Exploring the Potential of AI-Generated Lesson Designs Underpinned by the TPACK Framework for Educators in Higher Education: A Comparative Study

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Abstract: *This paper investigates the potential of integrating generative AI into lesson design underpinned by the Technological Pedagogical Content Knowledge (TPACK) framework for educators in higher education. The study introduces a novel workflow that uses multiple AI agents to generate tailored lesson designs in two learning environments: one in a traditional classroom and another in the metaverse learning environment. A comparative study was conducted in a university-level product design course using three lesson designs under three conditions: Lesson design (LD) 1 – Manually designed lesson design in a traditional classroom, LD 2 – AI-generated lesson design in a traditional classroom, and LD 3 – AI-generated lesson design in the metaverse environment. The TPACK framework with the same lesson objectives underpinned all the lesson designs. Through qualitative analysis, the paper compares the three lesson designs, examining the potential of AI-generated lesson designs in supporting teacher professional development. The findings indicate that AI-generated lesson designs have great potential to enhance lesson design underpinned by the TPACK framework for educators.*

Keywords: Generative AI, Lesson design, TPACK framework, Educational technology

1. Introduction

Technology integration into educational settings has profoundly transformed teaching practices, providing novel avenues for personalizing learning and fostering curriculum innovation. Despite these advancements, traditional approaches to lesson design often fall short in adaptability, struggling to keep pace with the rapidly evolving technological landscape. This gap underscores the need for robust frameworks that facilitate a more effective integration of these critical elements. The Technological Pedagogical Content Knowledge (TPACK) framework, introduced by Mishra and Koehler (2006), offers a comprehensive model that synergizes technology, pedagogy, and content knowledge, thereby enhancing the design of educational practices. This framework has been extended into various models, such as BOPPPS-TPACK and TPCK-W, which assist educators in acquiring and applying integrated knowledge in their teaching endeavors (Lee & Tsai, 2010; Zhang & Zhou, 2023).

However, the continuous evolution of educational technology necessitates ongoing adaptations of the TPACK framework to embrace new technological innovations and meet diverse educational needs effectively. In this context, recent developments in generative AI represent a significant opportunity, offering the capability to automate the creation of lesson designs that are contextually relevant and pedagogically coherent. Research by Durmus (2024) demonstrates the potential of tools like ChatGPT to reduce the time required for lesson design significantly. However, some studies also highlight limitations, such as the rudimentary nature of AI-generated lesson designs, which often require substantial refinement (Duha, 2023). These challenges stem from the general limitations of large language models, which may not adequately address the specificities of diverse educational contexts. Against this background, this paper aims to explore a novel workflow based on the TPACK framework, integrating multiple generative AI agents to bridge this gap.

2. Development of a lesson design workflow with multiple AI agents underpinned by the TPACK framework

Generative AI, while powerful in automating many aspects of educational design, still faces inherent limitations. These include the inability to handle particular, nuanced requests or customize lesson designs that require deep domain expertise. For instance, customizing lesson designs necessitates deep knowledge of subject matter, which generative AI lacks, potentially resulting in inaccuracies or oversimplifications (Giannakos et al., 2024). To address these challenges and enhance the flexibility of AI-generated lesson designs, the integration of multiple agents and Retrieval-Augmented Generation (RAG) technology can be employed.

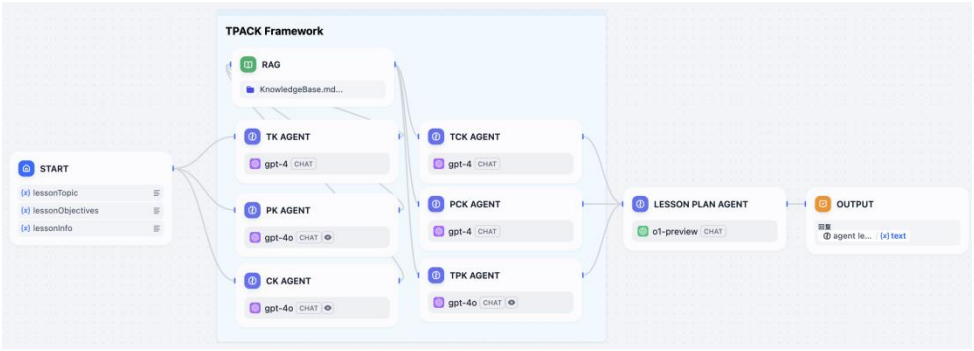

Fig.1 A lesson design workflow with multiple agents underpinned by the TPACK framework

Based on these technologies, the study developed a workflow integrating six distinct agents (see Figure 1). This workflow commences with the input of basic course information, followed by a two-stage lesson design process designed based on the TPACK framework. In the first stage, the TK (Technological Knowledge), PK (Pedagogical Knowledge), and CK (Content Knowledge) agents utilize RAG technology to retrieve the most relevant information based on the input. This information is then fed into the second stage, which includes the TCK (Technological Content Knowledge), PCK (Pedagogical Content Knowledge), and TPK (Technological Pedagogical Knowledge) agents. These agents simulate a teacher's cognitive process, deliberating across the three dimensions of TPACK to refine the lesson design.

3. Method

3.1. Research design

To evaluate the potential of AI-generated lesson designs, a comparative study was conducted in a product design course in higher education. The research question is: What are the differences among the three lesson designs: Lesson design (LD) 1, designed the manually, LD 2 and LD 3 created by generative AI? A teacher provided a manually designed lesson design (LD 1), in which essential information from this course (e.g., topics, learning objectives, necessary knowledge, and duration) was extracted. The information was then input into the AI workflow to generate two distinct lesson designs: AI-generated for the traditional classroom (LD 2) and AI-generated lesson design in metaverse-based classroom (LD 3).

3.2. Data collection

The data collection involved qualitative data from three lesson designs aligned with the same learning objectives. In addition to the lesson designs, semi-structured interviews were conducted with the teacher who facilitated the lessons. These interviews aimed to collect the educator's insights and reflections on the utility, practicality, and pedagogical potential of using AI-generated lesson designs.

3.3. Data analysis

The qualitative analysis involved a detailed comparison of the three plans. Content analysis was utilized to examine the extent to which each design is aligned with the six categories of content delivery, technology integration,

pedagogical approach, student engagement, flexibility, and ease of implementation adapted from Savage (2014). Teacher interviews were coded based on the six categories as a framework.

4. Findings and Discussions

Table 1 demonstrates a progressive integration of technology and pedagogical innovation across three lesson designs (LDs). LD1 employs basic digital tools (slides, videos) and traditional lectures, offering simplicity but limited interactivity and flexibility. LD2 integrates structured digital content, AI assistance, and project-based learning, achieving moderate technological integration while enhancing engagement without compromising feasibility. LD3, built on the metaverse platform Learningverse (Song et al., 2023) and inquiry-based methods, creates an immersive learning environment, demanding advanced technical expertise but significantly deepening student participation and cognitive development.

Comparative analysis reveals a hierarchical evolution across three dimensions: technological advancement, pedagogical methodology, and interactivity. Implementation complexity aligns directly with technological sophistication, positioning LD1 as ideal for conventional educational contexts, LD2 as a transitional model for incremental digital adoption, and LD3 as a frontier framework for advanced technology-enabled learning environments.

Table 1. Comparison of three lesson designs adapted from Savage (2014)

Category	LD 1	LD 2	LD 3
Content Delivery	Basic digital tools (slides, videos)	Enhanced digital tools and structured content	Highly interactive and immersive tools
Technology Integration	Minimal, with basic presentation tools	Moderate, with digital tools and AI assistance	High, with AI assistance and the metaverse-Learningverse
Pedagogical Approach	Traditional lectures and discussions	More dynamic, Project-based with AI-scaffolding strategies	Inquiry-based, highly interactive methods
Student Engagement	Limited interactivity	Improved interaction and participation	Extensive engagement with immersive technology
Flexibility	Low	Moderate; allows some customization	High; adaptable to real-time feedback
Ease of implementation	High; familiar environment	Medium; requires familiarity with AI tools	Low; needs technological proficiency

Feedback from the teacher during interviews was positive towards the AI-generated lesson designs. The teacher noted the time-saving benefits and enhanced adaptability of educational content provided by AI, which also offered a broader range of perspectives and richer content. This facilitated greater critical thinking and creativity in problem-solving among educators.

5. Implications and limitations

The analysis shows that lesson designs generated based on the workflow align more closely with student-centered, innovative teaching philosophies and incorporate emerging technologies such as AI and the Metaverse. This integration opens up new avenues for teachers to expand their instructional technology, offering novel ways to enhance pedagogical practices. While the study highlights significant benefits of integrating AI into lesson design, several limitations were identified that suggest areas for future improvement. One notable limitation is the dependency on a well-prepared knowledge base for the RAG technology to produce high-quality lesson designs. This preparation requires educators to provide comprehensive and detailed content in advance, which can be time-consuming and demands a high level of subject expertise. Therefore, there is a pressing need to enhance teacher competency in digital tools and technologies. Providing adequate training and support is essential for teachers to successfully adopt and integrate these innovative educational technologies into their teaching practices.

6. Conclusion

In conclusion, this study highlights the significant potential of AI-generated lesson designs to enhance educational practices through tailored content, dynamic pedagogical strategies, and advanced technological integration. However, the successful implementation of such plans requires not only sophisticated technological setups but also substantial teacher preparation. Addressing the practical challenges of these implementations, particularly in terms of the technological proficiency of educators, is crucial. Thus, enhancing teacher digital competencies is essential to fully leverage the capabilities of AI in education (Scarci et al., 2024). This approach will not only facilitate the seamless integration of cutting-edge technologies into classrooms but also ensure that educational outcomes are maximized in an era of rapid technological advancement.

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