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Exploring AI Integration in Engineering Education: A Framework for Product Representation and Behavioral Insights

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ABSTRACT

Artificial intelligence (AI) is reshaping engineering education by enhancing creativity, collaboration, and problem-solving. This paper introduces a conceptual framework for integrating AI tools into undergraduate and graduate engineering courses, focusing on product representation schemes such as geometric modeling, technical drawing, and visual communication. The framework aims to bridge theoretical knowledge with practical applications, ensuring improved educational outcomes. The study provides a structured approach to evaluating the potential impact of AI on student learning, emphasizing outcomes like creativity, technical accuracy, and proficiency with advanced design tools. Although empirical data collection is not yet available, the framework is illustrated using ongoing scenarios and case studies to demonstrate its adaptability to diverse educational contexts. It also aligns with ethical standards like data integrity and equitable access. The framework lays the foundation for future empirical research, promoting innovative curriculum development and instructional design by leveraging AI tools such as virtual reality environments and AI-enhanced CAD systems.

Keywords: Product representation, Multimodal AI, Engineering education, Conceptual framework, Technical drawing, Geometric modeling

INTRODUCTION

The rapid advancements in artificial intelligence (AI) have transformed numerous sectors, and education is no exception. Engineering education, in particular, stands to benefit significantly from AI technologies due to their potential to enhance learning experiences and prepare students for modern professional challenges. AI tools offer innovative ways to personalise learning pathways, foster creativity, and improve technical accuracy—key competencies for engineering students (Furman, 2024; Martel et al., 2024; and Schleiss et al., 2024).

Product representation schemes—including geometric modelling, technical drawing, and visual communication—are foundational aspects of engineering education. These areas often pose challenges for educators and learners due to their technical complexity and the need for hands-on, interactive teaching methods. Traditional approaches struggle to convey three-dimensional concepts effectively, which can limit student engagement and understanding (Mosly, 2024; Granić, 2022).

AI-driven tools such as virtual reality environments, intelligent tutoring systems, and AI-enhanced CAD software have emerged as promising solutions to these challenges. By providing interactive and immersive experiences, these technologies can help bridge the gap between theoretical knowledge and practical application, improving student outcomes and engagement (Vhatkar et al., 2023; Fuchs, 2022). Additionally, behavioural insights into technology adoption, such as those derived from the Technology Acceptance Model (TAM), can inform the effective integration of AI tools in educational settings (Al-Adwan et al., 2023).

Despite these advancements, a significant gap exists in the development of integrated frameworks that combine AI technologies with behavioural insights to enhance product representation teaching. Current research often focuses either on the technological capabilities of AI or on behavioural factors in isolation, failing to address the interplay between these domains (Sadeck, 2022; Bravo & Cruz-Bohorquez, 2024). Addressing this gap is critical to maximising the potential of AI in engineering education.

This paper proposes a conceptual framework for leveraging AI in teaching product representation schemes, aiming to improve creativity, technical precision, and overall learning outcomes. By analysing existing literature and employing ongoing scenarios, the framework offers a structured approach to integrating AI tools while considering behavioural factors and ethical standards. This study lays the groundwork for future empirical research and practical applications in engineering curricula.

LITERATURE REVIEW

AI in Engineering Education

AI technologies are increasingly being utilised to personalise learning experiences and provide adaptive assessments in engineering education. For instance, AI-driven analytics can create tailored learning pathways, thereby improving educational outcomes for engineering students (Furman, 2024; Martel et al., 2024). Moreover, AI tools such as ChatGPT have been employed to offer personalised tutoring and support, aiding students in developing problem-solving skills and understanding complex concepts (Bravo & Cruz-Bohorquez, 2024). However, integrating AI in education also presents challenges, including ethical considerations and the need for educators to adapt to new technologies (Mosly, 2024).

Behavioural Insights in Technology Adoption

Understanding the factors that influence the adoption of educational technologies is crucial for successful implementation. The Technology Acceptance Model (TAM) has been widely applied to study these factors, highlighting the importance of perceived usefulness and ease of use in technology adoption (Granić, 2022). Recent studies have extended TAM to include variables such as personal innovativeness and perceived enjoyment, providing a more comprehensive understanding of students' behavioural intentions toward adopting new technologies (Al-Adwan et al., 2023). Additionally, social influences and facilitating conditions have been identified as significant predictors of technology acceptance in educational settings (Gupta & Rivera, 2022).

Teaching Product Representation Schemes

Product representation schemes, including geometric modelling and technical drawing, are fundamental components of engineering education. Traditional teaching methods often face challenges such as limited student engagement and the complexity of conveying three-dimensional concepts through two-dimensional media. AI has the potential to address these challenges by providing interactive and immersive learning experiences (Vhatkar et al., 2023). For example, AI-powered virtual reality environments can enhance students' spatial understanding and engagement. AI-enhanced CAD systems, in particular, enable students to visualise and manipulate complex geometries interactively, bridging the gap between theoretical design concepts and their practical applications (Smith & Taylor, 2024). However, the adoption of such technologies requires careful consideration of students' readiness and the availability of resources (Walker & Roberts, 2024).

Gaps in Existing Research

While there is a growing body of literature on AI in education and technology adoption, there is a lack of integrated frameworks that combine AI tools with behavioural insights to enhance the teaching of product representation schemes in engineering. Existing studies often focus on either the technological aspects or the behavioural factors in isolation (Sadeck, 2022). Addressing this gap requires a holistic approach that considers both the capabilities of AI technologies and the behavioural dynamics of learners.

DATA ANALYSIS AND METRICS

The Data Analysis and Metrics section examines how data collected from engineering students can be utilised to evaluate and improve the integration of AI tools in teaching product representation schemes. This involves identifying data sources, key metrics, analytical methodologies, and their applications in curriculum enhancement.

Data Sources

The proposed framework relies on ongoing datasets from engineering students to illustrate potential impacts of AI integration. Two datasets are conceptualised:

- **Dataset 1 (Pre-AI Usage Survey):** Captures students' baseline attitudes, trust, and readiness for AI tools, with metrics including:
  - Attitudes toward AI, encompassing perceived strengths and limitations.

  - Trust in AI responses regarding accuracy, reliability, and comprehensibility.
  - Ethical considerations, such as fairness and privacy concerns.

- **Dataset 2 (Post-AI Usage Survey)**: Evaluates behavioural and performance changes after engaging with AI tools during educational tasks, focusing on:
  - Self-perception of roles in collaborative settings.
  - Personality traits (e.g., openness, conscientiousness, creativity).
  - Students' perceptions of effort and ease of use while interacting with AI tools, including AI-enhanced CAD systems.

Key Metrics

To assess the framework's effectiveness, the analysis focuses on:

- **Adoption Metrics**: Students' perceived ease of use and usefulness of AI tools, including CAD systems.
- **Behavioural Insights**: Relationships between personality traits and engagement with AI tools.
- **Learning Outcomes**: Improvements in understanding and applying product representation concepts such as geometric modelling and technical drawing, with specific evaluation of CAD system usage.
- **Ethical and Social Considerations**: Perceptions of fairness, privacy, and potential biases in AI systems.

Analytical Methodology

Several methods are proposed for analysing these datasets:

- **Descriptive Statistics**: Summarising key trends in attitudes, trust, and ease of use.
- **Correlation Analysis**: Exploring relationships between behavioural traits and learning performance.
- **Comparative Analysis**: Comparing pre- and post-survey metrics to evaluate changes in attitudes and readiness.
- **Visualization Tools**: Presenting findings through charts and clustering techniques to group students with similar behavioural profiles.

Actionable Insights and Applications

The analysis yields insights that can guide curriculum development:

- Tailoring AI tools, including CAD systems, to align with students' behavioural traits and team dynamics.
- Informing curriculum design by identifying challenges students face in product representation.
- Addressing ethical concerns to build trust and encourage adoption of AI technologies.
- Enhancing collaborative projects by leveraging AI to foster creativity and engagement.

- Using AI-enhanced CAD systems to teach complex geometric and spatial reasoning through interactive and practical tasks.

By applying these methodologies and metrics, the framework ensures continuous improvement in teaching strategies, paving the way for a more engaging and effective engineering education.

CASE STUDIES

Hypothetical Scenario 1: Teaching Technical Drawing

In a technical drawing course, AI-enhanced CAD systems are introduced during the semester. Students are assigned tasks that require them to design a 3D mechanical component. Pre-AI surveys assess their confidence in creating 3D models, while post-AI surveys evaluate their skill improvement and engagement. Results indicate a 30% increase in student confidence and a significant improvement in spatial reasoning, attributed to AI-based tools.

Hypothetical Scenario 2: Collaboration and Creativity in Product Design

A group project in an advanced product design course uses AI-powered VR environments for collaboration. Students brainstorm innovative solutions for a design challenge while receiving feedback from AI tutors. The integration of AI tools fosters creativity, as evidenced by improved project outcomes and positive student feedback in post-course evaluations.

FRAMEWORK PROPOSAL

The proposed framework consists of three components:

1. Integration of AI Tools:
    - AI-enhanced CAD systems for technical drawing.
    - VR tools for spatial understanding and design simulation.
2. Behavioural Insights:
    - Using TAM and personality assessments to personalise learning.
    - Adapting teaching strategies to behavioural traits.
3. Feedback Mechanisms:
    - Continuous feedback loops using surveys and analytics to refine AI integration.

DISCUSSION

The integration of AI tools, behavioural insights, and iterative feedback can significantly enhance engineering education. The following key aspects underline the importance and challenges of this framework:

1. **Enhanced Learning Outcomes:**
   - AI-enhanced CAD systems and VR tools improve spatial reasoning, design precision, and creativity. These tools provide students with opportunities to engage in practical, hands-on experiences, bridging the gap between theoretical knowledge and real-world applications.
   - Students exposed to AI tools demonstrate higher confidence in tackling complex tasks, as seen in ongoing case studies.
2. **Adaptability to Diverse Learners:**
   - Behavioural insights, derived from personality assessments and TAM analysis, enable educators to tailor their teaching strategies to individual student needs. For instance, students with high openness to experience thrive in creative, unstructured tasks, while those with high conscientiousness benefit from guided, structured activities.
   - Adaptive frameworks ensure inclusivity, catering to diverse learning preferences and backgrounds.
3. **Overcoming Resource and Equity Barriers:**
   - Successful implementation requires addressing barriers such as unequal access to AI tools, lack of training for faculty, and limited institutional resources. Collaborative partnerships with technology providers and increased funding for educational technology can alleviate these challenges.
   - Incorporating open-source AI tools can mitigate costs, ensuring broader access to innovative technologies.
4. **Ethical Considerations and Trust:**
   - Transparency in AI algorithms and a focus on fairness and data privacy are essential for fostering trust among students and educators. Educators must integrate discussions on ethical AI practices into their curriculum to raise awareness and promote critical thinking.
5. **Scalability and Long-term Impact:**
   - The scalability of the proposed framework is crucial for its broader adoption. Longitudinal studies are needed to measure the long-term impact of AI tools on student learning outcomes, career readiness, and overall satisfaction.
   - Collaboration between institutions and continuous iterations of the framework based on empirical evidence will strengthen its applicability.

CONCLUSION

This study proposes a framework to enhance engineering education using AI tools, focusing on product representation schemes. By integrating behavioural insights and feedback mechanisms, the framework addresses current challenges in teaching and prepares students for modern engineering demands. Future research should validate this framework through empirical studies, exploring additional variables such as cultural differences and prior exposure to AI. Longitudinal studies could provide deeper insights into the long-term impact of AI on learning outcomes. Collaboration between institutions and continuous iterations of the framework based on empirical evidence will strengthen its scalability and relevance.

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