Board 45: Generative Artificial Intelligence (GAI)-Assisted Learning: Pushing the Boundaries of Engineering Education.

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Generative Artificial Intelligence (GAI) Assisted Learning: Pushing the Boundaries of Engineering Education.

Abstract

Generative artificial intelligence (GAI) has long been used across various fields; however, its usage in engineering education has been limited. Some areas where GAI tools have been implemented in education include intelligent tutoring, assessment, predicting, curriculum design, and personalized student learning. The recent proliferation of CHATGPT and other GAI tools presents limitless possibilities for transforming engineering pedagogy and assessment. At the same time, there are challenges associated with implementation. Consequently, there is a need to conduct an empirical study to evaluate these tools' strengths, limitations, and challenges to highlight potential opportunities for their application in engineering education broadly and pedagogy specifically.

This study presents an overview of ongoing efforts to integrate GAI as a pedagogical tool at a Land Grant R1 University on the East Coast of the United States. Also, we are hoping to collect a within-case study of instructors who have successfully implemented artificial intelligence in their classrooms and course design. Data will be collected from the instructors through classroom observations and interviews on their classroom implementation. These will be thematically analyzed. Also, a deep exploration of students' learning experiences using the GAI will be conducted using focus group discussions and end-of-the-semester reflection. Other data sources that will be thematically analyzed include the syllabus, student ratings for teaching effectiveness, and instructors' reflections. Consistent with a case study design, the multiple sources of data serve as triangulation for this study. Also, we suggest that the data upon which these GAI tools are trained should be inclusive so it could serve diverse learners. In addition, this work discusses the ethical considerations of using GAI for instructors and students.

The next steps include collecting and analyzing data from multiple sources from the faculty and students. It is expected that the outcome of this study will provide data-driven evidence on the impact of GAI on learning, recommended pedagogical practices, and future research direction. Finally, this study will underscore limitations with GAI and suggestions for improving the tool as it is positioned to transform engineering education.

Keywords: Generative Artificial Intelligence, Pedagogy, Learning, Within-Case Study, Ethics, Engineering Education

Introduction

Where engineering has always taken a stance on the forefront of technological innovation, engineering education tends to be more hesitant when embracing new and innovative technologies in the classroom. With the emergence of technologies such as Generative Artificial Intelligence (GAI), it is imperative to develop effective strategies for integrating these new tools into the curriculum. GAI use is proliferating in society and the engineering workplace. To best prepare today's engineering students for the ever-evolving technological workplace, engineering instructors must provide opportunities within the classroom for students to acquire relevant skills and knowledge that will allow them to adapt and excel in their future careers.

GAIs offer a unique opportunity to improve engineering education practice and transform engineering pedagogy and assessment. For instance, GAI tools can provide real-time feedback and personalized learning experiences for students. They can also enable students to simulate complex engineering scenarios and problem-solving tasks. Engineering educators can use GAI tools in engineering design projects to enhance students' critical thinking skills and help students better understand real-world engineering challenges. There are a multitude of yet to be discovered applications and implications for integrating these tools into the classroom to better prepare our students for their future careers.

As with any new educational tool, GAI also poses new challenges to their implementations that may be deleterious to the overall learning experience. For example, new GAI tools may require significant time and resources to develop and implement, constraining engineering educators with limited resources. Moreover, there is a learning curve for both educators and students to learn how to use GAI tools effectively in the classroom, which could initially impede the learning process. Furthermore, there are ethical issues, algorithmic bias, and data privacy that may need to be resolved or addressed before using GAI in engineering policy, practice, research, and teaching. Considering these challenges, there is an urgent need for empirical studies to assess the impact of GAI on engineering learning experiences to address the potential challenges and concerns related to their implementation. This study aims to inform the field about the best practices for integrating GAI tools into engineering education pedagogy and assessment.

Purpose of this study

This work-in-progress paper aims to describe our efforts to explore the impact of integrating GAI as a tool for enhancing engineering education. In this paper, we will discuss the methodology we plan to use to assess the impact of GAI tools on engineering learning experiences, including the selection of participants, data collection methods, and analysis techniques. We will also highlight our theoretical framework for GAI in engineering education, a literature review on the topic, and the potential challenges and limitations of using GAI tools in this context.

Our ongoing research will delve into the realm of GAI-assisted learning, specifically focusing on its profound impact on engineering education through an in-depth case study. As we will explore the intersection of artificial intelligence and education, it becomes essential to understand the potential benefits and challenges of incorporating GAI into the learning environment. By addressing these aspects, we aim to contribute to the ongoing discourse on the effective

utilization of GAI in engineering education, ultimately expanding the horizons of how we perceive and engage with the process of learning in the field of engineering.

Literature Review

GAI in education

The widespread adoption of GAI in the educational context has impacted instructors and learners alike. Intending to enhance learning outcomes, instructors have adopted GAI in varied forms not limited to as a classroom pedagogical aid, an assessment tool, an instructional design guide, and an academic integrity tool. Similarly, learners explore how to use GAI for assessments, knowledge building, and other educational purposes. The sections below provide an overview of the implementation of GAI across different fields by instructors and learners.

GAI and Instructional Design

Instructional design (ISD) is a systems approach to create and evaluate learning experiences based on learners' goals and performance criteria [1]. To support ISD, numerous AI sites are emerging to support educators in the design process from learning objective creation to lesson planning to assessment development [2], [3], [4].

Recent studies have explored or demonstrated how GAI tools could streamline and enhance instructional design. Thompson et al. [5] predicted that integrating AI into course design will "lead to enhanced student learning outcomes, engagement, active participation, and learning approach." Chng [6] compared current methods of design (human-only) with an AI-enabled approach and noted AI's potential to improve the design process: "The introduction of AI into human processes has the potential to streamline operations, improve efficiency, and enhance decision-making capabilities." Similarly, Tinterri et al. [7] found that ChatGPT supports designing game-based engineering courses by bridging gaps in instructor knowledge, indicating the role of ChatGPT as an effective support for course design efforts.

GAI, Classroom Pedagogy, and Assessment

With respect to classroom pedagogy, GAI offers the potential to be used as a time-efficient, consistent, reliable, and scalable resource for improving access to education and learning outcomes [8]. In their review on GAI in education for sustainability, Kamalov et al. [8] identified relevant pedagogical applications of GAI in leveraging its capabilities to foster improved student learning outcomes. GAI can be applied to personalize the learning experience, leading to a deeper understanding of subject matter, self-regulated learning, improved accuracy of student data analytics, and enhancement of essential skills for industrial careers. Supporting this finding, Chen et al. [9] observed a high performance on quizzes focused on assessing business students' ability to recollect and understand conceptual knowledge alongside a consensus on the use of chatbots to foster higher-order skills such as critical thinking. Similarly, Hwang and Chang [10] highlighted the interactive feature of chatbots as a means of fostering deeper engagement with course concepts through conversations that go beyond text and videos.

The utility of GAI for assessment has been explored with assessment automation identified by Kamalov et al. [8] as a most common application by instructors in educational settings. A study by Gao [11] explored the use of automated essay scoring technology in medical education as an efficient form of technology that enables content specialists, i.e., instructors, to focus on the creative task of identification, organization, and selection of content for assessment. Recent advancements have seen more sophisticated applications of GAI to automate the grading process. Gao [11] and Parker et al. [12] provide personalized feedback to their students similar to Xu et al. [13], and Liao et al. [14] engage in formative evaluations to enhance student learning. In a study on the effectiveness of an AI-enabled report tool for biology students' formative assessment, Liao et al. [14] observed a greater effect size in learning achievement increase amongst students in the treatment group compared to students who received oral feedback. They further emphasized the significant role of GAI in offering process-level feedback to learners using Natural Language Processing (NLP) for compilation and analysis of incorrect answers, thus serving as a student time and energy saver.

Technology Literacy and Perceptions on Use of GAI

On the other hand, Singh et al. [15] reported on students' limited use of GAI due to a lack of in-depth skills and knowledge of the tools. They highlighted participants' concerns regarding the negative impact of GAI on critical thinking and investigative skills for optimal success in computer science education. Smolansky et al. [16] study on students' perception of GAI for assessments further reveals the existing skepticism among students on the use of GAI. Students expressed concerns as to a lower level of creativity in the use of AI for their learning as they risked not knowing how to write essays but rather learning to critique, analyze, and rewrite essays written by AI. These findings support the need to build students' competence in navigating the complex maze of technology, interaction, cognition, and ethical values, as AI tools are now an inseparable part of our world [17].

Benefits of GAI in Engineering Education

While there has been a flux of literature exploring the opportunities and implications of GAI in education [18], [19], [20], [21], [22], [23], [24], [25], there has been limited research on the applications of GAI in engineering education. Umme et al. [26] explored ways GAI can be utilized as a collaborative tool in engineering education. Duan and Brings [27] discussed the necessity of providing students with guidance about using ChatGPT to address and mitigate the potential negative consequences of unsupervised use by students when GAI is an integral part of the course. [28] identified strategies for integrating GAI into coursework that enriched the learning experiences and improved overall performance and competencies such as critical thinking and research skills of civil engineering students.

Ethical concerns with the use of GAI in engineering education

Despite the promising opportunities and potential of GAI, ethical concerns emerge among engineering educators and other communities. Some common ethical concerns associated with the application of GAI in engineering education include algorithmic bias, transparency and accountability, equity and access, data privacy and security, copyright and plagiarism,

technological unemployment, exploiting global cheap labor, among others. We must also be aware of the ethical issues of GAIs, such as human cost and societal impact, when we use it as a pedagogical and assessment tool. Qadir [30] also alluded to the need for measures to prevent unethical use of GAI in engineering education. Given its application in research, there have also been ongoing disputes regarding the eligibility of ChatGPT as an author [31], [32]. These ethical concerns play a valuable role by offering opportunities to steer the implementation of GAI in ethically responsible ways.

Research Questions

a) What are students' and instructors' perceived literacy of GAI (e.g. knowledge, skills, and abilities)?

b) How do students and instructors experience the usefulness and effectiveness of GAI in their course(s)?

Theoretical Framework

There are many theoretical lenses that one can consider when investigating the experiences of students and instructors using GAI. This paper is primarily interested in the participant literacy regarding GAI and their perceived usefulness and effectiveness of the technology. To explore this, we will use the Unified Theory of Acceptance and Use of Technology (UTAUT*)* model as it has been developed from a meta-analysis of eight existing technology acceptance models, aiming to capture their essential elements [33]. UTAUT examines the effects of the performance of the technology, participant effort in using the technology, social influence, and facilitating conditions that support the use of the technology [33].

This paper also explores the experiences of students and instructors from a user perspective in the specific technological area of GAI, which has its own peculiarities in the context of higher education. The literacy framework not only helps us to explore the usefulness, limitations, biases, and broader implications of GAI [34] from the users' perspective, but is also tailored to understand the knowledge and skills perspective of the participants. Farelly and Baker [35] proposed two literacy theories for this purpose, specifically Ng et al.'s Framework and Hillier's Framework, both of which have also been chosen for this study. Ng et al.'s framework [36] has four critical elements that are applicable to this study, which are knowing and understanding AI, the ability to use and apply AI, the ability to evaluate and create AI, and AI ethics. This framework is supplemented by the Hillers framework [37], which has some similarities but also provides more depth to these three elements and includes the ethical use of AI tools, the knowledge of AI affordances, use, and application, working effectively with AI tools, and evaluation of AI output, and use and integration into practice.

Methods

This study aims to inform the field about the best practices for integrating GAI tools into engineering education pedagogy and assessment. To achieve this aim, a qualitative within-case

study design will be employed. According to Merriam [38], “a qualitative case study is an intensive, holistic description and analysis of a single instance, phenomenon, or social unit.” (p. 27). Specifically, this study will use a *within-case stud*y design as conceptualized by Baxter and Jack by integrating data on how instructors have successfully implemented GAI in their classrooms and course design in addition to the students’ experience using GAI. This integration is geared at ensuring a holistic understanding of GAI in engineering education.

Context

The data for this study will be collected from a year-long case study of an undergraduate engineering classroom at a large land grant R1 University on the East Coast of the United States. In this study, we will focus on the instructors’ and students' experiences in the engineering classroom. Participants will be recruited from multiple departments and courses within the University’s College of Engineering.

Data Collection and Analysis

Data will be collected between Fall 2024 and Spring 2025. Semi-structured interviews, classroom observation notes, end-of-semester reflections, course assignments, syllabi, end-of-course evaluations, and teachers’ instructional materials will be collected throughout the period of study. Five to ten faculty who have taught and/or designed undergraduate engineering courses that utilize GAI tools will be engaged in the study. We hope to recruit one hundred engineering undergraduate students for the study. As criteria for student participants in our study, only undergraduate students who have participated in courses utilizing GAI will be recruited for the study**.** Also, they will be students taking a course from faculty who have consented to participate in our study. Our focus will be engineering majors consistent with our research goal of understanding the effectiveness of GAI in engineering classes[39].

Classroom observation will last for thirty to forty-five minutes. Also, the semi-structured interview with faculty will last for about fifty minutes. The interview questions will include participant knowledge of GAI tools, participants' experience using GAI in the course, the challenges encountered during the use of GAI in the classroom, and academic integrity concerns using GAI. Interview data will be transcribed using a third-party transcription service; the transcribed data will be coded using NVIVO software. For data analysis, thematic analysis will be employed to make sense of the data [40]. Members of the research team will familiarize themselves with the data by reading through the transcription repeatedly while taking memos. The coder will open-code the qualitative data in an iterative manner to identify both broader and finer codes. The trustworthiness of the analysis will be ensured [41].

Conclusions, Next Steps, and Future Work

GAI presents a promising avenue for revolutionizing engineering education, offering potential benefits in instructional design, classroom pedagogy, and assessment. This study provides an initial exploration into the implementation of GAI tools, in an engineering classroom at a Land Grant R1 University on the East Coast of the United States. The findings from this study will

inform engineering instructors about the pros and cons of use of GAI, for facilitating students learning and engagement. Also, the results will better inform recommendations to GAI developers to use inclusive training data to cater to diverse learners.

The next steps for this study will involve rigorous data collection and analysis from multiple sources, including faculty interviews, classroom observations, student reflections, course assignments, syllabi, and teaching effectiveness ratings. Triangulating these diverse data sources will provide a comprehensive understanding of the impact of GAI on learning experiences. The anticipated outcome of this research is to contribute data-driven evidence on the effectiveness of GAI in engineering education. Further analysis will focus on identifying pedagogical practices that leverage GAI effectively, fostering deeper insights into its transformative potential in engineering courses. The study aims to offer recommendations for pedagogical practices based on the empirical evidence collected. These recommendations can guide engineering instructors in integrating GAI tools seamlessly into their courses, optimizing their instructional design and assessment strategies. The study will critically evaluate the limitations of GAI in engineering education and propose suggestions for improvement. This includes addressing challenges related to seamless human-AI collaboration, aligning AI outputs with learning objectives, and benchmarking assessments.

Future efforts should consider the long-term impact of integrating GAI in engineering education by deploying longitudinal studies to gain deeper insights. This would involve tracking the progress of students who have experienced GAI tools throughout their academic journey and into their professional careers. In-depth studies should be done to compare students' performance during several semesters with and without the use of GAI tools, particularly isolating different course assessment components where the student's performance metrics were most influenced by GAI use. Also, as ethical concerns surrounding GAI persist, future studies should delve deeper into the issues of AI-assisted plagiarism, algorithmic bias, transparency, equity, data privacy, and security in engineering education learning and instruction.

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