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Piloting Implementation of Strategic Guidelines for AI use within an Engineering Design-Thinking Project

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ABSTRACT

CONTEXT

Artificial Intelligence (AI) is rapidly transforming teaching and learning in Engineering education. Simultaneously, design thinking (DT)—a human-centred approach to innovation—is important as a strategy for optimising engineering design projects. Despite DT's growing adoption, the integration of Generative AI (GenAI) and other AI tools across its phases remains underexplored.

PURPOSE OR GOAL

This study explores the strategic integration of AI tools within the DT framework in engineering education. Conducted as an exploratory pilot project, it aims to assess how embedding AI across DT phases can enhance both learning and innovative output. This pilot intends to give insights to the engineering education community on the design, implementation strategies, outcomes and challenges of integrating AI into a DT project, based on coordinator reflections.

APPROACH OR METHODOLOGY/METHODS

This was implemented as a pilot within a second-year elective at the University of Sydney. Various AI tools were integrated throughout the semester, aligned with DT stages. Student engagement and learning outcomes, as well as the challenges of strategically implementing AI tools within the curriculum are reflected upon through the unit coordinator’s lens.

ACTUAL OR ANTICIPATED OUTCOMES

There was a noticeable improvement in students’ management of complex tasks and engagement with the DT process. However, challenges included a steep learning curve for both students and the instructor, due to the need for introducing new tools and becoming proficient with a variety of tools, on a tight timeline. There was a need for better support in guiding critical engagement with AI and ensuring consistent skill development.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

AI tools can significantly enhance the DT process in engineering education, but successful integration requires attention to ethics and support for students and instructors. Expanding this approach across other disciplines could enhance educational outcomes and foster innovation.

KEYWORDS

Design Thinking, Artificial Intelligence, Engineering Education

Introduction

In engineering and project management education, the emergence of Generative Artificial Intelligence (GenAI) as well as other AI tools such as literature search and transcriptions tools, provide unprecedented opportunities to transform teaching and learning approaches to better prepare students for modern engineering challenges. Traditional educational approaches, often characterised by passive learning and theoretical instruction, are increasingly replaced by more interactive, project-based social and experiential learning frameworks (Ang et al., 2021). Among them, Design Thinking (DT) is a particularly effective approach due to its emphasis on user-centred problem-solving and iterative learning cycles (Milovanovic et al., 2021). Design thinking is an innovative problem-solving methodology that involves reframing complex problems with a human-centric approach that prioritises the user, their experience and emotions to arrive at human-centred solutions (Buchanan, 1992; Foster, 2021). Despite the increasing adoption of DT in engineering education, the potential synergies between DT and AI remain largely underexplored. This gap is reflected in the lack of strategic integration of AI tools in enhancing the DT processes within undergraduate engineering curricula, resulting in missed opportunities to maximise educational outcomes and increase student engagement in meaningful ways (Kamalov et al., 2023). Addressing this shortfall provides a significant opportunity to enhance the student learning experience and better prepare students for modern engineering challenges.

Introduction to Design Thinking

DT has emerged as a key methodology that advocates a human-centred approach with a strong focus on understanding and addressing the needs and experiences of end-users (Kamalov et al., 2023). This methodology ensures that the solutions developed are functional, yet efficient and user-friendly, tailored to meet specific real-world demands (Safitri, 2024). DT engages students in an iterative journey through five core stages: Empathise, Define, Ideate, Prototype, and Test. Each phase is designed to progressively deepen students' understanding of the end-user needs, challenge existing assumptions and explore a wide range of creative solutions, thereby enhancing their problem-solving abilities (Rodriguez et al., 2020). Further integration of DT and advanced technological tools (e.g., AI tools) has demonstrated significant improvements in the efficiency and effectiveness of learning cycles, thereby maximising the educational and innovative outcomes of DT (Rodriguez et al., 2020; Kamalov et al., 2023).

The Role and Potential of AI in Education

The transformative impact of AI on various fields has already emerged, among which the integration of AI in education has significantly progressed, influencing traditional teaching methods and learning processes (Boscardin, 2023). AI has been used in educational settings to create personalised learning experiences, provide adaptive feedback mechanisms, and increase student engagement (Boscardin, 2023). Jafari and Keykha (2024) explored the potential of AI in higher education by examining its impact across eight secondary subthemes: faculty members, students, the teaching and learning process, assessment, the development of educational structures, research structures, management structures, and academic culture. Their analysis also identified and categorised the various challenges AI poses for higher education institutions. In engineering education, Nikolic et al. (2024) conducted a comprehensive review of various GenAI tools and their suitability for various assessment contexts. Within this paper, the authors emphasised on the benefits brought about by using multiple GenAI tools for project work. Meanwhile, Usman et al. (2024) underscores the transformative power of AI in revolutionising industries via intelligent automation and decision-making. By leveraging AI, organisations can tap into unprecedented innovation, efficiency, and growth opportunities. This shift addresses critical societal issues and ensures a sustainable future for all stakeholders.

Within the framework of DT in engineering education, AI can play a key role at each stage of the DT process. For instance, during the Empathise and Define phases, AI-driven analytics can provide deeper and more nuanced insights into user behaviours and needs, while considering the paradoxical implications between sense-making and sense-taking between GenAI and the user (Clegg & Sarkar, 2024). In the Ideate phase, AI can help expand the creative possibilities by generating diverse and innovative solution ideas (Choi, 2024). During the Prototype phase, GenAI can facilitate rapid prototyping through automated design and testing tools, significantly accelerating the iterative design process and enabling effective solution refinement.

The Gap of Applying AI in DT Projects

Despite the promising outlook of integrating AI into DT, significant gaps, particularly in training and ethical considerations, require urgent attention (Liang, 2023). As AI becomes increasingly prevalent in educational settings, it is imperative to equip students with the necessary strategic and ethical frameworks to adeptly navigate the impacts of AI technologies. Integrating AI education into DT projects can enhance students' critical thinking skills, ethical reasoning, and understanding of the societal impacts of their designs. Furthermore, it is crucial to balance the benefits of AI tools and potential limitations, such as algorithmic bias, data privacy concerns, and the depersonalisation of the learning experience. Additionally, while AI has shown the potential to boost creativity and critical thinking (Safitri, 2024), further exploration is needed on how AI can enhance the DT process in engineering projects. Leveraging AI for ideation, rapid prototyping, and user feedback analysis can streamline workflows and lead to more innovative solutions. However, the lack of comprehensive research on the specific impacts of AI on DT outcomes in engineering education highlights the need for a deeper understanding of the synergies between AI and DT to maximise the potential of both approaches and promote educational innovation (Milovanovic et al., 2021).

Aim and Scope of this Research

This research is motivated by the need to explore how strategic integration of AI tools within the DT process can be specifically tailored for engineering and project management education. By systematically embedding AI tools (e.g., GenAI, automated literature search tools for information gathering, and AI-driven transcription services for efficient data processing) across the DT phases, this exploratory design research aims to significantly enhance both the learning process and the innovative output of engineering students. Conducted as a pilot project at the University of Sydney, this exploratory research seeks to design a scalable and replicable model that could potentially provide insights and frameworks for the integration of a variety of AI tools into DT projects for the engineering education community. Scope-wise, this report is primarily a reflection and evaluation from the pilot unit of study coordinator’s point of view, mainly drawn from the qualitative observations and discussions with students during class, and the qualitative observations of assessment submissions. The long-term goal is to optimise students' learning outcomes and to create a culture of innovation, critical thinking, and problem-solving among future engineers.

Methodology

Overview of the Pilot Project Design

The pilot program was conducted over one semester, from February to June 2024, and was supported by a University of Sydney Strategic Education Grant (SEG). This pilot was designed to gather data to inform the future application of AI-enhanced DT processes in larger core units (i.e. units of study with greater than 200 enrolments) across engineering disciplines.

The Pilot Unit and Assessment

The unit selected for this pilot is BMET2925/9925 Data, AI and Society in Health. It is an elective within the degree of Biomedical Engineering. However, this is mandatory for students taking the Biocomputation specialisation.

In the semester of delivery, the unit consisted of 87 students. The cohort composition was 55%-45% Female-Male and 35%-65% International-Domestic. Most students taking the unit were in their undergraduate degree's second or fourth year. However, enrolments included students from various stages, including seven postgraduate students.

This unit was chosen as a pilot because AI tools, specifically ChatGPT, had already been integrated into one of its major assessments in the previous year, providing an established framework for the pilot. The assessment, spanning nine weeks, required students to understand key problems faced by a specific healthcare organisation chosen by the student, such as the orthopaedic surgical theatre of a hospital. Students brainstormed AI tool ideas to address these problems, considering the overall impact and feasibility of implementation. Students then had to write a report on the implementation of the AI tool within the selected organisation. The assessment underwent several modifications pertinent to this paper over the past three years: In 2022, the students conducted online research without AI tools, relying on critical thinking and available resources; in 2023, ChatGPT was introduced, increasing productivity and allowing for the necessary time for students to engage directly with stakeholders to understand real-world issues, thereby enhancing the realism and networking aspects of the assessment.

Final Iteration of Assessment for Pilot Project in 2024

In 2024, the assessment was further expanded to include a range of AI tools, including text-based GenAI (e.g., ChatGPT, Google Gemini, Perplexity, Cogniti, Microsoft Copilot), literature search tools (e.g., Lumina Chat, Scite), transcription tools (e.g., AssemblyAI, Otter.ai, Notta), and reference managers (e.g., Mendeley, Paperpile). Tools were selected based on the presence of accessible and functional free plans at the point at which the semester started. Tutorials were designed to introduce and demonstrate the use of these tools based on their relevance to the assessment tasks. The assessment was structured around the DT framework, with the project divided into weekly checkpoints corresponding to the stages of DT as well as the assessment goals:

Weeks 1-4: Empathise Stage: Initial background research and stakeholder engagement.

Week 5: Define and Ideate Stages: Problem definition and brainstorming solutions.

Weeks 6-7: Prototype and Test Stages: Conceptual prototyping and testing within written reports.

Weeks 8-9: Iterative Review: Additional time allocated for revisiting and refining previous stages.

Weekly tutorials included 30-minute sessions introducing AI tools relevant to the upcoming stage of the project. Demonstrations and hands-on activities were conducted to ensure students could apply these tools effectively, while also managing cognitive load by gradually introducing relevant AI tools across the first six weeks.

In its final iteration, the primary learning outcomes for the assessment were (a) developing a deeper understanding of the user problems in order to enhance design solutions, (b) critical evaluation of the feasibility and ethical implications of AI tool implementation with healthcare, and (c) developing proficiency with AI tool use for improved productivity.

Pedagogical Alignment and Design Principles

Pedagogical Considerations: The synergy of Bloom's Taxonomy with Design Thinking and AI tools creates a robust educational framework that addresses various learning styles and needs and prepares students for success in modern, dynamic environments. Integrating AI tools was strategically designed to help students become more productive with routine tasks, such as email writing, initial background research, and scripting interview questions or questionnaires. By reducing time spent on these ‘menial tasks’, students could allocate more time to activities requiring deeper cognitive engagement, such as networking with stakeholders, problem definition, and ideation. To ensure students maintained foundational skills, tutorials first focussed on working on skills such as literature searches, written and verbal communication and problem solving *without* AI. Thereafter, they were taught how to utilise AI to improve productivity and efficiency, while utilising their foundational skills to ensure that AI responses were of appropriate quality. Assessed checkpoint submissions in weeks 3 and 7 of the semester required students to submit the first drafts of their emails and interview/questionnaire questions respectively, to ensure that their progress was assessed at key points of the semester, prior to their final report.

Collaboration and Stakeholder Involvement

Collaboration with academic and industry experts: A six-member external advisory team was formed to support the pilot project's brainstorming, design, strategic implementation of AI tools, and troubleshooting. The team comprised four academics (three national, one international) and two industry professionals (one national, one international). This collaborative approach ensured that the project benefited from diverse perspectives and expertise, contributing to a robust and well-rounded design.

The advisory team played a crucial role in selecting AI tools, determining their application at various stages of the DT process, refining research approaches, and designing the unit and assessments to integrate DT and AI effectively. The industry professionals also provided feedback on the assessments of students who opted-in for further evaluation of their reports, offering industry insights that enhanced the relevance and authenticity of the project tasks.

Assessment integrity

The assessment was essentially almost completely open to AI use, with the only exception being if stakeholders did not consent to utilising AI for transcription/evaluation of their discussions. The focus was on creating assessment tasks that require critical thinking, problem-solving, and creativity skills less likely to be directly replicated by AI tools. In order to ensure that students were still utilising their own skills throughout the process, a number of steps were taken: (a) looking into appropriate personalisation of emails in week 3 checkpoint, (b) evidence provided for having run interviews with stakeholders via recordings or transcripts, with necessary consent, within the week 7 checkpoint and (c) screenshots of key references highlighting the specific text that students used for their work, along with the reference list in the final submission.

Reflection Survey

A reflection survey was designed to evaluate the impact of AI tools on students' design thinking processes. The surveys were conducted to identify the best approaches for implementing DT and AI in future units, and were intended primarily for internal faculty use and to gather data on how students utilised and perceived these tools during their projects. In addition, as there is no ethics clearance to disclose the results of this survey, the survey results are not explored in this paper.

Analysis and Evaluation

Initial Observations and Reflections based on instructor perceptions

The following is a reflection and evaluation from the unit of study coordinator's point of view regarding his experience in the integration of AI tools within the DT process for his unit of study BMET2925/9925, mainly drawn from the qualitative observations and discussions with students during class, and the qualitative observations of submitted assessments.

Student Engagement and Interaction

The initial deployment of AI tools in educational settings was met with substantial scepticism, primarily due to fears concerning academic honesty. Many students viewed adopting AI tools and using them to assist in assessment completion and submission as possibly unethical, resulting in hesitancy in disclosing their use of such technologies. Even students who had previously utilised AI tools frequently expressed uncertainty about such ethical limits.

As the course progressed, our pedagogical approach, which included tutorials and hands-on activities, helped to shift students' perspectives. These sessions clarified that the ethical use of AI tools was permissible and encouraged within the unit's boundaries. This understanding was crucial in alleviating initial concerns and fostering a more open and constructive engagement with AI tools. Our inquiries revealed that while most students were familiar with ChatGPT, only a few had experimented with other AI tools such as Google Gemini. There was a general lack of awareness about AI tools for more specialised tasks like literature reviews, transcription and reference management. For many students, these tools represented a new and untapped potential of AI. The overall engagement with these AI tools was positive, with students reporting significant time savings. However, while some students found the AI-generated outputs satisfactory, others were less impressed, preferring their manually crafted work. This scepticism about AI's utility in academic tasks reflects a hesitancy by some students to fully trust AI in contexts that require critical thinking and creativity (Mousavi., et al. 2023; Butson & Lim, 2023).

Challenges and Benefits of Implementing AI Tools in Education

Integrating AI tools into the curriculum, led by the unit coordinator, was highly beneficial in meeting the unit's learning objectives. The objective of allowing for free use of AI tools was to allow students to shift their focus from menial tasks to more cognitively demanding activities, such as engaging deeply with stakeholders, empathizing with their problems, and defining issues more effectively and meaningfully. Dimitriadou and Lanitis (2023) explore a range of emerging AI-assisted technologies that encompass class management, teaching aids, and performance assessment tools. For each intelligent classroom technology discussed, the role of AI is examined, thereby clarifying AI's contributions to enhancing intelligent classroom environments. Algahtani (2024) conducted a detailed examination of AI-driven educational tools, focusing on their influence on user experience and educational efficacy, and this study also underscored the importance of comprehending teacher perspectives and experiences with AI to incorporate these technologies into educational frameworks seamlessly.

A significant challenge was the lack of pre-existing resources or materials, necessitating that the unit coordinator independently gathers information and develop proficiency with these tools. This required extensive online research and consultations with both the project team and the external advisory group. Additionally, each tutorial included sessions focused on both the technical aspects of AI and fundamental communication skills, such as drafting effective emails and interview questions, which were necessary for students to critically evaluate AI-generated content. Institutional policies added another layer of complexity. While the university did not prohibit the use of AI tools, it only allowed certain tools, such as a University proprietary GenAI tool Cogniti, and later Microsoft CoPilot, to be mandated for coursework. Other AI tools were permitted but could not be made mandatory. Despite these limitations, students were encouraged to explore these technologies on an optional basis. The recent paper by Nikolic (2024) emphasises the benefits of utilising multiple Gen AI tools for project work. Ethical standards were also emphasised, with students required to anonymise any identifying information from interviews and obtain consent from stakeholders before using AI tools. This consent process was rigorously enforced, ensuring that students adhered to ethical guidelines throughout the project.

Lessons Learned

Technical and Logistical Challenges

The unit coordinator faced a steep learning curve in navigating the broader AI tool landscape, which required self-directed learning and adaptation during the course. This experience highlights the importance of providing adequate support and resources for instructors when integrating new technologies into the curriculum. Despite these challenges, the faculty's full support, bolstered by a university grant, was instrumental in ensuring the successful implementation of AI tools.

Pedagogical Challenges

Aligning AI tools with the Design Thinking (DT) framework presented additional challenges. Integrating AI tools into the DT process required significant adjustments and was supported through consultations with the external advisory team. This experience underscores the need for ongoing professional development and collaborative support when introducing complex pedagogical innovations.

Ethical Considerations

Ethical considerations were paramount in implementing AI tools, particularly their use in human-centred design tasks. Students were required to obtain explicit consent from stakeholders before utilizing AI to process the information gathered. This consent process included informing stakeholders about the potential use of AI tools before interviews and ensuring that any private information was anonymised. Additionally, students needed to inform interviewees that the information gathered during the interview would be included in a report accessible to teaching staff. This rigorous consent process was necessary to maintain ethical standards and transparency.

A further ethical concern involved the varying levels of reliance on AI tools among students. Over-reliance on AI could undermine the development of essential skills, such as communication, writing, and conducting literature reviews. Conversely, students who under-relied on AI tools might have spent more time on assessments, potentially leading to difficulty keeping pace with their peers. This variation in tool usage highlighted the need for a balanced approach to AI integration, ensuring that students developed core skills while also benefiting from AI-enhanced efficiency. Moreover, integrating AI within educational frameworks presents an ongoing challenge due to the rapid pace of AI tool development. Resources for staff and students must be continuously evaluated and updated to remain relevant. For example, a key challenge faced was related to the focus on providing free tools to students for accessibility. However, some tools, such as Scite, which had a highly functional free tier at the start of the semester, transitioned to being almost exclusively a paid tool by the time it was introduced to students.

Potential Impact and Future Directions

Scalability and Transferability

The potential for scaling and transferring this project to other units within the Faculty of Engineering is significant. The reflection surveys provide valuable insights into students' experiences with various AI tools, revealing which tools were most and least favoured, the perceived benefits, and students' confidence in using them. By analysing these insights, we can draw correlations between students' confidence in using AI tools and the perceived benefits they experienced. Understanding the motivations behind tool usage—whether for efficiency, accessibility, or innovation—would further enriches our analyses. The extent of tool usage can be correlated with students' confidence levels, providing a comprehensive view of how these tools impacted the learning process. While the data from the reflection surveys cannot be directly used in this publication, these insights will guide decisions on which tools to implement and how to improve their integration in larger units.

Looking forward, we are developing a site on Canvas, our learning management system (LMS) specifically designed for design thinking and AI tool integration. This platform will serve as a comprehensive resource for both staff and students. This resource will allow staff to upskill themselves and act as a reference for students on AI use in DT projects. The benefit of this is two fold: (i) It provides a one-stop shop for staff to learn about DT and the available AI tools surrounding this approach, and (ii) Enables staff to reduce the amount of time dedicated to teaching students about DT and available AI tools in class, as they could simply refer the students to the Canvas site. Moreover, we plan to integrate an AI chatbot into this Canvas site, which will act as a consultant for design thinking and AI tool use. This AI-driven resource will streamline the learning process, making it easier to apply this approach across different units and disciplines within engineering and for students to get quick answers to basic questions.

However, the Faculty of Engineering encompasses various disciplines, each with unique project requirements. While communication with stakeholders may be a common thread across disciplines within DT projects, the specific engineering design components in fields like computer science, project management, or electrical engineering can vary significantly. This diversity poses a challenge in transferring the pilot project's approach to these other fields. Input from course coordinators will be essential in adapting the Canvas site to meet the needs of various engineering disciplines. Additionally, a "Students as Partners" approach could be employed, involving students in tailoring resources for different fields.

Long-Term Vision: Navigating the Evolving Landscape of AI in Education

Integrating AI within educational frameworks presents an ongoing challenge due to the rapid pace of AI tool development. Resources for both staff and students must be continuously updated to remain relevant. While our current focus is on providing free tools, some may transition to paid models, as seen during our pilot program. Moreover, the evolving landscape of education and industry necessitates anticipating which AI tools will become commonplace and identifying engineering areas that might resist AI adoption. Fostering collaborations with other academics and industry partners who are active in AI may facilitate keeping pace with this rapidly evolving field.

Conclusion

This study explored the strategic integration of AI tools within the DT framework in engineering education, focusing on the unit coordinator's perspectives. Conducted as a pilot in a second-year elective at the University, the project highlighted both the benefits and challenges of embedding AI into the DT process. While AI tools facilitated deeper engagement and more efficient workflows, the implementation required a steep learning curve, new instructional materials, and careful management of ethical concerns.

The coordinator's reflections underscore the need for ongoing support and professional development to navigate the complexities of AI integration. These insights are critical for informing the expansion of AI-enhanced DT processes into larger core units across engineering disciplines. Future efforts should focus on refining these practices and addressing the challenges identified to fully realise AI's potential in engineering education.

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