Sustainable Production through Advanced Manufacturing, Intelligent Automation and Work Integrated Learning, J. Andersson et al. (Eds.)

doi:10.3233/ATDE240211

Does the Improvement in AI Tools Necessitate a Different Approach to Engineering Education?

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Abstract.
The integration of artificial intelligence (AI) into the manufacturing sector introduces new challenges and demands for the engineering workforce in the evolving European economy. This paper investigates how advancements in AI tools, especially in manufacturing, necessitate a shift in engineering education to equip graduates with relevant skills and ethical understanding. While AI is not new to manufacturing, its ongoing development and increased accessibility bring forth fresh challenges related to required competencies and ethical considerations. Furthermore, this work explores the potential of incorporating recent AI tools, such as ChatGPT and other generative adversarial networks, into engineering education. This is illustrated through a case study of a master's level digitalization course. In this course, AI tools aimed to help students bridge their programming knowledge gaps and educate them on ethical AI use, providing a model adaptable to lifelong learning courses in the field. This inquiry also addresses the broader concerns related to AI misuse in academic settings and the subsequent difficulties in plagiarism detection and accurate learning outcome assessment. The discussion does not argue against AI adoption but emphasizes managing its inadvertent impacts on the industry and society. By integrating emerging technologies and their ethical use into the curriculum, the engineering education system can better align with the shifting demands of the workforce in an increasingly digitalized manufacturing landscape.

Keywords. AI, Engineering education, Technology-driven education, Case study

1. Introduction

The European economy is increasingly knowledge-driven, and global competition is intensifying. Recent crises have underscored the vulnerability of the European industry [1] and highlighted the need for enhanced prediction methods for more sustainable manufacturing [2]. Concurrently, technological advancements and augmented digitalization within the manufacturing sector, encompassing both small and medium enterprises (SMEs) and larger enterprises [3], are forging new prerequisites for future employees

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[4, 5, 6] and shaping how and what to teach in educational institutions [7]. Although teachers' education, university programs, and course curricula traditionally evolve slowly [8], the requisite technologies for students and the workforce are swiftly changing, causing many companies to struggle in finding engineers with the right skills. Addressing this mismatch has often involved offering lifelong learning courses to update employees on the latest technological developments [9]. Several industry associations, national and international authorities, and higher education institutions place considerable emphasis on tracking the new competencies required by engineering students [10, 4, 11].

Artificial intelligence (AI) plays a pivotal role in the digitalization and automation of the manufacturing industry [12, 13, 14, 7]. While neither AI nor its necessity in manufacturing is novel, and it is incorporated into numerous engineering study programs, understanding how AI, machine learning, and deep learning operate is vital for developing the services required by the manufacturing industry [15, 16, 17, 13, 12, 18]. Consequently, AI knowledge must be integrated into the curriculum for production engineering students.

The advent of ChatGPT and other generative adversarial networks has ushered in novel ways to explore cloud-stored knowledge, raising concerns among educators about the potential misuse by students. This misuse could compromise the integrity of assessments, making plagiarism harder to detect [19, 20] and raising doubts about whether students can achieve the learning outcomes set forth in curricula [19, 21]. Despite these challenges, the progress of technological advancements like AI should not be halted, given the potential benefits to society [19]. Instead, the focus should be on managing and regulating the unintended repercussions for both industry and society. This involves scrutinizing how engineering students can develop appropriate competencies in the field, which includes understanding and critically assessing AI applications, as well as leveraging new opportunities in their studies while adhering to ethical guidelines required for their academic work and examinations.

In light of these challenges, this article explores the possibility of alternative examination forms that might mitigate the risk of unauthorized usage. Based on a small case study involving first-year master's students in a course that explicitly includes AI in its learning objectives, we focus on two main areas:

- Utilizing AI to support learning: Investigating how AI technologies can aid students who need additional support in their learning process.
- Implementing alternative examination forms: Examining alternative examination strategies to ensure students develop the necessary competencies while maintaining academic integrity.

The aim is to provide insights into how AI can be integrated into educational settings in a manner that enhances learning while addressing the potential for misuse. The remainder of the article is structured as follows: Section two outlines the research methodology, section three presents the case study, section four discusses the case study results, and section five explores the implications of these findings for future educational practices.

2. Research Methodology

This paper aims to elucidate the purpose and objectives of studying the role of AI and its ethical ramifications within the realm of engineering education. Engineering education has seen a paradigm shift from being solely knowledge-driven to being competence-driven[10, 4, 15]. To enhance students' competencies, experiential learning methodologies, known for their efficacy in preparing students for real-world challenges, have been incorporated extensively over the years [17].

Our research employs a mixed-methods approach [22]. This study is anchored on preceding research on the subject. To delve deeper into AI's influence on education and the evaluation of student skills, we conducted an initial unstructured literature review through Google Scholar. Our search terms included: 'engineering education and AI', 'assessment of engineering students' skills and AI', and 'AI's necessity in post-2018 production'. We chose the post-2018 timeframe based on a case study that utilized a curriculum, which had incorporated an Intended Learning Outcome (ILO) related to AI in production since 2018. This review offered insights into the practical applications — for instance, which AI topics were being taught and in which courses. However, it fell short in providing a comprehensive understanding of the pedagogical rationale underpinning these curricula.

For a more holistic comprehension of AI's integration into engineering curricula, we embarked on a systematic literature review using the PRIMO DB at KTH, based on the methodology detailed in [3]. The chosen search phrase was 'AI in engineering education'. We limited our search to articles in English, published between 2013 and 2023. This extended 10-year timeframe, as opposed to the earlier 5-year span, was chosen because curricular developments often have long gestation periods before classroom execution. Our objective was to discern potential trends. This search yielded 76 entries, and after a thorough screening — evaluating titles, abstracts, and keywords — 10 entries remained for our analysis. The findings of this review will be presented in the subsequent section.

Complementing our literature review, we also conducted an empirical case study, recognizing that case studies can offer profound insights into real-world implementation challenges. This methodology is especially apt for exploring "how" and "why" questions, especially when researchers possess limited control over evolving events [23, 13]. Our case study focused on observing how students leveraged AI to bridge their knowledge and skill gaps in programming. Feedback was gathered through a questionnaire to capture students' personal experiences. While the questionnaire offered an anonymous platform for students' perspectives, educators' observations were essential for gauging the pedagogical impact and identifying potential refinements. The curriculum combined practical AI exercises with theoretical classes and an ethical considerations module. The questionnaire comprised ten questions: an inquiry about prior experience, three open-ended and six closed-ended questions on course experience. No control questions were incorporated. The outcomes of this empirical study will be elucidated in Chapter 5.

3. Similar works

A comprehensive literature search was conducted on PRIMO on October 12, 2023, using the search string "AI in engineering education". The search parameters were restricted to articles written in English and published between the years 2013 and 2023. Out of the initial 76 articles identified, a review of titles, abstracts, and keywords narrowed down. We further excluded three due to duplication, six that catered to K-12 education, eight emphasizing music, fifteen centered on utilizing AI for student assessment in classrooms, five on AI's role as teaching assistants, and fourteen on AI's application in language teaching (even when geared towards engineering students). Of the remaining ten, we conducted the full manuscript review. Three were set aside as their emphasis was on AI in imaging processing within a medical context. While this can be linked with certain engineering education facets, the main thrust of these articles leaned more towards medical pedagogy.

Among the literature that made the final cut, Stadelman et al. present a holistic view of the challenges and opportunities in assimilating AI topics into engineering education, enriching it with practical examples [24]. In contrast, How and Hung concentrate on bolstering students' AI-centric thinking within the broader scope of STEAM education [17]. Their focus aligns with fostering critical thinking skills, especially when applying AI in these disciplines. Luo's work integrates sensor networks with AI, primarily targeting quality assurance in MOOCs [25]. However, the insights offered are directly applicable to the course examined in our case study section. Chien and Yao's research, while not directly centered on AI pedagogy, highlights the potential of AI bots in participatory design [26]. This indirectly underscores the essential AI components that should be integral to engineering curricula. Lastly, Rahman and Watanobe delve into the intricacies of deploying ChatGPT in educational settings, echoing much of the debate we alluded to in our introductory section. Their perspectives are particularly invaluable for introspection on the ethical dimensions of engineering education [27].

An interesting perspective on the pedagogical approach to AI education is provided by the study of Kim and Shim (2022), which demonstrates how AI can be effectively taught to students with little to no prior formal education in the subject using augmented reality (AR). Though their target group comprised non-engineering students, the practical methodologies employed bear a resemblance to the theoretical introductions in our own curriculum, suggesting that hands-on approaches can significantly enhance students' comprehension of AI concepts. This study stands out in our initial literature review for providing empirical evidence supporting the efficacy of practical AI education methods [28].

However, the scarcity of empirical studies specifically targeting the use of AI tools to develop engineering students' programming skills underscores a critical gap in the literature. This gap is particularly pronounced given the absence of studies employing RCT designs, highlighting an area where our research could contribute significant new insights. The limited focus on computer science and high school students [29, 30] further narrows the scope of existing research, suggesting the need for studies that explore the impact of AI tools like ChatGPT across a broader range of educational contexts.

The conspicuous lack of publications detailing AI's integration into engineering curricula, despite its widespread inclusion in engineering programs, suggests potential interdisciplinary challenges and publication biases that merit further exploration. This publication deficit may reflect a broader issue within educational research, where innovative teaching methodologies, particularly those involving emerging technologies like AI, struggle to find their place within traditional research paradigms. Our study aims to bridge this gap by providing empirical evidence on the efficacy of AI tools in enhancing the engineering education experience, contributing to a more nuanced understanding of how these tools can be integrated into curricula to meet the evolving needs of the engineering workforce.

4. Case Study

The ”Digitalisation for Sustainable Production” course, offered at the master's level, primarily aims to enable students to seamlessly integrate the growing wave of digitalization in industrial production with the evolving needs of stakeholders. The prime objective is to prepare students to either offer or acquire digital solutions in the Industry 4.0 landscape.

Throughout this course, students are immersed in various technologies pivotal for data collection, storage, analysis, and visualization tailored for production and logistics applications. Beyond this, the curriculum ensures that students appreciate the transformative power of digitalization, understanding how it paves the way for sustainable production, amplifies servitization, and unlocks new avenues for business development. But digitalization isn't devoid of challenges; hence, the course also instills a foundation for students to critically analyze the ethical, safety, and integrity issues intrinsic to a digitally-dominated production environment. By the conclusion of the course, students are equipped to:

- Elucidate the building blocks of cyber-physical systems used in production and logistics, spanning areas like industrial IoT, autonomous systems, connectivity solutions, and big data analytics.
- Dissect the prerequisites and readiness level of a production unit for digital integration.
- Evaluate applications rooted in advanced data analysis, machine learning, AI, visualization, and ensure these are in harmony with stakeholders' expectations in the context of production and logistics.
- Synthesize the advantages of digitalization and map them to practical use-cases in production development and operations, encompassing lean production methodologies, management systems, and digital tools.
- Integrate the potential of digitalization with evolved business models and servitization to champion sustainable production.
- Conduct a rigorous critique of digitalized production with lenses focusing on ethics, personal privacy, cybersecurity, and data integrity.

A notable feature of this course is its emphasis on hands-on application. Students are introduced to platforms like Arduino and Raspberry Pi for data acquisition, while Python serves as the tool for data analytics and visualization. Given that these platforms require an understanding of languages like C++ (Arduino), JavaScript (some Raspberry Pi applications), and Python, students face an initial hurdle. This is primarily because the course does not mandate prior programming experience, resulting in many students grappling with these languages for the first time.

Recognizing the challenges faced by students due to the absence of prior programming experience, the integration of AI tools like ChatGPT becomes indispensable. These tools bridge the programming knowledge chasm, aiding students in quickly overcoming the steep learning curve associated with C++, JavaScript, and Python. Additionally, AI tools not only facilitate technical learning but also immerse students in understanding the ethical implications of AI in production, ensuring they are well-rounded digitalization experts.

Addressing the programming challenges faced by students, the course permitted the integration of AI tools like ChatGPT into their project work. This decision proved invaluable for many students who sought guidance in developing specific code snippets and solutions. ChatGPT, with its ability to generate code, provided a unique advantage to students, enabling them to bridge their immediate knowledge gaps and better grasp the real-world application of their course topics.

The incorporation of ChatGPT in the course, thus, not only acted as a programming aid but also stimulated a deeper comprehension of the challenges and solutions related to digitalization in industrial production. By having an on-demand, knowledgeable ”tutor” like ChatGPT, students could enhance both their theoretical and practical knowledge in the realm of Industry 4.0.

5. Results and Discussion

To gauge the impact of incorporating ChatGPT in the course project work, a detailed survey was administered. The survey aimed to capture a comprehensive view of the students' experiences, challenges, and the effectiveness of ChatGPT in their project work. The following questions were posed to the students:

1. Did you have any prior experience using ChatGPT before this project?
2. How easy or difficult did you find it to use ChatGPT for your project?
3. Did using ChatGPT help you to overcome the lack of programming experience in completing your project?
4. Which programming language did you get help to use from ChatGPT?
5. In what ways did you use ChatGPT in your project? (optional)
6. What were the main challenges you faced while using ChatGPT for your project?
7. How reliable did you find the outputs from ChatGPT in terms of accuracy and relevance?
8. Did using ChatGPT speed up your project workflow?
9. Would you recommend using AI tools like ChatGPT to other students lacking programming experience?
10. How would you improve the experience of using ChatGPT for future projects?

Responses from a subset of course participants provided insightful reflections on the utility and limitations of using ChatGPT in academic projects. Despite a low response rate of 26.7% (4 students), the feedback was valuable. Notably, three-quarters of the respondents had prior experience with ChatGPT, which likely contributed to the majority finding the platform user-friendly and straightforward for their project needs.

Students shared diverse ways of integrating ChatGPT into their projects, stating:

- “ChatGPT doesn't necessarily provide direct answers, but it offers an alternative perspective, which can be used or discarded depending on the problem's specifics.”

- "We predominantly utilized ChatGPT during the ideation phase to refine our concepts. A significant portion of our coding was generated through ChatGPT, though we made certain tweaks to ensure functionality and accuracy."
- "I utilized it for code in Node-RED, specifically for defining thresholds."

Challenges encountered with ChatGPT included:

- "I faced no hurdles using it. It was a supplementary tool that I didn't rely exclusively upon."
- "On occasions, ChatGPT repeatedly generated erroneous code. The free version also has constraints on the code output size, necessitating splitting the code into segments. However, this workaround didn't always yield the desired results."
- "The efficacy of ChatGPT's output is strongly tied to the precision and clarity of the user's prompt."

Despite these challenges, 75% of respondents felt that ChatGPT had accelerated their project workflows, and they expressed willingness to recommend such AI tools to peers lacking programming expertise. One respondent suggested creating an official guideline for future projects on using ChatGPT, which would include best practices, sample queries, and troubleshooting steps, ensuring that students can derive maximum benefit from this powerful AI tool.

6. Conclusions

The integration of AI tools, especially ChatGPT, into a master's level digitalization course has shed light on the nuanced role of AI in modern engineering education. From our findings, it is evident that while many students found significant benefits in using ChatGPT for their project work, there remained a segment that felt the tool did not wholly offset their lack of programming experience. However, the overarching sentiment was positive, with a majority highlighting how AI tools like ChatGPT streamlined their workflow. This suggests a growing acceptance and potential of AI interventions in academic contexts.

The implications of our study are manifold. As the wave of Industry 4.0 advances, the importance of AI tools in shaping the trajectory of engineering education becomes even more pronounced. The future engineering workforce will inevitably engage with an increasingly digitalized manufacturing sector, and having an understanding, complemented by AI tools, can prove invaluable. Yet, it is crucial to remember that AI tools should serve as enhancers of the learning journey, not as replacements. Their role is to fortify traditional learning, ensuring students gain a rounded educational experience.

For educators and institutions, there is a clear indication towards the need for structure when introducing AI into curricula. Providing clear guidelines on the ethical and efficient use of these tools is paramount. Emphasizing their role as supplementary resources ensures students are encouraged to think critically and solve problems organically. Moreover, as AI evolves, course content must adapt, ensuring it remains relevant and continues to stress the importance of both technological proficiency and ethical considerations.

Looking ahead, there is a rich tapestry of research opportunities. Exploring further the long-term impacts of AI tool usage on academic performance and industry readiness is a natural next step. Similarly, exploring the efficacy of other AI tools across various educational settings can provide a more comprehensive understanding. A critical area ripe for inquiry revolves around the ethical challenges associated with AI's extensive academic adoption, particularly in contexts of academic integrity.

In summary, the frontier of AI in engineering education, while promising, calls for a balanced approach. It's essential to harness its potential in a way that amplifies foundational educational tenets, ensuring students are both technologically adept and ethically grounded.

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