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Literature Review of Using AI Tools to Enhance Engineering Students' Proficiency of Professional Skills

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Literature Review of Using Artificial Intelligence Tools to Enhance Engineering Students' Proficiency of Professional Skills.

Introduction

Preparing engineering graduates for the work force has been a topic of research for decades. It is a category of the wider topic of "effectiveness in the workplace" where terms such as "professional skills" and "people skills" have been identified as contributing factors to the success that individuals find in the workplace. With the advent, wide spread use and acceptance of artificial intelligence (AI), and its rapid integration in many engineering fields as well as engineering education, this paper aims to perform a narrative literature review of how AI is used to teach engineering undergraduates professional skills to help to close the academia-to-industry skills gap upon entering the engineering industry or research fields. The most prominent professional skills needed in industry over the past ten years will also be studied in the literature review.

In hopes to further the engineering education research arena and advance research scholarship, the motivation for the literature review topic involves the training of engineering undergraduates to enter the workforce well-prepared. This preparation is essential to industry as it minimizes on-the-job-training and allows the workplace to maximize the productivity of new hires that have the necessary skills to integrate seamlessly and almost immediately into their workplace. The academia-to-industry skills gap in engineering has existed for many years, specifically in the areas of communication, collaboration, professionalism, project management, etc., which are collectively called professional skills [1], [2]. Professional skills in engineering can be defined as the skills needed to succeed in the engineering industry such as employability skills, leadership skills, interpersonal skills, organization skills, emotional intelligence skills, etc. The term "soft skills" was first referenced for engineering education in 1918 by Charles Riborg Mann, in which he claims that 80% of engineering success in engineering is due to "soft" skills and 20% due to "hard" skills as exhibited by working engineers [3]. The term "professional

skills" is more current in modern literature and will be used for the duration of this paper. Definitions such as skills pertaining "to personality, attitude and behavior rather than to formal or technical knowledge" and "soft skills engender automatic chains of psychological, emotional, and psychological responses which have an immensely real impact within the mind, body, and society at large" [4] are included in professional skills.

Collegiate undergraduate engineering programs are tasked with preparing students to enter the engineering industry. Typically, industry skills are taught in senior-level capstone classes [5] and a compelling effort within engineering education is to reduce the mismatch between industry needs and student preparedness [1], [2]. Engineering students will be better trained to enter industry if more industry skills are taught starting in the first year of an undergraduate degree rather than the traditional senior-level focus to increase student's fluency in their professional skills. Students feel more prepared to enter the engineering industry if they have been taught both the technical and professional skills throughout their entire undergraduate degree plan [2]. Therefore, it is important to study professional skills in engineering education programs; the earlier in the degree plan, the better.

Previous research surrounding the engineering readiness gap has covered topics such as active, collaborative, and project-based learning in which students are expected to solve an engineering problem while working in teams. The traditional coursework in an engineering undergraduate degree plan teaches technical and core classes in a sequence while later introducing capstone projects that combine the technical and professional skillsets needed to develop an industry-sponsored project during the senior year. The proficiency of concepts such as teamwork, communication, project management, and professionalism are expected to be used in senior-level engineering design classes but may not have been emphasized through the traditional sequential coursework, especially until the senior year.

The use of AI to help solve engineering problems as a collaboration tool is being used in engineering classrooms at increased frequency, hence the motivation of this paper to look at the use of AI in developing professional skills in engineering undergraduate education. Using AI as prompts to help students draft papers or laboratory reports is starting to emerge in undergraduate engineering programs, although using AI to teach or enhance professional skills seems to be a new area of research [5]. One paper found that the typical use and extent of using generative AI in engineering classes based on student surveys [6] and the general impact of AI in communication skills training has been studied [5], [7], [8], [9], but the specific application to engineering is less abundant in the literature.

The significance of using AI in the engineering classroom to help develop professional skills was reviewed to see if the idea can help to close the engineering readiness gap, using synthesis and gap-finding techniques in the existing literature. This paper focused on reviewing the existing literature with the aim of answering the following:

1. How have engineering educators used generative artificial intelligence (AI) tools to enhance students' proficiency of industry professional skills?
2. What are the most prominent engineering academia-industry readiness gap skills topics of the past 10 years?

Methods

The literature review's main methods will employ reviewing journal and conference papers in engineering over the past ten years. In screening the articles reviewed in the general search, specifics were looked for involving a combination of engineering, AI, and professional skills.

The search involved various methods to review the existing literature concerning professional skills, engineering, and academia-industry gap. A Google Scholar search was done to find relevant journal and conference papers and to determine the extent of research already completed. After the preliminary search, a more targeted search was conducted using Elsevier Engineering Village, Compendex and Web of Science. These database searches further narrowed the selection of the journal and conference papers to investigate in more detail and determine articles to fully read. Boolean strings and general search criteria used are shown in Table 1 below, with the primary search shown as the first bullet item:

• (AI OR "artificial intelligence" OR "generative AI" OR "generative artificial intelligence") AND ("engineer* education" OR "teaching engineer*" OR "engineer* curriculum") AND ("soft skills" OR "professional skills" OR "industry skills" OR "readiness skills") with a publication date range of 2014-2024
• (AI OR "artificial intelligence" OR "generative AI") AND "engineering education"
• engineering AND "industry readiness"
• "AI use to teach industry soft skills in engineering"
• "AI use in engineering classes"
• AI AND "measuring engineering soft skills"
• engineering AND ("academia-to-industry readiness gap" OR "industry readiness gap")
• "impact of using AI to teach engineering undergraduates industry skills"
• "undergraduate engineering curriculum using generative AI"

Table 1. Search Criteria

In screening the articles reviewed in the general search, specifics were looked for involving a combination of engineering, AI, professional skills, and the assessment of these skills in engineering curricula while emphasizing criteria such as scientific rigor, peer reviewed articles, and impact factor scores. Duplicate articles were removed by comparing the primary

search with the other general searches listed above. For the review's purpose, technical skills were not considered as the literature review did not show a large gap for these skills among new engineering graduates. Given the recent use of AI in academia, the search was limited to papers published in the last ten years. The types of generative AI used in engineering classes and narrowing the search to include engineering specific content was categorized in the screening stage.

The data was synthesized using a review matrix. Key column headings were “generative AI type”, “lesson context”, “transferability”, “student year level”, “type of class”, “skills measured”, and “outcomes.” Trends of engineering curriculum executed to teach professional skills, manners in which generative AI was used in the engineering classroom, the largest skills gap topics, and the overall significance of the skills gap size were considered when synthesizing the literature data. The topics were then sorted to answer the two research questions.

Results

This literature review focused on two major sets of literature: professional skills and the academia-industry readiness gap in engineering as well as AI use in engineering education concerning professional skills development.

Prominent Professional Skills

The Accreditation Board for Engineering and Technology (ABET) accreditation includes professional skills as part of the engineering curriculum quality standards in the U.S. and many other countries, namely communication, responsibility, teamwork, and critical thinking per the Criteria for Accrediting Engineering Programs, 2024 – 2025, Criteria 3. Student Outcomes list [23]. Engineering curricula and assessment systems, through programs such as ABET accreditation, are intended to prepare engineering students for the skills they need to enter industry.

The highest reported professional skills are summarized in Table 2 below, with teamwork and communication identified as being the most common skills lacking in recent engineering graduates. The definitions of communication and teamwork were not standard in the research papers reviewed, so an exact definition or expectation of these terms cannot be presented. However, it was clear that the general expectation was that successful engineers are expected to be good communicators and work well together, allowing employers to infer that their engineers will be able to collaborate and communicate successfully with stakeholders, clients, and the like.

Country	Highest Professional Skills Need	Citation
France	team spirit, autonomy, curiosity, and problem solving	[25]
Italy	emotional stability, self-control, self-confidence, communication	[26]
Lebanon	teamwork/leadership, communication and writing	[5]
Morocco	communication, organization, using technology, adaptability	[10]
South Africa	communication, critical thinking, conflict resolution	[1]
UK	teamwork, communication, problem solving, entrepreneurship	[2]
U.S.A.	teamwork, communication, responsibility	[27]

Table 2. Highest Professional Skills Needed per Country

Teamwork can be viewed as the collective skills needed to work with two or more people in a group. Teamwork is part of the interpersonal skills that define how an engineer interacts within a group. These interpersonal skills sometimes involve both teamwork and communication [10]. A total of 96 articles were reviewed for this paper, of which 71 cited communications as a prime professional skill, representing 74% of the population. The second most cited professional skill, collaboration, was cited in 61% of the reviewed population.

Communication is considered in both its written and oral forms, and is important for both one-on-one and team settings, and in today's environment, communication can also be considered between an engineering student and a generative AI software. Communication skills ranked in the highest professional skills needed in 86% of the countries listed and is the highest overall ranking skill needed in the engineering industry, per Table 2 above. Therefore, continued

emphasis on producing engineers with effective communication skills is of utmost importance in preparing undergraduate students to enter the engineering industry.

Teamwork, communication, critical thinking, and responsibility remain the highest priority skills needed in industry over the past decade [2], [3], [5], [7], [14], [24], [28]. Time management and project management skills were also popular skills prevalent in recent literature [5], [24]. These skills mostly mirrored the scoping review from 1980-2020 that listed communication, teamwork, problem solving, leadership, project management, and entrepreneurship as the most important skills needed for recent engineering graduates [2]. The literature reviewed included surveys from students, industry professionals, teachers, various countries, and engineering industries. Thus, the data was thorough for diversity of population and matches the student outcomes criteria for ABET accreditation [23]. The skills needed to enter the engineering industry in the past decade remain mostly unchanged from previous years and closely follow the ABET standards, which reflect industry input.

AI Effect on Professional Skills

Using AI in engineering undergraduate classrooms has been gaining in popularity with ChatGPT being the far most used generative AI tool. Chatbots have been used since the turn of the century, initially as rule-based systems and algorithms for frequently asked question responses and tutoring types of person-computer interactions [13]. In 2023, the use of ChatGPT by students in undergraduate engineering showed only a 4% AI use on a weekly basis [4]. In 2024, more research is available for AI in education and industry, including as a virtual assistant using AI as a prompting tool [14], and as a development bot to enhance software design [18]. With the popularity of ChatGPT increasing, from one million users in the first week during the launch in 2022, to more than 200 million weekly users in late 2024 [16], the usage of ChatGPT in college engineering courses is expected to follow a significant increase soon.

Using AI in the engineering classroom has been seen to offer both advantages and disadvantages. Students saw an increased confidence in decision-making, critical thinking and problem-solving skills using AI tools, which may help develop professional skills [14]; however, the decline in creativity, critical thinking and social relationships using AI tools may also have a negative effect on developing professional skills if the use of AI-generated content is not supplemented with the use of teamwork and collaboration skills [19], [29]. Increased AI use was seen to increase collaboration and professional skills of students in undergraduate computer science-type majors [20] but had a detrimental effect to other skills such as social relationships and creativity.

Productivity increases are thought to be enhanced by using generative AI. Using generative AI such as ChatGPT (text based) and Dall-E (image based) to speed up the ideation process in the design realm for text and image creation [17] is one example. This application can similarly be used in the engineering design cycle process during the brainstorming and ideation design phase. AI helps generate ideas, offer design suggestions, create visuals, integrate technology in artistic creation within the arts [31], which can be applied in the ideation phase of the engineering design cycle. Another example is using text entries to generate computer-aided design models in software for increased engineering efficiency. The engineer of Industry 5.0 and Education 5.0 is the combination of being investigative but also competent to manage resources, with a fusion of technology, communication, and leadership qualities [12]. Generative AI can help engineers become more productive in developing designs by using modern technologies to increase efficiency in their work [29].

Ethical cautions of using AI were prevalent in the literature [19], [20], [23]. These cautions involved not only students' ethical use of AI, privacy concerns, academic quality, quality of the results generated and legal considerations, but a focus on needs for future policy,

ethical review, and monitoring in evaluation of AI-generated content. Therefore, cautions should be held at the forefront of future research in engineering education and in the skills development of future engineers.

Discussion

RQ1: How have engineering educators used generative artificial intelligence (AI) tools to enhance students' proficiency of industry professional skills?

As the implementation of AI in engineering classrooms is still relatively new, a greater volume of future research concerning details of AI use to teach professional skills specifically is still forthcoming. The competency of AI educators has been lacking to date, per the most recent 5-year data [18], but educators are expected to become more competent in teaching AI proficient professional skills and limitations as they upskill. Teaching “prompt engineering” as a research skill may be the wave of the future. As AI competency skills increase in educators, the applications of AI use in engineering curriculum in general and using AI to teach professional skills should improve.

Closing the AI knowledge gap among first-year engineering students requires a multi-faceted approach that leverages the power of generative AI tools like ChatGPT while also grounding students in fundamental concepts. A key starting point is integrating AI literacy into the core curriculum, not as a standalone subject, but woven into existing courses like programming, design, and even introductory engineering principles [15]. This integration should begin by demystifying AI, explaining its basic functionalities, limitations, and potential applications within various engineering disciplines. Lectures can introduce core concepts like machine learning, natural language processing, and computer vision, while hands-on activities allow students to interact with these technologies through user-friendly interfaces. This

foundational understanding is crucial before diving into more advanced prompt engineering techniques.

Once students have a basic grasp of AI, the focus should shift to practical application. This is where using generative AI and prompt engineering become invaluable tools. Structured workshops can teach students how to craft effective prompts to elicit desired outputs from large language models [32]. This includes understanding the nuances of phrasing, providing context, and iterating on prompts to refine results. For example, students can be challenged to use generative AI to generate code snippets for simple engineering calculations, design preliminary prototypes based on textual descriptions, or even brainstorm solutions to open-ended engineering problems. These exercises not only familiarize students with the capabilities of AI but also encourage critical thinking about the outputs generated. It is crucial to emphasize the importance of verifying AI-generated results and understanding the potential biases inherent in these models [33].

Beyond structured workshops, incorporating AI tools into regular coursework can further solidify learning. Assignments can be designed where students are required to use ChatGPT or similar tools as part of their problem-solving process [34]. This could involve using AI to research existing solutions, generate initial design concepts, or even simulate different scenarios. By integrating AI into the learning process, students will naturally develop their prompt engineering skills and learn to leverage AI as a valuable tool. Furthermore, encouraging peer learning and collaboration can be beneficial. Students can share their experiences with prompt engineering, discuss effective strategies, and learn from each other's successes and failures. This collaborative environment fosters a deeper understanding of AI and its applications in engineering.

Also, continuous assessment and feedback are essential to ensure that students are effectively closing the AI knowledge gap. This can be achieved through regular quizzes, assignments that require the use of AI tools, and even project-based assessments where students apply their AI knowledge to solve real-world engineering problems [34]. Feedback should focus not only on the technical aspects of prompt engineering but also on the critical thinking and problem-solving skills demonstrated by students. By providing constructive feedback and adapting the curriculum based on student progress, educators can ensure that first-year engineering students are well-equipped to navigate the increasingly AI-driven landscape of the engineering profession. This comprehensive approach, combining foundational knowledge with practical application and continuous assessment, will empower students to harness the power of AI effectively and responsibly.

There have even been studies using ChatGPT to generate a study on the challenges and opportunities of generative AI for higher education. Some of the prevalent positive results from the AI-generated interview, using thing ethnography to engage with ChatGPT, are 24/7 support for learning, personalized and supplemental learning, language learning, and support for instructors. The summary of challenges presented in the study were academic integrity, expertise and authority concerns, collaboration, and quality control challenges [21]. How to not only use, but study generative AI tools, should continue to be a topic of engineering research. If used as a supplemental resource for information that is verified, AI can be an effective tool for engineering students [29].

Understanding the limitations and problems associated with AI systems, such as hallucination, alignment, runaway, discrimination, and lock-in problems, and how these issues change over time is important for educators to increase their AI literacy. Teaching prompt

engineering to minimize the potential errors and limitations of AI tools can help engineering students develop critical thinking skills and deepen their subject matter content mastery [32].

RQ2: What are the most prominent engineering academia-industry readiness gap skills topics of the past 10 years?

Research question two was addressed with a review of the most needed skills to enter the engineering profession in the past decade as compared to previous years. Engineering curricula should train engineers in technical and professional skills for students to transition smoothly from academia to industry. Teamwork and communication skills were cited in most papers reviewed out of a wide selection of other professional skills; therefore, these can be seen as the most important professional skills in engineering.

Professional skills evolve as the engineering industry changes, but many of the same prominent skills that new engineers need today have been the same for years. It is interesting to note that emotional stability ranked high in Italy but was not among the top professional skills needed in engineering among the other countries reviewed. Also, entrepreneurship was listed as a need in the UK, but not other countries. The idea of Industry 5.0 prioritizes the development of people and societies, with a specific focus on resiliency, adaptability, sustainability, and human-centric areas with human resources using digital technologies [11], [12]. With Education 5.0, the emphasis is on innovation and industrialization, with concerns for lifelong learning, resilience, and human-centric design [12]. Therefore, it is surmised that emotional intelligence and entrepreneurship skills are new in the engineering education arena and further, that these skills may become more prevalent in the future.

Future Research

Professional skills are not standardized the way technical skills training is in current engineering curricula. Measuring professional skills proficiency and content mastery is different

than assessing a technical concept in engineering. Specifically, how professional skills are assessed in undergraduate education is a topic for future research that may help to further bridge the academia-industry readiness gap and help to develop better engineers of the future. Also, the effect of AI-generated engineering work from the perspective of assessing aesthetics, emotion, human creativity, etc. should be studied. Thus, not only valid, but pleasing engineering design solutions are sure to be developed that meet all requirements and specifications.

Conclusion

The use of AI tools is increasing in use, in both education and industry. Using AI to teach professional skills remains a new application in engineering education. With each passing year, the use of AI is exponentially increasing among both students and educators alike, and this literature review has demonstrated that student's skills such as collaboration and teamwork can increase by using AI.

The largest academia-industry gaps in professional skills such as teamwork, communication, and critical thinking have remained relatively unchanged over the past thirty years indicating that it is a persistently required skill set that has yet to be satisfactorily addressed. ABET criteria for engineering curricula include communication, responsibility, teamwork, and critical thinking skills as necessary for quality undergraduate curriculum accreditation.

Implications of using AI to teach professional skills in industry as well as education can translate into improved skill sets for students, educators, and engineers. It is important to teach students up-skilling techniques by emphasizing prompt engineering, using AI as a learning tool, and using generative AI as a tool to teach professional skills. AI, when used cautiously as a learning tool, can help to increase communication, efficiency, collaboration, and personalized

learning in engineering and therefore, has the potential to help close the academia-industry skills gap in engineering.

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