STUDIES IN LOGIC, GRAMMAR
AND RHETORIC 69 (82) 2024
DOI: 10.2478/slgr-2024-0021

Paweł Polak
The Pontifical University of John Paul II in Kraków
Kraków, Poland
e-mail: pawel.polak@upjp2.edu.pl
ORCID: 0000-0003-1078-469X

PREPARING FOR THE PHILOSOPHICAL CHALLENGES OF DIGITAL TECHNOSCIENCE: "PHILOSOPHY IN TECHNOLOGY" FOR MODERN ENGINEERING TEACHING

Abstract. The article presents philosophical challenges to the development of modern technoscience in the context of engineering education. We use the term technoscience because modern technology not only makes extensive use of the results of science, but also applies elements of scientific methodology. We find many philosophical issues in technology, but their influence is particularly evident in modern technoscience. Hence the question of how to prepare engineers for the rapid development of technoscience and the growing role of philosophy. To this end, it was proposed to introduce philosophy as one of the pillars of engineering education and to base philosophical education on the concept of "philosophy in technology". Why this concept is extremely useful for engineers is justified, allowing them to be well prepared for the uncertainties associated with the development of technoscience and to stimulate innovation. Concrete proposals for such a curriculum are also indicated.

Keywords: Engineering education, philosophy education, uncertainty, innovation, computer science.

Introduction

Technology has always had a particularly powerful impact on society, with it even affecting the way we think (e.g., Bolter, 1984). While any new technology has always changed the way that societies function, the transformation that is currently underway is unique in many ways, such that it is sometimes referred to as the Fourth Industrial Revolution (Schwab, 2017; Schwab & Davis, 2018) or even Industry 5.0 (Gürdür Broo et al., 2022).[1] New digital technologies not only pose various philosophical challenges – they are also driving an evolution in the concept of engineering. Indeed, they are blurring the traditional disciplinary boundaries, especially between engineering and the humanities and social sciences.[2] Consequently, the question of how to prepare for the momentous changes in technology and engineering has become one of great importance.

In this paper we seek to analyze the question of whether and how philosophy should be involved in shaping future technological development.[3] This question is discussed using the example of digital technologies, and key ideas are presented as to how the teaching of philosophy at technical universities could provide opportunities for ensuring appropriate technological development.

Literacy could be used as a way to prepare for new technologies and the need for a transdisciplinary, integrative perspective, and three forms of literacy are mentioned: data literacy, technological literacy, and human literacy (Aoun, 2017; Gürdür Broo, 2022).[4] One characteristic of new digital technologies relates to how they introduce into engineering some questions that go beyond our previous understanding of technical issues (Polak, 2023). Moreover, in modern technologies we can directly find philosophical issues, such as epistemic filters (i.e., provoking epistemological harm), artificial entities, new forms of human relations, ethical or social machines, and so on (Cervantes et al., 2019; Kroes & Verbeek, 2014; Misselhorn, 2022).

The philosophical issues in technology that are listed above are perhaps some of the more commonly cited examples of how humanities' concepts affect new technologies today. Indeed, the relationships between philosophy and technology have already been analyzed (e.g., Poel & Goldberg, 2010), and the need for philosophy has often been raised (e.g., Bowers, 2023; D'Alessandro, 2021; Pirtle et al., 2021; Grimson, 2007; Mitcham, 1998). What is important to us in this article, however, is how it is becoming increasingly clear that the concept of engineering has expanded considerably to include issues that are typically associated with the humanities, especially philosophy. This then raises a question about how to educate engineers in a way that will prepare them for the ever-expanding concept of engineering and the unknown challenges that lie ahead. While this discussion has already begun (e.g., part II of Christensen et al., 2012), this paper aims to contribute to it from a specific philosophical perspective.

We recall here the concept of *technoscience*.[5] We do this to show that modern technology is not only closely related to science, with it being based on scientific results – it also adopts many aspects of scientific methodology (e.g., Boon, 2021). With science bringing benefits to technology, it becomes apparent that this modern view of technology and engineering must be reconciled with human values, otherwise technology could become one of the greatest existential threats to societies and even civilization as a whole. This has been a classic problem in the philosophy of technology. Once we discovered that modern technology directly applies philosophical concepts in an uncritical and simplified way, we recognized a new kind of technological threat. In this paper we draw inspiration from Stanisław Lem's visionary approach to technology development (Polak & Krzanowski, 2022). He showed how bad philosophy could affect engineering, with philosophy being the best way to prepare for an unknown technological future.

The novelty of our approach lies in providing a clear conceptual framework for the relationships between philosophy and technology, and profiting from experiences with a similar, fruitful program named "Philosophy in Science" that was pioneered by M. Heller (Heller, 2019; Polak, 2019). By adopting Heller's concepts, we propose a philosophical program named "Philosophy in Technology" (Polak, 2023) to better understand technologies, especially digital ones. This approach was formulated to understand the role of philosophy in technology and rationally shape it for fruitful long-term development.

We begin this article by pointing out the novelty of modern engineering problems in digital technologies. We do this by comparing classical electrical engineering with modern digital engineering problems, and then we take a closer look at the presence of philosophy in modern engineering in order to better understand the contemporary challenges. We then show how philosophy in engineering could serve to prepare for these challenges. Finally, we present a proposed philosophy program to prepare engineers at technical universities for the philosophical challenges of modern engineering.

Classical engineering problems vs. modern ones

The above-mentioned incorporation of classical humanistic issues into the field of technology has led to a broadening of technology and engineering concepts, and this should be taken into account when preparing for the challenges of developing modern technology. In order to highlight the characteristics of the transformations taking place, we briefly compare the typical features of engineering issues in classical technology with those of contemporary technologies. This overview is of course sketchy and far from exhaustive, but the aim here is to simply demonstrate how the role of the humanities, especially philosophy, has changed in relation to technology and engineering.

Let us very briefly compare two example systems: First, take the design of an electronic tube amplifier as a classic engineering example. Such devices were developed more than a century ago, so they can certainly be considered classic from today's point of view. As a modern technology example, we use social robots as a good example of something that presents emerging engineering challenges. Of course, such a comparison seems so far apart that it seems like we are comparing incommensurable things.[6] Nevertheless, note that in both cases we are referring to concepts from engineering, so these very different sorts of technologies are within the same field. This example shows that classical engineering was able only to develop artifacts like an amplifier (e.g. one modality, one-function), while modern engineering develops multi-functional, multi-modal artifacts (e.g. a social robot).[7] More specifically, the comparison is intended to highlight the qualitative differences between electronic engineering and digital engineering. I chose these two cases because modern digital systems rely on electronic circuits at a deeper layer, so a new form of activity (modern engineering) has been superimposed on classical engineering, so a modern engineer should be able to understand both when creating or analyzing a digital system.

In classical engineering, including with our amplifiers, we encounter problems that are well defined with known constraints. They are measurable and easily described through mathematical theories. In the case of tube amplifiers we could cite many specific problems that should be taken into account by an engineer, such as:

– Frequency Response,
– Signal distortion,
– Output impedance,
– Output power,
– Power consumption,
– Amplifier dimensions,
– Amplifier weight,
– Accessibility of components (tubes),
– And last but not least, amplifier cost.

Each of these aspects is well defined and can be measured, and the design of an amplifier is based on circuit theory (e.g., Belevitch, 1962).

When designing a specific device, engineers need to find a balance between the defined requirements, the available parts, known circuit solutions, and so on. The existing engineering education system precisely supported this way of approaching engineering problems, and it has clearly been effective from a classical engineering perspective. Of course, there have also been problems of a more general nature that go beyond the established engineering canon, such as aesthetic issues related to the appearance of the amplifier or the subjective quality of the reproduced sound. (For a general view of such problems see, for example, the work of Schummer et al. [2009].) From the point of view of the technical design itself, however, a professional consensus has been developed based on the adopted norms and values, or such issues were successfully marginalized without major problems.

If we compare our example of a classical engineering problem with modern attempts to create social robots, we see that in addition to the requirements that are typical of classical engineering, new types of requirements are superimposed over the classical ones. Thus, while classical requirements continue to play an important role, new problems are emerging that, for the sake of brevity, we will present in the form of questions that need to be answered within engineering practice. These are:

- What is an artificial agent?
- Is every robot an artificial agent?
- What does it mean for a robot to have a social attitude?
- Is it possible to measure social/ethical attitude?
- Is it possible to appropriately describe a desired social/ethical attitude for a technical implementation?
- How do we choose an appropriate ethical system for the robot?
- Is it possible to validate the robot's ethical behavior?
- What will change in the structure of the reaction/behavior of the person who interacts with such systems?

These questions were selected due to their underlying philosophical nature, which is evident in the general tone of the questions and the direct references to some philosophical concepts. The emerging new questions could also of course touch upon psychological and sociological issues. For this paper, which is intended for a philosophical journal, we focus on philosophical questions. We also chose this perspective because AI-based technologies, such as social robotics, are based on a new kind of engineering that has philosophical issues at its core. For example, consider Alvarado's concept of AI as an epistemic technology (Alvarado, 2023).

We must note here, however, that the philosophical questions above would be relevant to any system that we label a social robot, because any specific social robot will need to be based on some resolution of similar philosophical questions. With the advent of such advanced modern technologies, the need to apply philosophy has become more obvious, yet at the same time the real philosophical roots of technology have become more obscured.

Moreover, the roles played by philosophy in modern technology go beyond just fundamental assumptions. We will discuss this matter in more detail in the following section.

Philosophy in technology: An unseen but essential presence in technology

Philosophy plays various roles in technology and engineering these days, but its presence is typically only partially seen. Research into the philosophy of engineering (Miller, 2021; Miller et al., 2021) has revealed that philosophical traditions influence engineering from the general perspective, but we are interested here in a more detailed perspective. We want to focus on the philosophical assumptions and philosophical concepts that are directly used in engineering systems and artifacts.[8] The example of social robotics that we mentioned above exemplifies how every system involves some concrete philosophical assumptions and concepts, even if the designers are not (fully) aware of it.

Philosophy in Technology (PinT) is a research program that seeks to explore the philosophical roots of engineering and technology (Polak, 2023), although similarities, even in the name, can also be found in the works of Christensen et al. (2007) and especially that of Grimson (2007). Broadly speaking, this program seeks to reveal the philosophy that is "internal" to technology. We mentioned above that the design and use of technical artifacts is based on some, usually tacit, philosophical assumptions, so we could surmise that some philosophy is embodied in technical artifacts. Note that we should keep in mind that we are using the concept of philosophy here in a broad sense that is far removed from the typical academic discipline sense.[9]

It is convenient to familiarize ourselves with the PinT concept by considering its four main goals. First, it seeks to explore the implicit philosophical foundations of technology and engineering and the role they play in shaping technological solutions. Second, it tries to explain the ontological, metaphysical, axiological, and methodological dimensions of technology. Third, it reveals how technology development contributes to traditional philosophical problems (e.g., agency). Fourth, it clarifies the semantic gap between technical and philosophical concepts and attempts to bring them together under one perspective. The latter plays a crucial role in developing digital technologies due to the direct application of some philosophical concepts, such as for ethical machines.

This approach is not entirely new, however, because some aspects could be found in a traditional philosophy of technology. In general, though, PinT is intended to complement the existing philosophies of technology.[10] The need for such an approach is driven by the various pitfalls of digital and AI technologies (Wooldridge, 2021; Krzanowski, 2021). Indeed, the AI program has stalled due to failed philosophical ideas that were not evaluated critically enough.

Proposed curricular changes for philosophical studies at technical universities in Poland

Since there are various academic traditions, we adopt a local perspective in this section. The existing teaching model at Polish technical universities focuses only on selected aspects of new technologies, with it usually omitting most of the broader humanistic context and fundamental philosophical issues. Such a model blocks innovation at the grassroots level and misses opportunities to set new directions in technological development. As such, Polish technical thinking is essentially limited to reproducibility and imitation. This educational model also means engineers do not understand the goals of the technologies they are developing, leading to an instrumentalization of these engineers' role in the modern world.

Although the teaching of humanities, including philosophy, forms part of the curricula at technical universities, it is served as a separate appendix, so it fails to show the role that philosophy plays for engineers. Some attempts are being made to address this shortcoming, and the following reflections are based on the experience of attempting to introduce elements of PinT at the Wroclaw University of Technology. A theoretical preparation is provided by a series of *Philosophy in Technology* conferences organized by the Pontifical University of John Paul II in Kraków together with leading Polish technical universities. (In 2022 it was held together with the Warsaw University of Technology, while in 2023 it was held in coordination with the Wrocław University of Technology).

The goals of incorporating the PinT program (Polak, 2023) into the curricula of technical universities are (1) to show the concrete role that philosophy plays in modern technology; (2) to highlight the philosophical assumptions of technology; and (3) to study how certain philosophical concepts are unconsciously adapted by engineers for use in their designed technical systems. In general, the goal of this new approach to teaching philosophy at Polish Technical Universities is to encourage future engineers to be sensitive to philosophical problems related to the development of technology, so they can be more creative and avoid the philosophical pitfalls of technology.

The underlying idea is to provide the knowledge and skills needed to correctly recognize the role of philosophical assumptions in technology and show the importance of conceptual work in new technology. It acts as a means for raising engineers' awareness of the role that values play in technology (e.g., Schummer et al., 2009; van de Poel, 2009) and how such values are wider ranging than just the utilitarian ones. The proposed course does not aim to make philosophers out of engineers[11] but rather prepare them to work in inter/transdisciplinary teams and make reasonable use of philosophy. A complementary task, of course, would be to properly train philosophers with the skills needed to work fruitfully in such teams. We believe that in order to understand their role in such teams and be open to different perspectives and goals, philosophers could also benefit from research into philosophy in technology.

To prepare the engineers of the future, we should demonstrate how philosophy has contributed to the development of technology and how this development has depended on philosophical foundations. By analyzing case studies and selected classical texts, we could also build some basic philosophical skills. Since we must assume a general lack of philosophical preparation among the students and a limited number of class hours,[12] we propose that the program develop the following skills, which currently seem the most relevant for engineering digital technologies. This list should of course be the subject of interdisciplinary discussions between philosophers and the engineers developing the latest technologies. Given the dynamic development of digital engineering, it will also undoubtedly be necessary to constantly revise the list of skills and the examples used.

These are the suggested basic philosophical skills for a future engineering education:

- General cultural, sociocultural, and sociolinguistic competencies as foundations for contributing to society (e.g., Varava et al., 2021): The point here is to strengthen such competencies and highlight their importance, because it is obvious that such competencies are the result of an overall long-term educational process rather than being developed from scratch in classes.
- Critical thinking. This is typically mentioned as a fundamental skill because it forms the basis for being open to a dynamically changing reality, so it seems to be the best preparation for the unknown unknowns of technology development (Polak & Krzanowski, 2022).

- Creative thinking. This complements critical thinking and plays a crucial role in developing and constantly adapting.
- The art of argumentation. This is needed to find and communicate reasonable solutions among non-homogeneous teams with different educational and theoretical backgrounds, so it plays a crucial role in the efficiency of inter/transdisciplinary teams.
- Understanding the role of philosophical assumptions in technology. This represents a kind of sensitivity and openness to philosophical problems in technology and engineering.
- Open-mindedness. This general attitude allows engineers to understand and rationally evaluate different positions.
- Basic knowledge of scientific epistemology, such as falsification, theory-ladenness, observation, a doxastic view of knowledge, and so on. Since modern technology is closely related to science (i.e., technoscience), we need to understand the specificity of the scientific approach in order to avoid imposing simplistic, popular stereotypes on technoscience.
- Basic hermeneutic skills. These are needed to better understand others and analyze given texts.
- Basic knowledge of the ontologies involved in technoscience (e.g., a comparison of Reism with systems ontology) and the importance of systems ontology. Systems thinking has been identified as one of the basic skills for modern engineering for decades now (e.g., Konieczny, 1983; Aoun, 2017; Gürdür Broo, 2022).
- Basic knowledge about ethical issues in engineering.

The proposed method for developing the above competencies should be primarily based on case studies, with the idea being to analyze cases where the impact of philosophy on technology can be demonstrated. Part of this case analysis should be devoted to the role of philosophical assumptions (e.g., an analysis of the AI program's pitfalls) and values for technology. The second part of these case analyses should be devoted to examining the use of philosophical concepts in engineering and a basic attempt to compare it with other ways for understanding these concepts (e.g., the concept of ethics in machine ethics, concepts of ontology in computer science, epistemological concepts in AI). After analyzing the selected examples, especially if time permits, it would be worthwhile to devote part of the course to analyzing selected classical texts. In the context of computer science, Alan Turing's texts about the theory of computation and AI (Turing, 1937, 1950) may be of particular interest. It would also be worthwhile to analyze at least the introduction to Shannon's classic work and the caveats that follow it (Shannon, 1948, 1956), because this will help students to understand that Shannon's concept, while important, is not scientific dogma, and it has certain limitations that are even mentioned by the author himself. Similarly, other classic texts, or fragments of such texts, could be selected to demonstrate how the problems that engineers deal with have a much broader background and significance than is usually implied in engineering lectures.

At a later stage, of course, the course could be supplemented with a textual analysis and discussion of important theses that extend the initial field of philosophy of technology to the basic questions of philosophy of technology, such as a philosophical discussion on the nature of technology. A discussion of selected interesting theses about the relationship between technology and philosophy, such as Bolter's thesis about the impact of technology on thinking (Bolter, 1984; Polak, 2015), could also be undertaken. At a later stage, following the acquisition of basic skills, such a course could also of course greatly benefit trained engineers, but we should not start with them because they would require a solid preparation.

How to teach philosophy for engineers

The philosophical pitfalls of AI exemplify the need to better prepare engineers for future technology development. We need not only more of the so-called "soft skills"[13] but also a more transdisciplinary approach, greater creative thinking, and so on. The story of AI's development has taught us that future technology development can be unfruitful when there is bad philosophy behind it. This then begs the question of how to prepare for the unknown unknowns.[14] We will therefore try to show what we should change in philosophy education to better prepare engineers to face the sophisticated technological pitfalls.

The question of how to adjust our education system for these challenges is of special interest, with existing proposals focusing on including human factors in technical education (dos Santos et al., 2023), proposals for lifelong-learning, and a remodeling of the entire education system (Aoun, 2017), and so on.

Once we agree that we need to learn how to deal with the emerging philosophical pitfalls of technology and prevent modern technologies from drastically deforming society's humanistic dimension, we should seriously try to introduce the philosophical perspective into engineering education. Consequently, we need to fundamentally change the way that philosophy is taught in technical universities.

Nevertheless, we do not need to teach philosophy at technical universities starting with the classics from the history of philosophy, nor do we need to analyze the basic concepts. Indeed, the former is almost impossible without a proper context, something that cannot be provided within a relatively short philosophy course for engineers. Understanding such classical problems requires various philosophical skills, such as critical thinking and hermeneutics. This is obviously the wrong approach, because we need to prepare future engineers for such skills during philosophy courses. The latter approach is also inappropriate because it would be too abstract and require advanced philosophical skills. Thus, we need to rethink how to teach engineers about philosophy. Some interesting and promising attempts at the philosophy of computer science were made by Rapaport (2005), and we can benefit from his ideas while developing our view.

Philosophy for engineers should be considered in two different areas: The first important area of philosophical education for future engineers should relate to questions of practical philosophy. For example, courses in ethics are necessary to educate responsible engineers, and there are already concrete proposals in this regard as to how to adapt to the contemporary challenges (Frigo et al., 2021; Gwynne-Evans et al., 2021, see also the literature review of Lawlor, 2021). Ethical issues also play a fundamental role for technology assessment, especially in ethical technology assessment (see, e.g., Palm & Hansson 2006; Harris et al. 2011).

The second, generally neglected area of philosophical education for future engineers relates to questions about understanding the philosophical assumptions of technology, as well as the technological use of philosophical concepts. Such topics should be taught to students who have already gained adequate technical knowledge and experience, such as in their final year of study. The idea is that they should have the necessary background to understand the examples used while teaching philosophy, because moving from the known to the unknown is a classic teaching method.

In this regard, it seems that the PinT approach could be a reasonable way to include such philosophical issues in an engineering curriculum. We choose PinT because it demonstrates how classical engineering is philosophy-laden, or it at least has philosophical consequences, so it *is not philosophically neutral.* This is a crucial point when understanding the role of philosophy in technology and engineering. By discovering such aspects of philosophy in technology through case studies and discussing some classical texts, we can demonstrate the importance of the philosophical perspective for technology and engineering.

The PinT approach is also significant because by exposing and critically evaluating philosophical assumptions, we can avoid the pitfalls of technological development. Such philosophical pitfalls were first revealed on a large scale within the AI program. This example serves to show that to develop new technologies properly we need to understand the philosophy involved. We should also reject simplistic, caricatured philosophies that are embodied by engineers who are ignorant of philosophy, such as for the ethical concepts that are typically embodied in so-called ethical machines.[15] These assumptions underlie the proposed changes in philosophical curricula at technical universities.

Conclusions

In this paper we have considered the question of how to prepare for the future development of digital technoscience. We took a philosophical perspective, which while it is not the only one, it plays a key role in technological development. Technology is never philosophically neutral, because it is based on certain philosophical assumptions and has philosophical consequences. This is especially important today as we design and use increasingly complex systems. This is true not only at the level of assumptions but also at the level of directly used concepts, so these systems require more and more philosophical input.

This paper proposes that the concept of "philosophy in technology" is the most convenient perspective for describing the ways in which philosophy is "invested" in the development of contemporary digital technoscience. By analyzing selected examples of classical and modern artifacts, we can show how philosophical challenges are posed by the further development of technology. We then showed how the concept of "philosophy in technology" makes it possible to reflect on the role that philosophy plays in technology.

On this basis, the issue of formulating methods and defining philosophical content for an engineering education was addressed. Given the diverse academic traditions, proposals for a program of philosophical study for engineers, based on the given approach, were formulated within the context of the needs of Polish technical universities. Nevertheless, these solutions could easily be adapted to other conditions after appropriately diagnosing the current educational system that is to be enhanced.

We therefore proposed a set of basic philosophical skills to teach in future engineering education, namely general cultural competencies, sociocultural and sociolinguistic skills, critical thinking, creative thinking, the art of argumentation, an understanding of the role of philosophical assumptions in technology, open-mindedness, basic knowledge of scientific epistemology, basic hermeneutic skills, and a basic knowledge of the ontologies involved in technoscience. The intention here is to start a discussion among philosophers about the philosophical skills that will be needed by future engineers, as well as how they can be taught within time-limited philosophy curricula.

The considerations presented here also reveal the need to include a discussion about the role that philosophy plays in contemporary discussions of future engineering. For example, we should analyze what philosophical assumptions are involved in the three ways of thinking that were described by Gürdür Broo (2022). It is then worth discussing them critically and deciding if they also need further revision or clarification.

After all, the evolution of technology constantly presents us with new unknowns, so it requires us to constantly reassess the adequacy of our ideas and the solutions we apply. Moreover, we must be prepared for the need to constantly adapt, including in how we prepare the next generation for the evolution of technoscience and the unknown unknowns it may bring.

Acknowledgements

I would like to thank Roman Krzanowski and Łukasz Mścisławski, with whom I have repeatedly discussed concepts related to PinT. They reviewed an early draft of this article and provided many valuable comments that helped me improve the text.

I am also grateful to Maksymilian Smolnik for his comments on Konieczny's work, which I have referred to in this article, and its relevance to the present situation.

NOTES

[1] Research is already underway to determine the skills that future engineers will need. We could recall here some examples, such as Motyl et al. (2017) and Varava et al. (2021). In this article, however, we take a different starting point: we do not examine the opinions of employers, teachers or students, because while they are important, they are always based on a rather limited perspective. We instead try to diagnose the basis of the emerging problems in order to determine how to rationally address them and consciously shape the development of technology.

[2] A typical expression of such problems can be found in this excerpt from the already quoted work of Gürdür Broo et al. (2022): "The connections between different disciplines are becoming the core of the new technologies, in a not multi-, not inter-, but in a trans-disciplinary, seamless manner. At the same time, the boundaries between different disciplines (and many other things) are eroding [...]. In fact, what engineering is and what basic sciences are (even the social sciences for that matter) is nowadays difficult to define. In short, we are going through a phenomenon of convergence of different disciplines, necessitating a thorough discussion on what engineering education should be like in the future."

[3] We focus here on the influence of philosophy, since this discipline based on rational thinking has been an important factor in the transformation of civilization since Ancient Greece, and the specific role of philosophy in the positive reception and taming of new technologies has been repeatedly pointed out (see, e.g. Polak & Krzanowski, 2022).

[4] It is noteworthy that Gürdür Broo's (2022) proposals are mainly based on how to adapt ways of thinking to the requirements of new technologies. This implies that changes are needed at the general level of thinking, something that we traditionally call philosophical assumptions. Gürdür Broo's three proposed mindsets (system mindset, design mindset, futuristic mindset) reflect three different future fields of engineering with different philosophical assumptions, although he does not explicitly mention philosophy.

[5] In this paper, we use the term *technoscience* to reflect how the distinction between the classical concepts of science and technology has been blurred by the emergence of deep interdependencies between science and technology. We do not attempt to define this concept, however, due to its nebulous nature and the varying views on the matter. Hottois (2023) explained this concept along these lines: "Technoscience refers to the strong interactions in contemporary scientific research and development (R&D) between that which traditionally was separated into science (theoretical) and technology (practical), especially by philosophers. The emphasis that the term *techno(-)science* places on technology as well as the intensity of the connection between science and technology varies."

By *digital technoscience,* we refer to the area of technoscience that relates to digital technologies (i.e., technologies based on existing digital computers and computing). For the sake of brevity and due to their marginal use in contemporary technologies, we do not include here applications of broader concepts of computers and computing, such as natural computing. Their role may also of course be important in time, and they should be analyzed further. In this paper, we often use the traditional term "technology" instead of technoscience for convenience, but the reader should keep in mind that it is referring to the modern composite of science and technology. In contrast, the term "classical technologies" refers to the older technologies that were not so closely associated with science.

[6] Roman Krzanowski pointed out to me in personal communication that this comparison seems inappropriate because an "amplifier tube may be better compared to a screw or a wire rather than a complex system such as a robot, while a social robot may be better compared to something more complex, such as a factory or similar."

Roman may have been right that we are dealing with completely different levels of complexity, but the same applies to his example, where the level of complexity is also different. Indeed, if you look at various artifacts – such as a hammer, an amplifier, and a social robot – they have all been designed to serve specific functions. The comparison is therefore possible, although of course the actual function is radically different in each case. Nevertheless, we certainly should not replace a hammer with an amplifier or a social robot, or vice versa.

[7] This sentence, which accurately summarizes the difference, was formulated by the second reviewer, to whom I am very grateful for this clarification. I found that he/she expressed the problem of interest perfectly and succinctly, so I thought it best to use his/her formulation directly.

[8] For examples of how working with ideas could look, see, for example, Chapter 2 of (Aoun, 2017).

[9] The philosophy we have in mind here, however, is closely related to the entire philosophical tradition. First, like any reasonable philosophy, it is a response to general problems of a philosophical nature that arise in various areas of human activity. Second, it draws on methods and concepts developed in the philosophical tradition. Third, like any critical philosophy, it is based on critical rationalism. What distinguishes it from typical academic philosophy is that it is not based on the analysis of traditional texts, but attempts to reconstruct, explain, and critique issues that arise in engineering practice.

This understanding of philosophy should not be confused with fashionable expressions of philosophy as a set of general rules, such as 'philosophy of programming in C++' or the like.

[10] Comparing it to some well-known distinctions like Carl Mitcham's distinction between the engineering philosophy of technology and the humanistic philosophy of technology, we could say that the PinT proposal is orthogonal to them.

[11] Even more absurd would be the expectation that students of philosophy could become engineers after a short course. Of course, the personal union of philosopher and engineer is an ideal solution for overcoming specialization barriers. However, we are aware that although more and more engineers are studying philosophy in its entirety, on a larger scale it is only possible to introduce a certain compromise model, which we describe in this article.

[12] Similar assumptions for modernizing the education system for engineers were made, for example, in the work of Varava et al. (2021).

[13] In (Varava et al., 2021, p. 1), soft skills are defined as "non-technical" as opposed to (technical) hard skills. Many studies (Grimson, 2007; Mitcham, 1994, 1998; Polak, 2023) have shown that this is an oversimplification, but such concepts are still used in debates about technology education.

[14] An interesting case pointing to the effectiveness and further potential of philosophy to prepare for an unknown future; we previously analyzed the example of the fractious effectiveness of Stanislaw Lem's predictions about the future of technology (Polak & Krzanowski, 2022; Krzanowski & Polak, 2021).

[15] For example, one of the typical gross oversimplifications is to reduce ethics and ethical behavior to AI rule systems with built-in hierarchies.

BIBLIOGRAPHY

Alvarado, R. (2023). AI as an Epistemic Technology. *Science and Engineering Ethics*, *29*(5), 32. https://doi.org/10.1007/s11948-023-00451-3

Aoun, J. (2017). *Robot-proof: Higher education in the age of artificial intelligence.* The MIT Press.

Belevitch, V. (1962). Summary of the History of Circuit Theory. *Proceedings of the IRE*, *50*(5), 848–855. https://doi.org/10.1109/JRPROC.1962.288301

Bolter, J. D. (1984). *Turing's man: Western culture in the computer age.* University of North Carolina Press.

Boon, M. (2021). Scientific Methodology in the Engineering Sciences. In D. P. Michelfelder & N. Doorn (Eds.), *The Routledge Handbook of the Philosophy of Engineering* (pp. 80–94). Routledge Taylor & Francis Group.

Bowers, J. (2023, April 26). *Engineer-philosophers: Thinkers of the future and men of action.* Polytechnique Insights. https://www.polytechnique-insights.com/en/columns/society/engineer-philosophers-thinkers-of-the-future-and-men-of-action/

Cervantes, J.-A., López, S., Rodríguez, L.-F., Cervantes, S., Cervantes, F., & Ramos, F. (2019). Artificial Moral Agents: A Survey of the Current Status. *Science and Engineering Ethics.* https://doi.org/10.1007/s11948-019-00151-x

Christensen, S. H., Martin Meganck, & Delahousse, B. (Eds.). (2007). *Philosophy in engineering*. Academica.

Christensen, S. H., Mitcham, C., Li, B., & An, Y. (Eds.). (2012). *Engineering, Development and Philosophy* (Vol. 11). Springer Netherlands. https://doi.org/10.1007/978-94-007-5282-5

D'Alessandro, F. W. (2021, February 18). *Why Works of Engineering Need Philosophers*. https://www.linkedin.com/pulse/why-works-engineering-need-philosophers-francesco-w-d-alessandro

dos Santos, C. M., de Souza Assumpção, G., & de Carvalho Castro, A. (2023). Preparing Human Factors for Digital Transformation: A Framework for Innovations in Industrial Engineering Education. In J. C. Gonçalves dos Reis, F. G. Mendonça Freires, & M. Vieira Junior (Eds.), *Industrial Engineering and Operations Management* (pp. 289–301). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-47058-5_23

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

Grimson, W. (2007). Engineering – an Inherently Philosophical Enterprise. In S. H. Christensen, Martin Meganck, & B. Delahousse (Eds.), *Philosophy in engineering* (pp. 89–102). Academica.

Gürdür Broo, D. (2022). Transdisciplinarity and three mindsets for sustainability in the age of cyber-physical systems. *Journal of Industrial Information Integration*, *27*, 100290. https://doi.org/10.1016/j.jii.2021.100290

Gürdür Broo, D., Kaynak, O., & Sait, S. M. (2022). Rethinking engineering education at the age of industry 5.0. *Journal of Industrial Information Integration*, *25*, 100311. https://doi.org/10.1016/j.jii.2021.100311

Gwynne-Evans, A. J., Chetty, M., & Junaid, S. (2021). Repositioning ethics at the heart of engineering graduate attributes. *Australasian Journal of Engineering Education*, *26*(1), 7–24. https://doi.org/10.1080/22054952.2021.1913882

Harris, Ian, Richard C. Jennings, David Pullinger, Simon Rogerson, i Penny Duquenoy. (2011). Ethical Assessment of New Technologies: A Meta-methodology. *Journal of Information, Communication and Ethics in Society* 9(1), 49–64. https://doi.org/10.1108/14779961111123223

Heller, M. (2019). How is philosophy in science possible? *Philosophical Problems in Science (Zagadnienia Filozoficzne w Nauce)*, *66*, 231–249. https://zfn.edu.pl/index.php/zfn/article/view/482

Hottois, G. (2023, September 18). *Technoscience* (J. A. Lynch, Trans.). Encyclopedia of Science, Technology, and Ethics. Encyclopedia.Com. https://www.encyclopedia.com/science/encyclopedias-almanacs-transcripts-and-maps/technoscience

Konieczny, J. (1983). *Inżynieria systemów działania* (Wydanie I). Wydawnictwa Naukowo-Techniczne.

Kroes, P., & Verbeek, P.-P. (Eds.). (2014). *The Moral Status of Technical Artefacts* (Vol. 17). Springer Netherlands. https://doi.org/10.1007/978-94-007-7914-3

Krzanowski, R. (2021). The road to conscious machines: AI through failed ideas. *Philosophical Problems in Science (Zagadnienia Filozoficzne w Nauce)*, *70*, 171–181. https://zfn.edu.pl/index.php/zfn/article/view/556

Krzanowski, R., & Polak, P. (2021). The Future of AI: Stanisław Lem's Philosophical Visions for AI and Cyber-Societies in Cyberiad. *Pro-Fil*, *22*(3 (special issue)), 39–53. https://doi.org/10.5817/pf21-3-2405

Lawlor, R. (2021). Teaching engineering ethics: A dissenting voice. *Australasian Journal of Engineering Education*, *26*(1), 38–46. https://doi.org/10.1080/22054952.2021.1925404

Miller, G. (2021). Western Philosophical Approaches and Engineering. In D. P. Michelfelder & N. Doorn (Eds.), *The Routledge Handbook of the Philosophy of Engineering* (pp. 38–49). Routledge Taylor & Francis Group.

Miller, G., Wang, X. (Tom), Sethy, S. S., & Atsushi, F. (2021). Eastern Philosophical Approaches and Engineering. In D. P. Michelfelder & N. Doorn (Eds.), *The Routledge Handbook of the Philosophy of Engineering* (pp. 50–65). Routledge Taylor & Francis Group.

Misselhorn, C. (2022). Artificial Moral Agents: Conceptual Issues and Ethical Controversy. In O. Mueller, P. Kellmeyer, S. Voeneky, & W. Burgard (Eds.), *The Cambridge Handbook of Responsible Artificial Intelligence: Interdisciplinary Perspectives* (pp. 31–49). Cambridge University Press. https://doi.org/10.1017/9781009207898.005

Mitcham, C. (1994). *Thinking Through Technology The Path Between Engineering And Philosophy*. University of Chicago Press. http://archive.org/details/ThinkingThroughTechnologyThePathBetweenEngineeringAndPhilosophy

Mitcham, C. (1998). The Importance of Philosophy to Engineering. *Teorema*, *17*(3), 27–47.

Motyl, B., Baronio, G., Uberti, S., Speranza, D., & Filippi, S. (2017). How will Change the Future Engineers' Skills in the Industry 4.0 Framework? A Questionnaire Survey. *Procedia Manufacturing*, *11*, 1501–1509. https://doi.org/10.1016/j.promfg.2017.07.282

Palm, Elin, and Sven Ove Hansson. (2006). The Case for Ethical Technology Assessment (eTA). *Technological Forecasting and Social Change* 73(5), 543–58. https://doi.org/10.1016/j.techfore.2005.06.002

Pirtle, Z., Tomblin, D., & Madhavan, G. (Eds.). (2021). *Engineering and Philosophy: Reimagining Technology and Social Progress* (Vol. 37). Springer International Publishing. https://doi.org/10.1007/978-3-030-70099-7

Poel, I. van de (2009). Values in Engineering Design. In A. Meijers (Ed.), *Philosophy of Technology and Engineering Sciences* (pp. 973–1006). North-Holland. https://doi.org/10.1016/B978-0-444-51667-1.50040-9

Poel, I., & Goldberg, D. (Eds.). (2010). *Philosophy and Engineering: An Emerging Agenda* (Vol. 2). Springer Netherlands. https://doi.org/10.1007/978-90-481-2804-4

Polak, P. (2015). Sieć, software czy obliczenia naturalne? Jakie techniki definiują myślenie filozoficzne Homo informaticus? *Studia Metodologiczne*, *34*, 143–170. http://studiametodologiczne.amu.edu.pl/wp-content/uploads/2016/02/SM34-08.pdf

Polak, P. (2019). Philosophy in science: A name with a long intellectual tradition. *Philosophical Problems in Science (Zagadnienia Filozoficzne w Nauce)*, *66*, 251–270. https://zfn.edu.pl/index.php/zfn/article/view/472

Polak, P. (2023). Philosophy in Technology: A Research Program. *Philosophical Problems in Science (Zagadnienia Filozoficzne w Nauce)*, *75*, 59–81. https://doi.org/10.59203/zfn.75.682

Polak, P., & Krzanowski, R. (2022). Stanisław Lem's Visions of a Technological Future: Toward Philosophy in Technology. *Filozofia i Nauka*, *10*, 41–50. https://doi.org/10.37240/FiN.2022.10.1.6

Rapaport, W. (2005). Philosophy of Computer Science: An Introductory Course. *Teaching Philosophy*, *28*(4), 319–341.

Schummer, J., MacLennan, B., & Taylor, N. (2009). Aesthetic Values in Technology and Engineering Design. In A. Meijers (Ed.), *Philosophy of Technology and Engineering Sciences* (pp. 1031–1068). North-Holland. https://doi.org/10.1016/B978-0-444-51667-1.50042-2

Schwab, K. (2017). *The Fourth Industrial Revolution* (Illustrated edition). Currency.

Schwab, K., & Davis, N. (2018). *Shaping the future of the Fourth Industrial Revolution: A guide to building a better world* (First American edition). Currency.

Shannon, C. E. (1948). A mathematical theory of communication. *Bell System Technical Journal*, *27*(3), 379–423, 623–656. https://doi.org/10.1002/j.1538-7305.1948.tb01338.x

Shannon, C. E. (1956). The bandwagon. *IRE Transactions on Information Theory*, *2*(1), 3. https://paginas.fe.up.pt/~vinhoza/itpa/bandwagon.pdf

Turing, A. M. (1937). On Computable Numbers, with an Application to the Entscheidungsproblem. *Proceedings of the London Mathematical Society*, *42 (series 2)*(1), 230–265. https://doi.org/10.1112/plms/s2-42.1.230

Turing, A. M. (1950). Computing Machinery and Intelligence. *Mind*, *59*(236), 433–460. https://doi.org/10.1093/mind/LIX.236.433

Varava, I. P., Bohinska, A. P., Vakaliuk, T. A., & Mintii, I. S. (2021). Soft Skills in Software Engineering Technicians Education. *Journal of Physics: Conference Series*, *1946*(1), 012012. https://doi.org/10.1088/1742-6596/1946/1/012012

Wooldridge, M. (2021). *The Road to Conscious Machines: The Story of AI.* Penguin.