidance, (g) social injustices, (h) distributive injustices, (i) epistemic injustices, and (j) ethical distress. Their research includes the Canadian Engineering Council. The research is significant for two reasons: Firstly, the engagement with different stakeholders resulted in representative opinions. Secondly, the units of meaning can be used to build supervisors’ and students’ capacity to deal with ethical matters in research, which will include practical work.
- The Engineering Profession Act (2000) states that the Engineering profession should be ethical [15]. Although no specific mention is made of ECSA’s graduate attributes, the implicit importance is aligned with the reference to “attitude”. The International Academy for Production Engineering Research (CIRP) presented the results of its Ethics in Manufacturing questionnaire in August 2024 [16] based on 18 questions. From these outcomes, it is expected that a CIRP Ethical Code of Practice can be drafted. Two questions from the questionnaire are particularly relevant. Question 5 addresses the main ethical ambitions perceived concerning manufacturing, while Question 11 assesses engineers’ confidence in understanding the ethical considerations related to manufacturing technology. Han [17] refers to the American National Society for Professional Engineers’ code of ethics, which confirms the importance of ethics because of protecting public safety, by only performing tasks they are qualified to do, being honest in public communications, remaining faithful and trustworthy to employers and acting with integrity. Schuurman [18] comments that an ethic of responsibility is the most suitable approach for an ethics of technology because it integrates ethos, intention, values, and norms coherently.
- Ethics embodies care: responsible care is used as a concept within engineering ethics. This concept combines professional behaviour as required by the engineering profession and as an expression of responsibility towards clients, the community, and the environment. Responsible care is required because standards and operating procedures are not enough to perform a task [19]. Employee wellness will continue to be a priority for organisations as job performance and digital integration become increasingly important in a complex workplace. With the rise of information and

communication technologies (ICTs), individuals are more connected to their jobs than ever before. This constant connectivity has significant implications for employees' overall health and well-being [20]. A useful approach to care in engineering is the concept of care ethics, considering the vulnerability of people, building a relationship to accommodate their vulnerability and achieving the desired outcomes [21].

From the thematic results, the focus is now on the policy and professional expectations for doctoral studies.

3 Ethics and professional training for doctoral degree studies – policy expectations

The *Higher Education Qualifications Sub-framework* (HEQSF) (2014) provides an overview of postgraduate qualifications based on the National Qualifications Framework (NQF) [22]. A summary of these qualifications is presented in Table 1 [23]. As the higher doctorate is not relevant to the scope of this article, it is not further discussed here.

Table 1. Summary of postgraduate qualifications based on the NQF [23].

Qualification	NQF Level	Minimum Total Credits	Minimum Research Credit	Purpose and Characteristic
Honours degree	8	180	30	Qualification prepares for research-based postgraduate studies. It deepens discipline-specific knowledge and develops research capacity in the methodology and techniques of the discipline. High-level theoretical engagement is required for this qualification.
Postgraduate Diploma	8	180	Research project is not required.	Qualification is directed at working professionals. It strengthens and deepens knowledge in a discipline or profession. It undertakes advanced reflection and development based on a systematic survey of current thinking, practice, and research methods relevant to the specialisation. High-level theoretical engagement is required for this qualification, as well as the ability to relate knowledge to the profession or highly skilled work.
Master's degree	9	180	60 credits for coursework master's	Qualification can either be a research qualification based on a dissertation, coursework or a mini-dissertation. Both qualifications should give evidence of significant research. In essence, this qualification should lead to the contribution and development of

				knowledge. In the master’s programme by coursework, knowledge should be related to a profession. In a master’s study, the student should be able to deal with complex problems, design and critically evaluate research, make decisions based on the research results, and communicate the results to peers and the public.
Professional Master’s degree	9	180	45 credits	This qualification should lead to the contribution and development of knowledge relevant to professional employment. Work-integrated learning can be integrated into the curriculum. In a master’s study, the student should be able to deal with complex problems, design and critically evaluate research, make decisions based on the research results, and communicate the results to peers and the public.
Doctoral degree	10	360		The defining characteristic of a doctorate is the demonstration of high-level research capability and a significant and original contribution toward the knowledge base of a discipline. The qualification can be discipline-based, multidisciplinary, or applied research.
Professional Doctoral degree	10	360	60%	The defining characteristic of this qualification revolves around high-level research capability, integration of theory with practice, and training for a profession or industry.

From this summary, it is evident that postgraduate studies contribute towards knowledge development. For Master’s degrees, ECSA [24] is specific on the learning outcome as articulated by the NQF Level Descriptor: “Ethics and professional practice: The ability to make autonomous ethical decisions that affect knowledge production or complex organisational or professional issues and an ability to critically contribute to the development of ethical standards in a specific context”. At the postgraduate level, graduates engage with complex problems. Their decisions, based on their research findings, have the potential to impact society and the workplace. As this impact can be negative, it is important that decisions are grounded in ethical considerations. The type of ethical foundation required is clearly outlined by SAQA [1], which includes level descriptors that refer to the expected learning outcomes for academic and occupational qualifications. Ethics and professional practice are identified as one of the key cross-cutting level descriptors. Table 2 provides an overview of the expected SAQA learning outcomes for master’s and doctoral studies.

Table 2. Ethics learning outcomes for master’s and doctoral degree studies [1].

NQF Level	Level Descriptor
NQF Level 9 (master’s)	The student should be able to make decisions affecting knowledge production, or complex organisational or professional issues. The student should also be able to develop ethical standards for a specific context.
NQF Level 10 (doctoral)	The student should be able to identify, address and manage emerging ethical issues. In addition, the student should also be able to advance processes of ethical decision-making and to monitor and evaluate the consequences of decisions.

The NQF Level 9 descriptor implies that the student should be able to lead ethical practice in new scenarios. For NQF Level 10, the student should be able to shape and define ethical practice. These expected learning outcomes are well informed by the prior qualification levels’ learning outcomes. For example, the ethics learning outcomes for NQF Level 7 and NQF Level 8 qualifications can be considered. NQF Level 7 is an exit qualification with which students can enrol for NQF Level 8 qualifications that are regarded as postgraduate qualifications. However, NQF Level 8 can also include four-year undergraduate qualifications, which will give access to NQF Level 9 studies (master’s qualifications). NQF Level 8 qualifications can therefore be undergraduate and postgraduate qualifications. NQF Level 8 qualifications are also regarded as pipeline qualifications to master’s and eventually doctoral programmes. These qualifications’ learning outcomes support ethical matters and decisions that inform ethical and professional behaviour.

Table 3. Ethics learning outcomes for NQF Level 7 and 8 qualifications [1].

NQF Level	Level Descriptor
NQF Level 9	The student should make decisions leading to ethical and professional behaviour and justify the decisions and actions taken.
NQF Level 10	The student should be able to identify and address ethical matters.

In a publication on ethics in Science, Technology, Engineering, and Mathematics (STEM), it is stated that engineering education should attend to the need for ethics in its training [25]. The need for such training is well argued in publications, reports and views from the professional council. Although ECSA’s GAs are more relevant for undergraduate education [2], the critical need remains at the postgraduate level to act professionally and ethically, also in research and practical work, specifically to meet ECSA Outcome 8 competencies relating to professional ethics for professional registration [26]. The emphasis on exercising judgement and taking responsibility should be regarded as a requirement that follows up to the doctoral degree level. When the SAQA and ECSA requirements are jointly considered, it can be concluded that professional and ethical behaviour is common to education at the postgraduate levels.

From a qualification and professional perspective, it is evident that sufficient guidelines are available to support the ethical training for postgraduate students. The question is what the practice tells us about this preparation?

4 Ethics and professional training – some considerations

Engineers are expected to conduct their work ethically, following Outcome 8 of the ECSA Professional Engineer Standards [23]. This outcome aligns with the Washington Accord’s Graduate Attribute WA8, which requires graduates to apply ethical principles and demonstrate a commitment to professional ethics, responsibilities, and the norms of

engineering practice [4]. ECSA's GA10 shows this expectation: Engineering professionalism – apply ethical principles and commit to professional ethics and norms of engineering practice and adhere to relevant national and international laws [3].

However, the question is how postgraduate engineering education ensures that students continue to develop ethical competencies. Students entering higher degree programmes typically hold a bachelor's degree in engineering, which implies they have already demonstrated competence across all ECSA graduate attributes. This foundational competence serves as the entry point for advanced studies. Postgraduate education, therefore, plays a vital role in further deepening ethical understanding and preparing students for the professional competencies required for registration as a professional engineer under ECSA. To substantiate this comment, a general requirement for admission to the doctoral programme is that the doctoral candidate must pass either a course/module in Research Methodology or provide evidence of his/her knowledge regarding Research Methodology to the satisfaction of his/her promoter.

Third space support is provided for postgraduate students in the form of institutional workshops and training on a variety of topics [27]. One such topic deals with research ethics and integrity. Within the range of these topics, reference can be made to the Singapore Statement on Research Integrity (2010) [28] and the South African Joint Statement on ethical research and scholarly publishing practices (2019) [29]. The Singapore Statement states that research should be trustworthy and to the benefit of society. The South African Joint Statement comments on the impact of research on society, marginal groups, and individuals. Conducting research involves much more than only obtaining ethical clearance, ethical approval for the study, or gatekeeper approval from institutional participants.

The following contributions support research and integrity within doctoral studies.

Although practices are in place to support the research ethics and integrity associated with doctoral studies, no obvious evidence is available for ethics education in these studies. Research ethics is different from professional ethics insofar as the former deals with the research process and the latter with public engagement, either in the workplace, with a client or society in general. Research ethics is not sufficient to address the professional needs of the doctoral student.

The examination form (as part of summative assessment) may not require information on this learning outcome. An evident absence of a viva voce also limits the opportunity to assess these learning outcomes.

Research ethics training can contribute to professional ethics if the scope of research ethics extends beyond the conventional scope of the right thing to do and includes more understanding of matters such as ethical risk and ethical engagement as a professional. Industry 5.0's emphasis on human and non-human collaboration in the workplace requires a new orientation in training. Apart from having the know-how in AI or sensitivity towards ethical matters in the context of AI, the potential "co-working" with machines demands a new appreciation for work and learning how to do so. At the research level, interaction with AI models must be declared, but surely this is not enough to prepare students to operate in the new world of work.

Anchor strategies serve as a powerful catalyst for universities to actively connect with their surrounding communities, fostering collaboration and partnership aimed at driving profound social and economic transformation within the city and its regions, as well as enhancing the university's impact and growth. Through this engagement, universities can contribute to revitalising local economies, addressing pressing social issues, and creating inclusive opportunities for all, thereby establishing themselves as pivotal players in the evolution and prosperity of their environments. At the same time, it is an ideal place to foster the ethical and professional behaviour of students.

Research ethics education promotes the integration of ethical values in all aspects of the research process, starting with admission to graduation and the uptake of research results. Research ethics is understood as the application of ethical principles to the research process, focusing on how the research is conducted and its value to the community, starting with access and admission into the university and extending to research uptake as the final dissemination of research results to a public audience [30-31]. Research integrity promotes confidence and trust in methods and results (from the community to the researcher). However, the integrity of research does not end once it has been published and/or presented in the public domain. For knowledge to be trustworthy, it requires professional behaviour, transparent research processes and building relationships with the science community and research partners.

5 A research ethics framework for doctoral degree students: enhancing ethical and professional behaviour

The ethical units identified by Drolet et al [14] can be a useful guide to draft a framework for research ethics for doctoral degree engineering studies, considering the SAQA level descriptors [1] and ECSA’s identified graduate attributes [2].

Looking at Drolet et al.’s [14] ethical units from a thematic lens (see the Section on Thematic Observations) and the doctoral degree quadruplet relationship between university, supervisor, student and profession, these units can be reorganised from a relational perspective. This indicates that in each of these unique relationships, specific matters must be addressed, as these relationships are interrelated. Table 4 categorises these groupings.

Table 4. Ethics units in relational perspective.

Relationship	Characteristic of the relationship	Drolet et al.’s ethical unit [14]
University	Creates and maintains institutional frameworks (policies, enrolment regulations, supervisory standards, and support structures) that enable ethical research and learning. Ensures compliance with professional standards, especially for interdisciplinary students.	Research integrity, Conflict of interest, Respect for research participants, Understanding injustices, and Ethical distress
Supervisor	The supervisor leads the research process by transferring expert knowledge and skills to the student while assuming responsibility for the overall conduct of the study. In this role, the supervisor provides academic and ethical mentorship, supporting the student in meeting the ethical expectations outlined in professional competency outcomes. Additionally, the supervisor ensures the research is conducted responsibly, upholding research integrity and fostering the student’s professional development.	Supervision and power imbalances Ethical guidance
Student	The student conducts the research project following the approved design, protocol, and ethical clearance, demonstrating integrity throughout the research process. The student incorporates ethical	Individualism and performance

	considerations into their work and reflects on personal accountability while balancing independent inquiry with supervisory guidance.	
Profession	Sets ethical standards and expectations for practice, including accountability to clients and the public. Encourages critical engagement with social justice and professional responsibility.	Identifying injustices in service delivery and work performance

The allocation of ethical units does not mean that the other partners are excluded from contributing to or taking co-ownership of an ethical unit, but rather where the accountability for an ethical unit should be. This implies that the profession should come much closer to the research ethics training of doctoral degree students, rather than being a stakeholder with requirements only. Another implication is that the responsibilities are co-owned and are based on scholarly and professional requirements. The same can be said about power imbalances, the diversity of injustices and ethical distress. These behaviours not only deserve special attention but also cannot be regarded as the responsibility of one partner only to deal with these matters. When the SAQA learning requirements are considered, it is evident that the university has the responsibility for these learning outcomes and to ensure that the professional requirements are addressed on graduation. With this said, it does not mean that the university is the only responsible partner here.

The last two comments suggest that the university has a dual responsibility, namely, a regulatory responsibility and a professional responsibility. The first responsibility is typically reserved for matters directly related to a qualification, whilst the second responsibility is to prepare the student for the world of work. Responsibility and care can be extended to four domains for engineering ethics for the academic profession. These domains are:

- Principles, motives, and values: Although the principles of beneficence, non-maleficence, justice, and autonomy were initially designed for bioethics, they can be regarded as the basis for normative ethics and hence are relevant to engineering ethics [32]. The role of motives, power relationships, and values can be added to these principles [18].
- Workplace responsibility: Important for engineering ethics and is an ethics value chain aimed at workers, corporate social responsibility, and the environment [33].
- Relationship building: Care ethics supports relationship building between people, especially because of people’s vulnerability [18].
- Education: The question is asked if “machines” will be moral, or will they behave similarly to their “creators”? This remark raises questions about the morality of AI [34].

The comments thus far were built in a framework for training doctoral degree engineering students in ethics and professional behaviour as part of research ethics. Figure 1 presents this framework.



Fig. 1. A framework for training doctoral degree engineering students in ethics and professional behaviour.

These domains also present an engineering ethic for the academic profession, as shown in Figure 2.

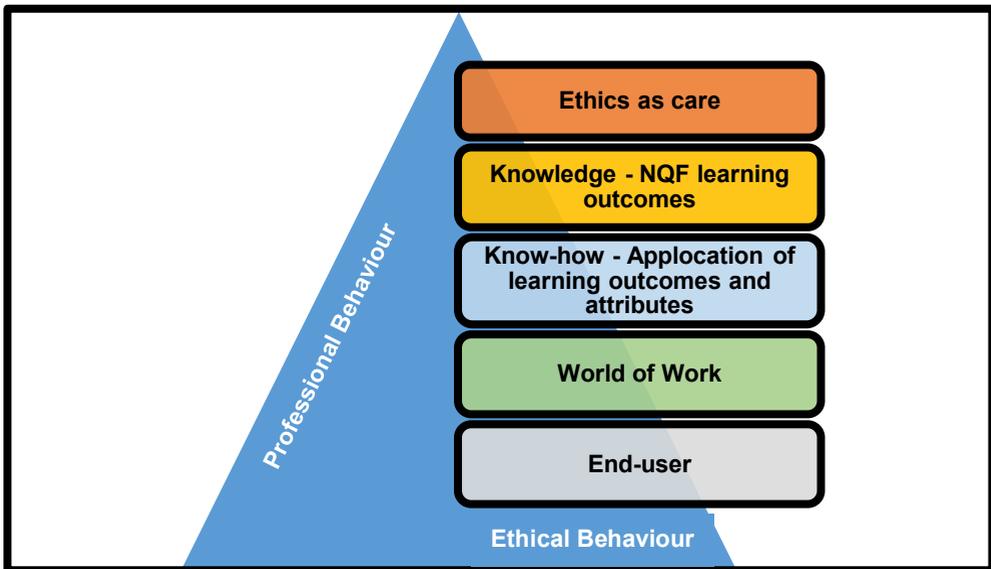


Fig. 2. Basis of engineering ethics.

Ethics as care is at the centre of engineering ethics. An ethical orientation influences knowledge and know-how (skill) as learning outcomes. Based on these learning outcomes, the doctoral degree student should be prepared for the world of work. End-users (the society) will benefit from their work. All work and applications should express professional behaviour.

6 Conclusion

This paper proposes a research ethics framework for training engineers in doctoral programmes. The framework is based on ethical and professional behaviour as fundamental learning outcomes and graduate attributes. It incorporates key ethical concerns identified by

Drolet et al. [14] along with insights and perspectives from SAQA [1] and ECSA [2,24]. The framework emphasises responsibility and care and can be applied across the four domains of the proposed framework, namely (a) Principles, motives, and values, (b) Workplace responsibility, (c) Education and (d) Relationship building.

Declaration: Grammarly was used for sentence construction and language improvement.

References

1. South African Qualifications Authority (SAQA), Level Descriptors for the South African National Qualifications Framework, Pretoria (2012). https://www.saqa.org.za/wp-content/uploads/2023/02/level_descriptors.pdf
2. Engineering Council of South Africa (ECSA), (2025). <https://www.ecsa.co.za/default.aspx>
3. Engineering Council of South Africa (ECSA), E-02-PE: Qualification standard for Bachelor of Science in Engineering / Bachelor of Engineering: NQF Level 8 (Revision 7) (2023).
4. R. King, H. Hanrahan, 25 years of the Washington Accord: Celebrating international engineering education standards and recognition 1989–2014, International Engineering Alliance (2014).
5. Council on Higher Education (CHE), National Doctoral Standards Report, Pretoria (2022). <https://www.che.ac.za/sites/default/files/inline-files/CHE%20Doctoral%20Degrees%20National%20Reporte.pdf>.
6. Future of jobs report for 2023. (2023). Available at: <https://www.weforum.org/reports/the-future-of-jobs-report-2023/digest>
7. S. Bouhouita-Guermech, P. Gogognon, J-C. Bélisle-Pipon, Specific challenges posed by artificial intelligence in research ethics. *Front. Artif. Intell.* 6:1149082. (2023). <https://doi.org/10.3389/frai.2023.1149082>
8. World Health Organization (WHO). Compendium of World Health Organization and other United Nations guidance in health and environment, 2024 update. Geneva: World Health Organization. License: CC BY-NC-SA 3.0 IGO. (2024). <https://www.who.int/publications/i/item/9789240095380>
9. V. Stern, E. Castell, The value of higher education goes far beyond a good job. *University World News*, 13 July 2024. (2024). <https://www.universityworldnews.com/post.php?story=20240709154757173>
10. J. Hecker, N. Kalpokas, Thematic Analysis Literature Review. (2025). <https://atlasti.com/guides/thematic-analysis/thematic-analysis-literature-review>
11. Degree Doctor®, Literature review (2025). <https://www.thedegreedoctor.com/blog/thematic-literature-reviews-and-chronological-literature-reviews-whats-the-different-and-which-one-should-you-choose-for-your-phd-literature-review>
12. H. Morgan, *The Qualitative Report* **27**, 64 (2022). <https://doi.org/10.46743/2160-3715/2022.5044>
13. A.J. Gwynne-Evans, M. Chetty, S. Junaid, Repositioning ethics at the heart of engineering graduate attributes. *Australas. J. Eng. Educ.* **26**, 7 (2021). <https://doi.org/10.1080/22054952.2021.1913882>
14. M.J. Drolet, E. Rose-Derouin, J.C. Leblanc, M. Ruest, B. Williams-Jones, Ethical Issues in Research: Perceptions of Researchers, Research Ethics Board Members and Research Ethics Experts. *J. Acad. Ethics* **21**, 269 (2023). <https://doi.org/10.1007/s10805-022-09455-3>

15. Republic of South Africa (RSA), Act 46 of 2000: The Engineering Profession Act (2000).
16. CIRP, CWG Ethics in Manufacturing: Survey Results, August (2024).
17. E. Han, Why are ethics important in engineering? Harvard Business School Online, 16 February 2023. (2023). <https://online.hbs.edu/blog/post/ethics-in-engineering>
18. E. Schuurman, Responsible ethics for global technology. *Axiomathes* **20**, 107 (2010). <https://doi.org/10.1007/s10516-009-9079-y>
19. C.E. Harris, M.S. Pritchard, M.J. Rabins, Engineering Ethics: Concepts and Cases, Belmont: Thomson and Wadsworth (2005). http://dx.doi.org/10.1007/978-3-319-05544-2_171-1
20. World Economic Forum, Future of Jobs Report (2023). <https://www.weforum.org/reports/the-future-of-jobs-report-2023>
21. R. Burggraef, Baarmoederlijkheid van mens en God, Halewijn (2021).
22. Republic of South Africa (RSA), Act 67 of 2008: National Qualifications Framework Act, 2008, as amended (2008).
23. Republic of South Africa (RSA), Higher Education Qualifications Sub-framework (HEQSF), Dept. of Higher Education, Gov. Gaz. No. 38116, 17 October (2014).
24. Engineering Council of South Africa (ECSA), Qualification Standard for Master of Engineering: NQF Level 9, E-22-PE Rev. 3 (2023). <https://www.ecsa.co.za/ECSADocuments/Shared%20Documents/E-22-PE%20-%20Qualification%20Standard%20for%20Master>
25. L.O.K. Lategan, A Framework for STEM Ethics Education in South Africa: Holding Values Paramount, in: E. Hildt, K. Laas, E.M. Brey, C.Z. Miller (eds.), Building Inclusive Ethical Cultures in STEM, Int. Libr. Ethics Law Technol. **42**, Springer, Cham (2023). https://doi.org/10.1007/978-3-031-51560-6_6
26. Engineering Council of South Africa (ECSA), Professional Engineer Registration. (2024). <https://www.ecsa.co.za/register/SitePages/Professional%20Engineer.aspx>
27. L.O.K. Lategan, E. Bitzer, N. Tshuma, C. Swart, 'Third space' activities and support as contributors to facilitating relationships within postgraduate supervision, 9th PGS Conf., 25–25 March (2025).
28. Singapore Statement on Research Integrity, 2010. www.singaporestatement.org
29. Academy of Science of South Africa, Council on Higher Education, Department of Higher Education and Training, Department of Science and Technology. Universities South Africa, Statement on Ethical Research and Scholarly Publishing Practices (2019). <https://www.assaf.org.za/wp-content/uploads/2014/06/Statement.pdf> (accessed 28 November 2022).
30. G.D. Miteu, Ethics in scientific research: a lens into its importance, history, and future. *Ann Med Surg (Lond)*. Mar **21**;86(5). (2024). <https://doi.org/10.1097/MS9.0000000000001959>
31. P.P. Kumavat, A study on Ethics, Integrity, and Trust in Research: An Interdisciplinary Perspective. *Research Review Journal of Indian Knowledge Systems*, **1**(1) (2024). <https://doi.org/10.31305/rrijks.2024.v1.n1.004>
32. T.L. Beauchamp, J.F. Childress, Principles of Biomedical Ethics, 7th Ed., Oxford Univ. Press (2013). <https://doi.org/10.1080/15265161.2019.1665402>
33. S. Goldman, Ethical supply chains in 2025: Definition, examples, trends. *The Future of Commerce* (2023). <https://www.the-future-of-commerce.com/2020/01/22/ethical-supply-chain-definition-stats/>
34. T. Walsh, *Machines Behaving Badly: The Morality of AI*, La Trobe Univ. Press (2020).