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Research Article

A theoretical analysis of philosophical dimensions in engineering education

Valeriia Lysak [1,*]

[1] Bohdan Khmelnytskyi National Academy of the State Border Guard Ukraine, Ukraine
* Correspondence: lera19lusak@gmail.com

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Abstract: This article presents a theoretical analysis of the philosophical dimensions embedded in engineering education, highlighting the importance of integrating ethical, social, and environmental considerations into the development of future engineers. As engineering increasingly shapes society through technological innovation, philosophical inquiry becomes crucial in addressing contemporary challenges such as sustainability, technological ethics, and social justice. The paper explores how philosophical frameworks, such as utilitarianism, deontology, and virtue ethics, provide engineers with tools to critically evaluate the broader impact of their designs and decisions. By embedding these ethical perspectives within the engineering curriculum, educators can prepare students to navigate the moral complexities inherent in technology and innovation. Moreover, the analysis underscores the role of philosophy in promoting sustainability in engineering, encouraging students to adopt a long-term view of environmental stewardship and resource management. The discussion also highlights the importance of addressing issues related to technological ethics, particularly in the development of artificial intelligence, automation, and biotechnology, where ethical challenges are becoming increasingly prominent. In addition, the paper examines the contribution of philosophy in fostering critical thinking and social responsibility, ensuring that engineers consider the societal implications of their work, especially in marginalized communities. Ultimately, this theoretical analysis argues that integrating philosophy into engineering education is essential for preparing engineers who are not only technically proficient but also ethically conscious, socially responsible, and capable of addressing the complex global challenges that define modern society.

Keywords: deontology, ethics, sustainability, innovation, social responsibility

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1. Introduction

Philosophy plays an important role in scientific and pedagogical activity by providing a foundational framework for understanding and interpreting knowledge (Hannon & Nguyen, 2022). It encourages critical thinking, fostering an analytical approach to problem-solving and inquiry that is essential in both fields (Azzaakiyyah et al., 2023; Nadurak, 2023). Philosophical inquiry prompts educators and scientists to question the underlying assumptions of their disciplines, promoting a deeper comprehension of concepts and methodologies (Leng, 2020). In education, philosophy informs pedagogical theories and practices, guiding the development of curricula that not only convey knowledge but also improve ethical reasoning and social responsibility (Alemdar & Aytaç, 2022; Syahidi et al., 2023). Moreover, it enhances the ability to communicate complex ideas effectively, bridging the gap between abstract concepts and practical applications, ultimately leading to more effective teaching and research outcomes (Musheke & Phiri, 2021).

For engineering, philosophy is integral as it provides a critical framework for examining the ethical, social, and epistemological dimensions of engineering practices and innovations (Laktionova, 2023). It encourages engineers to reflect on the implications of their designs and technologies, fostering a sense of responsibility towards societal needs and environmental sustainability (Eklund, 2024). Engaging with philosophical principles, engineers can better navigate complex dilemmas related to safety, equity, and the impact of technology on human life. Additionally, philosophy promotes critical thinking and problem-solving skills, which are

essential for addressing the multifaceted challenges faced in engineering projects (Azzaakiyyah et al., 2023; Claris & Riley, 2012). This thoughtful approach not only enhances the quality and integrity of engineering solutions but also ensures that they contribute positively to society as a whole.

The recent findings show that modern engineering education is characterized by its emphasis on interdisciplinary approaches, integrating concepts from various fields such as computer science, environmental science, and social sciences to address complex real-world challenges (Kotsis, 2024; Ming et al., 2024). This shift reflects the growing demand for engineers who can adapt to rapidly changing technologies and collaborate across disciplines. Additionally, there is a strong focus on experiential learning, where students engage in hands-on projects, internships, and collaborative problem-solving activities, enhancing their practical skills and fostering innovation (Abdul-Rahaman & Tindam, 2024). The incorporation of digital tools and technologies, such as simulation software and online learning platforms, artificial intelligence, further enriches the educational experience by providing access to diverse resources and facilitating remote collaboration (Chmyr et al., 2024; Chmyr & Bhinder, 2023). Moreover, modern engineering education prioritizes soft skills development, including communication, teamwork, and ethical reasoning, preparing students not only to design and create but also to think critically about the societal impacts of their work (Claris & Riley, 2012; Musheke & Phiri, 2021).

Obviously, the interrelation between philosophy and engineering education is vital, as philosophy provides the foundational principles that inform ethical decision-making, critical thinking, and reflective practice within the engineering field (Ferdman & Ratti, 2024). Incorporating philosophical inquiry into engineering curricula, educators encourage students to explore the moral implications of their work, fostering a sense of responsibility towards societal and environmental challenges (Ferdman & Ratti, 2024; Martin et al., 2021). This philosophical lens helps future engineers to critically assess the impact of technology on human life and to engage with complex ethical dilemmas, such as sustainability, equity, and safety (Chmyr et al., 2024). Moreover, philosophy promotes analytical skills that enhance problem-solving capabilities, enabling students to approach engineering challenges with a deeper understanding of the societal contexts in which they operate (Heywood, 2022). Ultimately, the integration of philosophy into engineering education cultivates well-rounded professionals who are not only technically proficient but also socially conscious and capable of contributing positively to the world.

The research problem concerning the interrelation between philosophy and engineering education is highly topical, particularly in the context of today's rapidly evolving technological landscape and the pressing global challenges such as climate change, inequality, and ethical governance of artificial intelligence (Chmyr & Bhinder, 2023; Claris & Riley, 2012; Musheke & Phiri, 2021). As engineers are increasingly tasked with designing solutions that significantly impact society and the environment, understanding the philosophical underpinnings of their work becomes essential for responsible innovation. This intersection encourages the development of critical thinking, ethical reasoning, and a holistic perspective, equipping future engineers to navigate complex moral dilemmas and make informed decisions (Ferdman & Ratti, 2024). Furthermore, the rise of interdisciplinary approaches in education underscores the necessity of integrating philosophical inquiry into engineering curricula, fostering a new generation of engineers who can engage thoughtfully with the societal implications of their designs (Kotsis, 2024). Consequently, this research problem not only addresses a gap in educational discourse but also contributes to the formation of ethically conscious engineers who are better prepared to meet the challenges of the XXIst century (Heywood, 2022).

Therefore, the research aim is to analyze philosophical dimensions in engineering education at the modern stage of development of society.

The research is to answer the following questions:

(1) What specific philosophical theories and principles are most relevant to shaping ethical decision-making in engineering education, and how are they currently integrated into curricula?

(2) In what ways do philosophical dimensions enhance students' critical thinking and problem-solving abilities within the context of engineering education?

(3) How can a deeper understanding of philosophical dimensions in engineering education contribute to addressing contemporary societal challenges, such as sustainability and technological ethics?

(4) How can the integration of philosophical frameworks in military engineering education during the war in Ukraine enhance professional competence among future military

engineers faced with complex operational challenges?

2. Materials and Methods

The research design for the article is grounded in a qualitative approach, emphasizing the exploration and interpretation of philosophical theories and their relevance to engineering education (Dhobi, 2023; Gabay et al., 2023; Matta, 2021). This design allows for a comprehensive examination of how various philosophical frameworks can inform the ethical and practical dimensions of engineering practice. Employing qualitative methods, the research seeks to gather rich, detailed insights from existing literature, theoretical texts, and case studies that highlight the interplay between philosophical principles and engineering education.

A qualitative approach to studying the interrelation between philosophy and engineering education is rooted in understanding the complexities and nuances of human experience, perception, and social interaction. This method emphasizes exploration and interpretation over quantification, allowing researchers to delve deeply into how philosophical principles influence engineering education and practice. Theoretical foundations of this approach are drawn from various qualitative research traditions, such as phenomenology (Alhazmi & Kaufmann, 2022; Neubauer et al., 2019), grounded theory (Zhuang & Song, 2019), and constructivism (Burns et al., 2022; Matta, 2021), which prioritize the subjective experiences of individuals and the contexts in which they operate.

Phenomenology, for instance, focuses on the lived experiences of students and educators, examining how philosophical ideas shape their understanding of ethical decision-making and critical thinking in engineering. By conducting interviews or focus groups, researchers can gather rich narratives that illuminate how individuals interpret and apply philosophical concepts in their educational journey. Grounded theory, on the other hand, seeks to develop theories based on data collected from participants, allowing researchers to construct a framework that explains the dynamic relationship between philosophy and engineering education. This iterative process of data collection and analysis fosters a deeper understanding of how philosophical dimensions inform curriculum design, pedagogical approaches, and students' professional development.

Constructivism, as a theoretical underpinning, posits that knowledge is socially constructed through interactions and experiences. This perspective is particularly relevant when exploring the interrelation between philosophy and engineering education, as it highlights the collaborative nature of learning and the importance of context in shaping educational outcomes. By employing qualitative methods, researchers can examine how philosophical discourse within engineering education evolves through dialogue among students, faculty, and industry practitioners. This holistic view not only provides insights into the impact of philosophical inquiry on engineering practices but also emphasizes the need for interdisciplinary approaches to foster well-rounded, ethically conscious engineers who can navigate the complexities of their field in a socially responsible manner.

The methodology involves a literature review to identify key philosophical theories pertinent to engineering education (Gabay et al., 2023). This includes analyzing the contributions of major philosophical schools, such as ethics, epistemology, and metaphysics, and their implications for engineering practice. The research will draw upon interdisciplinary sources, incorporating insights from philosophy, engineering ethics, and education theory to develop a robust theoretical framework (Dhobi, 2023). Through this literature review, the article aims to elucidate the philosophical dimensions that influence ethical decision-making, critical thinking, and problem-solving skills among engineering students (Matta, 2021).

A literature review is a structured and comprehensive method for identifying, evaluating, and synthesizing existing research on a specific topic, making it an effective approach for studying the interrelation between philosophy and engineering education. This method involves a clear, replicable process that minimizes bias and ensures that the review is thorough and methodologically sound. Adhering to predefined protocols, researchers can systematically gather relevant literature, assess its quality, and extract insights that contribute to the understanding of how philosophical principles influence engineering education.

The first step in conducting a literature review is to formulate specific research questions that guide the review process. For instance, questions could include how philosophical theories inform ethical decision-making in engineering or what role philosophy plays in developing critical thinking skills among engineering students. After defining the research questions, researchers develop a comprehensive search strategy, identifying relevant databases, keywords, and inclusion/exclusion criteria. This step is crucial for ensuring that

the review captures a wide range of literature, including academic journal articles, books, conference proceedings, and relevant grey literature that may provide insights into the topic.

Once the search strategy is implemented, the next phase involves screening the identified literature for relevance and quality. This typically includes reviewing abstracts, applying inclusion/exclusion criteria, and assessing the methodological rigor of the studies. After selecting the relevant studies, researchers systematically extract data and synthesize findings to identify themes, patterns, and gaps in the literature. This synthesis helps articulate how philosophical dimensions are integrated into engineering education, revealing insights into best practices, pedagogical approaches, and the impact of philosophy on ethical reasoning and professional development. By presenting a coherent narrative of the findings, the systematic literature review not only contributes to the academic discourse on the interrelation between philosophy and engineering education but also offers practical recommendations for educators and policymakers seeking to enhance the ethical and reflective capacities of engineering students.

Data collection primarily relied on existing scholarly works, providing a foundation for theoretical analysis rather than empirical data collection. This approach facilitates a nuanced understanding of how philosophical concepts can be operationalized within engineering curricula. The findings will be synthesized to highlight best practices for integrating philosophical dimensions into engineering education, ultimately proposing recommendations for educators and policymakers. By focusing on the theoretical analysis of philosophy's role in shaping engineering education, the research aspires to contribute to the broader discourse on fostering ethical, responsible engineers capable of addressing contemporary challenges.

When studying the interrelation between philosophy and engineering education, several data analysis methods can be employed to extract meaningful insights from both qualitative and quantitative data. Thematic analysis is particularly useful for analyzing qualitative data from interviews or focus groups, as it involves identifying and reporting patterns (themes) that reflect participants' experiences with philosophical concepts in engineering contexts. Content analysis can systematically categorize and quantify themes from written materials such as academic literature and course syllabi, providing insights into the prominence of philosophical ideas within engineering education. Employing these methods, researchers can gain a comprehensive understanding of how philosophy shapes ethical reasoning, critical thinking, and the overall educational experience of engineering students.

3. Results and Discussion

RQ1: What specific philosophical theories and principles are most relevant to shaping ethical decision-making in engineering education, and how are they currently integrated into curricula?

The analysis of scientific sources demonstrated that several specific philosophical theories can significantly shape engineering education by informing ethical decision-making, critical thinking, and problem-solving approaches (figure 1) (Heywood, 2022; Laktionova, 2023). Utilitarianism, for example, emphasizes the consequences of actions and decisions, advocating for choices that maximize overall happiness and minimize harm (Mitcham, 2009). This theory can guide engineering students in evaluating the potential impacts of their designs and innovations on society and the environment (Bouville, 2008). Incorporating utilitarian principles into the curriculum, educators can encourage students to consider the broader implications of their work, fostering a sense of social responsibility and ethical awareness. Furthermore, deontological ethics, which focuses on adherence to rules and duties, can also play a crucial role in engineering education by instilling a commitment to professional standards, safety regulations, and ethical guidelines (Ferdman & Ratti, 2024). Teaching students to uphold these principles prepares them to navigate complex ethical dilemmas in their future careers.

Another relevant philosophical theory is constructivism, which posits that knowledge is actively constructed through experiences and interactions rather than passively absorbed (Burns et al., 2022; Matta, 2021). This perspective can influence engineering education by promoting hands-on learning, collaborative projects, and experiential activities that encourage students to engage with real-world challenges. Applying constructivist principles, educators can create learning environments that foster critical thinking and problem-solving skills, enabling students to develop their understanding of complex engineering concepts. Philosophical hermeneutics, which focuses on interpretation and understanding, can enhance engineering education by encouraging students to engage deeply with philosophical texts and theories, fostering a critical examination of the underlying assumptions and values within

engineering practices (Hovey et al., 2022). When these diverse philosophical theories are integrated into engineering education, educators can cultivate well-rounded professionals who are not only technically skilled but also ethically informed and socially conscious.

A fifth specific philosophical theory that can shape engineering education is virtue ethics (Frigo et al., 2021). This theory emphasizes the importance of character and the development of moral virtues in individuals, focusing on what it means to be a good person rather than merely following rules or assessing outcomes (Ferdman & Ratti, 2024). In the context of engineering education, virtue ethics encourages students to cultivate personal qualities such as integrity, responsibility, and empathy. Fostering these virtues, educators can help future engineers understand the ethical implications of their work and the importance of making decisions that reflect their character and commitment to the greater good.

Integrating virtue ethics into engineering curricula can also promote discussions around professional conduct and the responsibilities engineers have towards society, the environment, and their colleagues (Martin et al., 2021). This approach not only emphasizes the significance of ethical behavior but also encourages students to reflect on their values and how those values influence their actions and decisions in their professional lives. By nurturing a sense of moral character, virtue ethics contributes to developing engineers who are not only competent in their technical skills but also committed to ethical practices that positively impact society (Ferdman & Ratti, 2024).

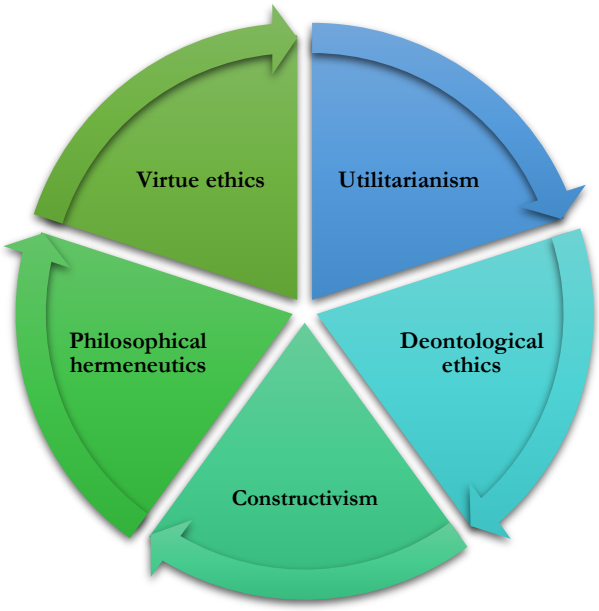

Figure 1. Philosophical theories affecting engineering education.

Further, to answer the research question, it is necessary to analyze the principles that are most relevant to shaping engineering education and significantly affect the decision-making of future engineers (figure 2). Firstly, the recent findings specify ethical decision-making (Heywood, 2022). This principle emphasizes the importance of making choices that align with ethical standards and values. Engineering education can integrate frameworks such as utilitarianism and deontological ethics to help students analyze the consequences of their decisions and understand their professional responsibilities. Secondly, sustainability is a significant principle affecting engineering education (Bano et al., 2024). It was found that emphasizing sustainable practices is crucial in engineering education. This principle encourages future engineers to consider environmental, social, and economic impacts when designing solutions, ensuring that their work contributes to the long-term well-being of society and the planet.

Thirdly, it is worth mentioning social responsibility (Børsen et al., 2020). This principle underscores the obligation of engineers to serve the public good. By instilling a sense of social responsibility, engineering education prepares students to consider the broader implications of their work, particularly regarding safety, equity, and access to technology. Fourthly, the scholars distinguish collaboration and interdisciplinary thinking (Ming et al., 2024). Engineering challenges often require interdisciplinary solutions (Kotsis, 2024). Teaching the value of collaboration across disciplines fosters critical thinking and innovative problem-

solving, equipping future engineers with the skills to work effectively in diverse teams and consider multiple perspectives. Fifthly, we found that continuous learning and adaptability affect engineering education significantly (Kobernyk et al., 2022). The rapid advancement of technology necessitates a commitment to lifelong learning. Engineering education should instill the principle of adaptability, preparing students to embrace new knowledge and skills throughout their careers in a constantly changing landscape.

Sixthly, the findings stress on the importance of integrity and professionalism (Heywood, 2022; Kobernyk et al., 2022). Upholding high standards of integrity and professionalism is essential in engineering. This principle reinforces the importance of honesty, accountability, and ethical behavior, shaping the character of future engineers and influencing their decisions in complex situations. And seventhly, critical thinking and problem-solving are named as integral principles affecting engineering education (Azzaakiyyah et al., 2023; Nadurak, 2023). They encourage students to analyze situations rigorously, question assumptions, and develop innovative solutions. Integrating critical thinking into engineering education fosters a mindset that enables future engineers to approach challenges systematically and creatively. Incorporating these principles into engineering curricula, educators can shape the decision-making processes of future engineers, preparing them to tackle complex challenges ethically and responsibly while contributing positively to society.

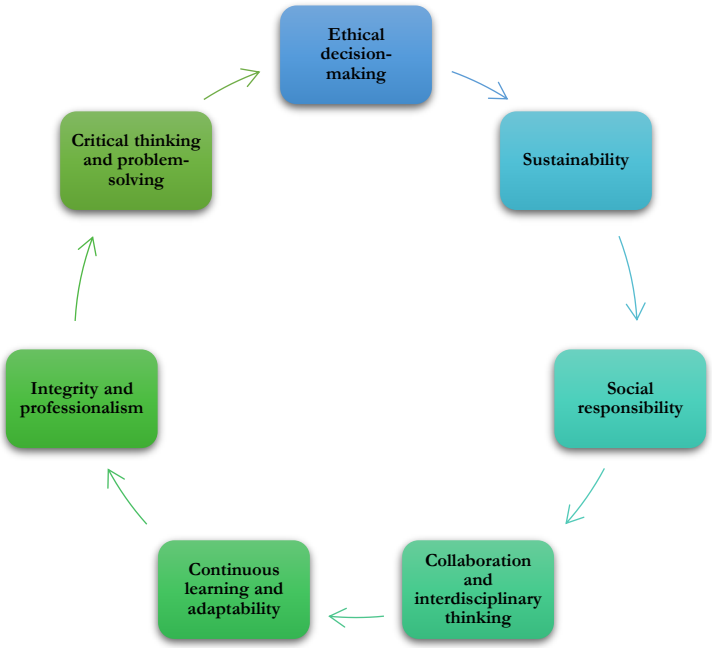

Figure 2. The principles shaping modern engineering education

The findings demonstrated that some philosophical theories and principles, such as utilitarianism and deontological ethics, have a profound impact on engineering curricula by shaping how future engineers approach ethical decision-making (Bouville, 2008). Courses that incorporate these principles focus on teaching students to evaluate the societal and environmental consequences of their actions, ensuring that designs and innovations align with the greater good. Through case studies, ethics courses, and discussions on professional responsibility, engineering students learn to balance utility (maximizing benefits while minimizing harm) with adherence to professional codes and safety regulations (Børsen et al., 2020). This training prepares them to navigate complex, real-world dilemmas and make decisions that prioritize public safety and social welfare.

Sustainability is also increasingly integrated into engineering curricula, reflecting the growing importance of addressing global challenges such as climate change and resource depletion (Narong & Hallinger, 2024). Emphasizing sustainability, educators encourage future engineers to design systems, processes, and products with long-term environmental impact in mind. Sustainability-focused courses often teach life cycle analysis, sustainable materials, and energy-efficient technologies, equipping students with the skills to develop solutions that are not only technically sound but also environmentally responsible (Tell & Hoveskog, 2022). This prepares engineers to contribute to creating a more sustainable future, aligning their work with the values of environmental stewardship and social equity.

Furthermore, principles like collaboration, social responsibility, and critical thinking are

essential in shaping the structure of engineering curricula (Van den Beemt et al., 2020). Engineering education increasingly involves interdisciplinary projects that require teamwork and problem-solving across various fields, encouraging students to integrate multiple perspectives when approaching a challenge. Emphasizing social responsibility ensures that engineers are conscious of their role in society and are equipped to address issues such as inequality, accessibility, and public health. Critical thinking is fostered through project-based learning and experiential education, helping students develop the analytical skills necessary to question assumptions, devise innovative solutions, and adapt to emerging technologies. Integrating these philosophical principles, curricula not only prepare future engineers to excel technically but also to be ethical, responsible, and forward-thinking professionals.

RQ2: In what ways do philosophical dimensions enhance students' critical thinking and problem-solving abilities within the context of engineering education?

Obviously, philosophical dimensions enhance students' critical thinking and problem-solving abilities in engineering education, fostering a deeper, more holistic approach to challenges they may face in their careers (Azzaakiyyah et al., 2023). It was found that philosophical frameworks such as utilitarianism and deontological ethics push students to reflect on the ethical dimensions of their decisions (Mitcham, 2009). By grappling with ethical dilemmas, students are encouraged to think beyond technical solutions and consider the broader consequences of their designs and actions. This process of ethical reflection cultivates critical thinking, as students must weigh competing values, assess risks, and make judgments based on incomplete information – skills crucial for problem-solving in complex, real-world engineering scenarios (Abdul-Rahaman & Tindam, 2024).

Besides, philosophy encourages students to approach problems from a holistic perspective, connecting technical aspects with social, environmental, and ethical dimensions (Ming et al., 2024). Theories such as constructivism and philosophical hermeneutics emphasize understanding problems in their broader context, encouraging students to think about how their solutions impact different stakeholders (Burns et al., 2022). This interdisciplinary thinking helps students develop comprehensive solutions that consider all variables, thus improving their problem-solving abilities by not only focusing on immediate technical fixes but also on long-term, sustainable outcomes.

Also, philosophy often requires students to challenge assumptions and question the status quo, which directly translates into critical thinking (Hovey et al., 2022). For example, engaging with philosophical hermeneutics or critical theory can prompt students to interrogate underlying assumptions in engineering practices, opening them up to alternative approaches. This mindset encourages creative problem-solving, as students are more likely to consider unconventional solutions and innovative ideas when they move beyond traditional ways of thinking. Integrating philosophical inquiry, engineering education nurtures a deeper level of analytical reasoning and adaptability, essential for tackling future technological and societal challenges (Brink et al., 2024; Purzer et al., 2022).

Incorporating these philosophical dimensions into engineering education equips students with the ability to think critically and solve problems in a more reflective, ethical, and creative manner, ultimately making them more capable and responsible engineers. Further, considering the recent findings (Heywood, 2022; Sánchez-Carracedo & López, 2020), we will analyze practical examples of how philosophical dimensions enhance students' critical thinking and problem-solving abilities within the context of engineering education (Table 1).

Table 1. The impact of philosophical dimensions on students' critical thinking and problem-solving abilities

Example of impact of philosophy	Explanation how philosophy enhances students' critical thinking and problem-solving abilities
Ethical case studies	encouraging students to think critically about the consequences of design decisions; considering multiple factors – technical, ethical, and social – when analyzing errors.
Sustainability projects	students are tasked with developing a product or system that minimizes environmental impact; engaging students balancing short-term goals with long-term consequences.
Ethics in design courses	courses must focus on deontological ethics; students are to design a technology while adhering strictly to

	safety regulations; students must critically evaluate the efficiency of projects and ethical responsibility
Interdisciplinary projects	students learn to appreciate systems thinking; students consider social, environmental, and political factors in addition to the technical design.
Philosophical debates on technology	students engage in debates about the ethical implications of emerging technologies; they articulate and defend their viewpoints, fostering critical thinking about the broader impacts of their field.
Critical analysis of assumptions	students develop a deeper understanding of their limitations, which leads to more innovative problem-solving approaches.
Virtue ethics in engineering leadership	students reflect on the moral qualities; they practice their decision-making and leadership skills through ethical reflection.
Simulation-based ethics training	students must weigh the benefits and harms to different groups, sharpening their problem-solving.
Design thinking with philosophical inquiry	students are encouraged to construct their own understanding of a design challenge; they to integrate feedback, reflect on their assumptions, and iterate their designs, enhancing critical thinking.
Philosophical inquiry in technology impact assessments	students are asked to assess the social and environmental impacts of an engineering technology through a philosophical lens; they enhance critical thinking by challenging to see beyond the technical aspects.
Problem-based learning with ethical dimensions	students work on open-ended problems; they must consider ethical and philosophical questions alongside technical challenges, enhancing their ability to think critically and devise comprehensive solutions.
Hermeneutics in engineering	students learn to interpret complex engineering problems in context.

These practical examples show how integrating philosophical dimensions into engineering education strengthens students' ability to think critically and solve problems in creative, ethical, and socially responsible ways.

RQ3: How can a deeper understanding of philosophical dimensions in engineering education contribute to addressing contemporary societal challenges, such as sustainability and technological ethics?

Philosophy's contribution to engineering education is increasingly significant as engineers confront complex societal challenges like sustainability and technological ethics (Dhobi, 2023). Traditionally, engineering has focused on technical expertise, but the growing importance of global issues – such as environmental degradation, resource scarcity, and ethical dilemmas surrounding emerging technologies – demands a broader, more reflective approach. Integrating philosophical principles, engineering education encourages students to think critically about the consequences of their work on society, the environment, and future generations (Azzaakiyyah et al., 2023; Claris & Riley, 2012).

One of the most critical areas where philosophy contributes is in promoting sustainability (Eklund, 2024). Engineers are central to designing systems and technologies that shape how society uses resources. Philosophical inquiry encourages engineers to think beyond short-term solutions and consider long-term environmental impacts. Sustainability, as a guiding principle, aligns with the philosophical concept of stewardship, where individuals and societies bear responsibility for maintaining the planet for future generations (d'Escoffier et al., 2024). This perspective challenges engineers to develop technologies that minimize resource depletion, reduce pollution, and promote energy efficiency. Incorporating sustainability into the engineering curriculum, students learn to balance technological innovation with environmental preservation.

Philosophy also addresses the ethical responsibilities of engineers through technological ethics (Martin et al., 2021). As engineers design new technologies, they must consider not only their technical feasibility but also the social, ethical, and moral consequences. For

instance, in the realm of artificial intelligence and automation, engineers must weigh the benefits of innovation against potential risks such as privacy violations, job displacement, and biased decision-making algorithms. Philosophical frameworks, such as utilitarianism and deontology, equip engineers with tools to evaluate the moral trade-offs involved in technological development, fostering a sense of accountability and ethical decision-making (Mitcham, 2009).

Moreover, philosophy provides a foundation for thinking about the role of social justice and equity in engineering (Alemdar & Aytaç, 2022). Engineering projects often have far-reaching effects on different communities, and not all groups are equally impacted. Philosophical discussions about justice encourage engineers to consider how their work affects marginalized or vulnerable populations (Syahidi et al., 2023). This is especially important in contexts like urban development, infrastructure design, and public health, where technological choices can either mitigate or exacerbate existing inequalities. Engineers educated in philosophical ethics are more likely to advocate for inclusive designs that benefit a wider range of people, promoting fairness in the distribution of technological benefits and burdens.

Finally, philosophy fosters critical thinking and the ability to address uncertainty in decision-making (Heywood, 2022). In an era of rapid technological change and environmental crises, engineers need to navigate complex, unpredictable situations. Philosophy encourages open-ended questioning and reflection on the nature of knowledge, uncertainty, and risk. This intellectual rigor helps engineers approach problems holistically, considering not just the technical dimensions but also the ethical, social, and ecological implications. Integrating philosophy into engineering education, future engineers are better equipped to address the multifaceted challenges of sustainability and technological ethics in contemporary society.

During the research the special attention was paid towards philosophy's contribution to military engineering education, particularly in times of conflict, such as the ongoing war in Ukraine (Chmyr, 2022; Kuzmenko et al., 2022; Vyshnevska & Chmyr, 2022). Military engineering goes beyond the technical and tactical aspects of building fortifications, clearing obstacles, or maintaining infrastructure. Philosophical training instills a deeper understanding of the ethical, strategic, and human dimensions of warfare. Integrating philosophical principles, military engineers gain a broader perspective on their role, encouraging critical thinking about the moral implications of their actions and the long-term societal consequences of war-related engineering decisions.

One of the key areas where philosophy contributes to military engineering education is in the realm of ethical decision-making during warfare (Chmyr, 2022). In the context of war, military engineers must often make rapid, high-stakes decisions that impact both combatants and civilians. The war in Ukraine has highlighted the importance of upholding international humanitarian laws and ethical standards, even in the face of extreme challenges (Arhun et al., 2023). Philosophical ethics, particularly just war theory and discussions about the morality of war, help military engineers navigate dilemmas around the proportionality of force, the protection of non-combatants, and the ethical use of technology in warfare (Chmyr et al., 2024). These reflections ensure that military engineering solutions, such as the construction of defensive structures or the use of unmanned systems, are designed with ethical principles in mind.

Also, the findings showed that philosophy enhances the understanding of responsibility and accountability in military engineering (Kushnirenko & Gakhovich, 2023). In war, military engineers are responsible not only for accomplishing their missions but also for the broader impacts of their work on the environment and civilian populations. In Ukraine, military engineers are working in environments where civilian infrastructure, such as hospitals, schools, and energy systems, has been severely damaged. Philosophical education encourages military engineers to think about their role in reconstruction efforts and how they can contribute to rebuilding sustainable and resilient infrastructures that serve both military and civilian needs. This awareness fosters a commitment to minimizing harm and restoring essential services in post-conflict settings.

Furthermore, philosophy fosters resilience and adaptability, which are vital in the unpredictable and chaotic conditions of war, such as those faced in Ukraine (Lavrysh et al., 2022; Matviichuk et al., 2022). Military engineers must constantly adapt their strategies and technologies to rapidly changing circumstances, often with limited resources. Philosophy equips engineers with the intellectual tools to deal with uncertainty and ambiguity, encouraging flexible problem-solving approaches. Teaching future military engineers to reflect on the nature of war, human suffering, and the consequences of their actions,

philosophy cultivates a mindset that is not only technically proficient but also morally grounded and adaptable in the face of evolving challenges. This combination of technical expertise and philosophical insight is essential for addressing the complexities of military engineering during conflicts like the one in Ukraine.

Therefore, philosophy contributes to military engineering education by fostering ethical decision-making, critical thinking, and adaptability in complex war environments. It helps military engineers navigate moral dilemmas related to warfare, such as protecting civilians and adhering to international laws, while also considering the long-term societal and environmental impacts of their work. In the context of conflicts like the war in Ukraine, philosophical insights encourage military engineers to take responsibility for rebuilding sustainable infrastructures and to remain resilient in rapidly changing, high-stakes situations. This integration of ethical reflection and technical expertise enhances the effectiveness and humanity of military engineering.

5. Conclusions and Implications

This theoretical analysis has demonstrated the profound impact that philosophical dimensions can have on engineering education, particularly in addressing the ethical, social, and environmental challenges that define modern technological development. Engineering is no longer limited to the application of technical knowledge; it involves a deep engagement with societal needs and moral questions. By integrating philosophy into the engineering curriculum, educators can equip future engineers with the critical thinking skills and ethical frameworks necessary to navigate these complexities.

The analysis highlighted several key areas where philosophy enhances engineering education. First, philosophical inquiry into technological ethics ensures that engineers consider the broader societal consequences of their work, particularly in rapidly advancing fields such as artificial intelligence and biotechnology. Ethical frameworks like utilitarianism and deontology provide tools for evaluating the potential benefits and harms of technological innovations, fostering a sense of accountability in engineers as they develop new solutions.

Second, sustainability has emerged as a critical concern, and philosophy encourages engineers to take a long-term view of resource management and environmental stewardship. Engineers who are trained to reflect on the ethical implications of their designs are more likely to create technologies that contribute to sustainable development and reduce ecological degradation.

Finally, the integration of social justice into engineering education through philosophical discourse ensures that technological advancements are inclusive and equitable, addressing the needs of marginalized and vulnerable populations. By promoting a sense of social responsibility, philosophy helps engineers balance innovation with the ethical imperative to improve the quality of life for all members of society.

In conclusion, incorporating philosophical dimensions into engineering education is essential for developing engineers who are not only technically competent but also ethically aware and socially responsible. This approach will better prepare engineers to tackle the complex challenges of the XXIst century, ensuring that technological progress aligns with the broader goals of humanity.

The implications of this research on the philosophical dimensions of engineering education are significant for both curriculum development and the professional practice of engineers. Integrating philosophy into engineering programs challenges traditional technical-focused education by encouraging a more holistic approach. Educators can design courses that teach not only technical proficiency but also critical ethical thinking, sustainability principles, and social responsibility. This interdisciplinary approach equips students to navigate the complex moral and societal implications of their work, preparing them to make more informed and responsible decisions in their professional careers. As engineering increasingly impacts global issues like climate change, resource management, and the ethics of emerging technologies, these philosophical insights will become indispensable.

Furthermore, the findings suggest a shift in the expectations of professional engineers. Embedding ethical and philosophical considerations into engineering education, the profession as a whole can adopt a more reflective and socially conscious outlook. Engineers would be encouraged to move beyond merely solving technical problems to also consider the broader impact of their work on society, particularly marginalized communities and the environment. This shift may lead to increased public trust in engineering solutions, as well as more sustainable and ethically sound innovations. The integration of philosophy into

engineering education has the potential to transform not only how engineers are educated but also how they approach their roles as key contributors to solving global challenges.

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References

Abdul-Rahaman, A.-M., & Tindam, T. N. (2024). Assessing the Effectiveness of Science, Technology, Engineering, and mathematics (STEM) Education on Students' Achievement in Secondary Schools. *EIKI Journal of Effective Teaching Methods, 2*(2). https://doi.org/10.59652/jetm.v2i2.179

Alemdar, M., & Aytaç, A. (2022). The impact of teachers' educational philosophy tendencies on their curriculum autonomy. *Journal of Pedagogical Research, 6*(1), 270-284. https://doi.org/10.33902/JPR.2022.166

Alhazmi, A. A., & Kaufmann, A. (2022). Phenomenological Qualitative Methods Applied to the Analysis of Cross-Cultural Experience in Novel Educational Social Contexts. *Frontiers in psychology, 13*, 785134. https://doi.org/10.3389/fpsyg.2022.785134

Arhun, S., Trunova, I., Hnatov, A., & Hnatova, H. (2023). Innovative approaches to the education of students of technical specialties in the conditions of war in Ukraine. *Vehicle and Electronics. Innovative Technologies, 24,* 83–90. https://doi.org/10.30977/VEIT.2023.24.0.4

Azzaakiyyah, H. K., Wanof, M. I., Suherlan, S., & Fitri, W. S. (2023). Business Philosophy Education and Improving Critical Thinking Skills of Business Students. *Journal of Contemporary Administration and Management (ADMAN), 1*(1), 1–4. https://doi.org/10.61100/adman.v1i1.1

Bano, F., Alomar, M. A., Alotaibi, F. M., Serbaya, S. H., Rizwan, A., & Hasan, F. (2024). Leveraging Virtual Reality in Engineering Education to Optimize Manufacturing Sustainability in Industry 4.0. *Sustainability, 16*(18), 7927. https://doi.org/10.3390/su16187927

Børsen, T., Serreau, Y., Reifschneider, K., Baier, A., Pinkelman, R., Smetanina, T., & Zandvoort, H. (2020). Initiatives, experiences and best practices for teaching social and ecological responsibility in ethics education for science and engineering students. *European Journal of Engineering Education, 46*(2), 186–209. https://doi.org/10.1080/03043797.2019.1701632

Bouville, M. (2008). On Using Ethical Theories to Teach Engineering Ethics. *Science and Engineering Ethics, 14*, 111–120. https://doi.org/10.1007/s11948-007-9034-5

Brink, S. C., de Hei, M., Sjoer, E., Carlsson, C. J., Georgsson, F., Keller, E., … Admiraal, W. (2024). Curriculum Agility principles for transformative innovation in engineering education. *European Journal of Engineering Education*, 1–17. https://doi.org/10.1080/03043797.2024.2398165

Burns, M., Bally, J., Burles, M., Holtslander, L., & Peacock, S. (2022). Constructivist Grounded Theory or Interpretive Phenomenology? Methodological Choices Within Specific Study Contexts. *International Journal of Qualitative Methods, 21*. https://doi.org/10.1177/16094069221077758

Chmyr, V, Koriekhov, A, Psol, S, Partyka, S. (2024). Fostering digital transformations in militray engineering education: Introduction of a technology-enhanced learning environment. *Problems of Education in the 21st Century, 82*(2), 162-185. https://doi.org/10.33225/pec/24.82.162

Chmyr, V. & Bhinder, N. (2023). AI in the Higher Military Institutions: Challenges and Perspectives for Military Engineering Training. *Rupkatha Journal, 15*(4). https://doi.org/10.21659/rupkatha.v15n4.11

Chmyr, V. (2022). Ways to increase the efficiency of usage of automobiles by the organs of the State Border Guard Service of Ukraine while carrying out transportation during the Martial Law. *Collection of scientific works of the National Academy of the State Border Guard Service of Ukraine. Series: Military and Technical Sciences, 88*(3), 332-347. https://doi.org/10.32453/3.v88i3.1213

Claris, L., & Riley, D. (2012). Situation critical: critical theory and critical thinking in engineering education. *Engineering Studies, 4*(2), 101–120. https://doi.org/10.1080/19378629.2011.649920

d'Escoffier, L. N., Guerra, A., & Braga, M. (2024). Problem-Based Learning and Engineering Education for Sustainability: Where we are and where could we go?. *Journal of Problem Based Learning in Higher Education, 12*(1). https://doi.org/10.54337/ojs.jpblhe.v12i1.7799

Dhobi, S. (2023). Philosophical Approaches in Qualitative Research. *Journal of Population and Development, 4*(1), 145–154. https://doi.org/10.3126/jpd.v4i1.64248

Eklund, M. (2024). Conceptual engineering and conceptual innovation. *Inquiry*, 1–24. https://doi.org/10.1080/0020174X.2024.2384066

Ferdman, A., & Ratti, E. (2024). What Do We Teach to Engineering Students: Embedded Ethics, Morality, and Politics. *Science and Engineering Ethics, 30* (7). https://doi.org/10.1007/s11948-024-00469-1

Frigo, G., Marthaler, F., Albers, A., Ott, S., & Hillerbrand, R. (2021). Training responsible engineers. Phronesis and the role of virtues in teaching engineering ethics. *Australasian Journal of Engineering Education, 26*(1), 25–37. https://doi.org/10.1080/22054952.2021.1889086

Gabay, G., Hackett, P. M. W., & Hayre, C. (2023). Editorial: Philosophical perspectives on qualitative psychological and social science research. *Frontiers in psychology, 14*, 1237980. https://doi.org/10.3389/fpsyg.2023.1237980

Hannon, M., & Nguyen, J. (2022). Understanding philosophy. *Inquiry*, 1–37. https://doi.org/10.1080/0020174X.2022.2146186

Heywood, J. (2022). Philosophy and Engineering Education: Should Teachers Have a Philosophy of Education?. In *Philosophy and Engineering Education. Synthesis Lectures on Engineering, Science, and Technology.* Springer, Cham. https://doi.org/10.1007/978-3-031-03761-0_1

Hovey, R. B., Vigouroux, M., Noushi, N., Pavate, V., & Amja, K. (2022). Applied Philosophical Hermeneutic Research: the unmethod. *International Journal of Qualitative Methods, 21*. https://doi.org/10.1177/16094069221101237
Kobernyk, O., Yashchuk, S., Yermakova, S., Chmyr, V., Bukina, T., & Romanenko, V. (2022). The Latest Trends in The Professional Training of Masters in the Field of Engineering and Technology. *Revista Românească pentru Educație Multidimensională, 14*(1Sup1), 453-471. https://doi.org/10.18662/rrem/14.1Sup1/561
Kotsis, K. T. (2024). Teaching Physics in the Kitchen: Bridging Science Education and Everyday Life. *EIKI Journal of Effective Teaching Methods, 2*(1). https://doi.org/10.59652/jetm.v2i1.109
Kushnirenko, O., & Gakhovich, N. (2023). Strategic directions of Ukrainian engineering post-war recovery. *University Economic Bulletin, 56,* 05-15. https://doi.org/10.31470/2306-546X-2023-56-05-15
Kuzmenko, A., Matviienko, L., Kanova, L., Burenko, M., & Bukliv, R. (2022). Development of Ukrainian education and science in the context of global challenges and military aggression: results, problems, prospects. *Amazonia Investiga, 11*(58), 177–185. https://doi.org/10.34069/AI/2022.58.10.19
Laktionova, A. (2023). Philosophy of Engineering and Design Technological Actions: Rationality, Argumentation, Modelling. *Filosofiya Osvity. Philosophy of Education, 29*(1), 125–140. https://doi.org/10.31874/2309-1606-2023-29-1-7
Lavrysh, Y., Lytovchenko, I., Lukianenko, V., & Golub, T. (2022). Teaching during the wartime: Experience from Ukraine. *Educational Philosophy and Theory*, 1–8. https://doi.org/10.1080/00131857.2022.2098714
Leng L. (2020). The Role of Philosophical Inquiry in Helping Students Engage in Learning. *Frontiers in psychology, 11*, 449. https://doi.org/10.3389/fpsyg.2020.00449
Martin, D. A., Conlon, E., & Bowe, B. (2021). A Multi-level Review of Engineering Ethics Education: Towards a Socio-technical Orientation of Engineering Education for Ethics. *Science and Engineering Ethics, 27*, 60. https://doi.org/10.1007/s11948-021-00333-6
Matta, C. (2021). Philosophical Paradigms in Qualitative Research Methods Education: What is their Pedagogical Role? Scandinavian Journal of Educational Research, 66(6), 1049–1062. https://doi.org/10.1080/00313831.2021.1958372
Matviichuk, L., Ferilli, S., & Hnedko, N. (2022). Study of the Organization and Implementation of E-Learning in Wartime Inside Ukraine. *Future Internet, 14*(10), 295. https://doi.org/10.3390/fi14100295
Ming, X., van der Veen, J., & MacLeod, M. (2024). Competencies in interdisciplinary engineering education: constructing perspectives on interdisciplinarity in a Q-sort study. *European Journal of Engineering Education,* 1–22. https://doi.org/10.1080/03043797.2024.2397419
Mitcham, C. (2009). A historico-ethical perspective on engineering education: from use and convenience to policy engagement. *Engineering Studies, 1*(1), 35–53. https://doi.org/10.1080/19378620902725166
Musheke, M., & Phiri, J. (2021) The Effects of Effective Communication on Organizational Performance Based on the Systems Theory. *Open Journal of Business and Management, 9*, 659-671. https://doi.org/10.4236/ojbm.2021.92034
Nadurak, V. (2023). Critical thinking: concept and practice. Filosofiya Osvity. Philosophy of Education, 28(2), 129–147. https://doi.org/10.31874/2309-1606-2022-28-2-7
Narong, D. K., & Hallinger, P. (2024). Traversing the Evolution of Research on Engineering Education for Sustainability: A Bibliometric Review (1991–2022). *Sustainability, 16*(2), 641. https://doi.org/10.3390/su16020641
Neubauer, B. E., Witkop, C. T., & Varpio, L. (2019). How phenomenology can help us learn from the experiences of others. *Perspectives on medical education, 8*(2), 90–97. https://doi.org/10.1007/s40037-019-0509-2
Purzer, Ş., Quintana-Cifuentes, J., & Menekse, M. (2022). The honeycomb of engineering framework: Philosophy of engineering guiding precollege engineering education. *Journal of Engineering Education, 111*(1), 19–39. https://doi.org/10.1002/jee.20441
Sánchez-Carracedo, F., & López, D. (2020). Innovation in Engineering Education for Sustainable Development – Introduction to a Special Issue. *Sustainability, 12*(19), 8132. https://doi.org/10.3390/su12198132
Syahidi, K., Sarjan, M., Rokhmat, J., Syahrial, A., Mertha, I. G., Arizona, K., Syamsuddin, S., & Sucilestari, R. (2023). Educational Philosophy and Its Relationship to Development Curriculum 2013. *Lambda : Jurnal Pendidikan MIPA dan Aplikasinya, 3*(1), 1-12. https://doi.org/10.58218/lambda.v3i1.514
Tell, J., & Hoveskog, M. (2022). Applied engineering education for soft skills in the context of sustainability and mobility. *International Journal of Sustainability in Higher Education, 23*(8), 324-336. https://doi.org/10.1108/IJSHE-07-2022-0202
Van den Beemt, A., MacLeod, M., Van der Veen, J., Van de Ven, A., van Baalen, S., Klaassen, R., & Boon, M. (2020). Interdisciplinary engineering education: A review of vision, teaching, and support. *Global Journal of Engineering Education, 109*(3), 508-555. https://doi.org/10.1002/jee.20347
Vyshnevska, N., & Chmyr, V. (2022). Formation of the professional competence of future border officers of the engineering and technical subdivisions of the State Border Guard Service of Ukraine. *Science and Technology Today, 12*(12), 118-127. https://doi.org/10.52058/2786-6025-2022-12(12)-118-127
Zhuang, Y., & Song, Z. (2019). A Systematic Review of Grounded Theory Methodology: Re-Grounding in Weber. *Journal of Applied Business and Economics, 21*(9). https://doi.org/10.33423/jabe.v21i9.2689