Integrating Generative AI in Teacher Education: A Qualitative Exploration of TPACK Growth and Critical Reflection

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Abstract
This study investigates how generative AI technologies influence pre-service teachers' pedagogical thinking and instructional design practices within a vocational education context. Drawing on a qualitative framework, the research engaged students in a task-based learning environment that integrated tools such as ChatGPT and image generators into authentic teaching design tasks. Data were collected through reflective journals, interviews, and teaching artifacts.
Thematic analysis revealed three core trajectories of professional growth: (1) a shift from uncertainty to confidence in using AI tools; (2) the situated development of TPACK through iterative design and reflection; and (3) the emergence of critical awareness regarding AI ethics, accuracy, and bias. Students not only explored how AI could support their instructional creativity, but also expressed concerns about content reliability and the limitations of automated outputs. Their reflections illustrated an evolving understanding of AI not just as a tool, but as a co-participant in instructional reasoning.
The findings suggest that meaningful integration of generative AI requires more than technical training; it calls for pedagogical framing, ethical discourse, and reflective space. Teacher education programs must therefore cultivate not only AI fluency, but also critical and adaptive instructional mindsets capable of navigating the complexities of AI-supported teaching.
Keywords: Generative AI, TPACK, Pre-Service Teachers, Critical Reflection, Vocational Education, Instructional Design

1. Research Background and Rationale

The rapid advancement of generative artificial intelligence (AI) tools—such as ChatGPT, DALL·E, and other content generation systems—has introduced new possibilities and tensions in teacher education. While such technologies offer novel forms of instructional support, they also challenge pre-service teachers to rethink the roles of creativity, authorship, and judgment in designing learning experiences. In vocational education contexts, where instructional precision and applied problem-solving are crucial, these tensions become even more pronounced.

Pre-service teachers, often lacking extensive teaching experience, may struggle to make informed, pedagogically sound decisions when confronted with powerful yet opaque AI tools. Traditional teacher training programs tend to emphasize technological fluency or tool functionality, yet seldom provide the reflective space needed to critically interpret AI-generated outputs or ethically navigate their use in educational settings.

This study emerges from the need to better understand not just *how* pre-service teachers use generative AI in instructional tasks, but *how they make sense of it*. Rather than treating AI as a neutral aid, the study conceptualizes it as a co-actor in the instructional design process—one that mediates teacher cognition, amplifies design possibilities, and provokes reflection. By situating the research in an authentic, task-based learning environment, this study aims to explore the following:

- How do pre-service teachers experience the integration of generative AI tools into their instructional design practices?
- In what ways does AI use influence their development of TPACK-related thinking and teaching identity?
- What challenges, tensions, and ethical reflections arise in the process of using AI to solve authentic pedagogical problems?

In addressing these questions, this study contributes to a growing body of scholarship calling for critical, experience-based approaches to AI in education—ones that honor the complexity of teaching, and the evolving identity of teachers as designers, evaluators, and ethical agents in AI-supported classrooms.

2. Literature Review

2.1 TPACK as Situated Knowledge Construction

The Technological Pedagogical Content Knowledge (TPACK) framework has long been used to conceptualize how teachers integrate technology into subject-specific instruction. Originally proposed by Mishra and Koehler (2006), TPACK emphasizes the dynamic interaction between technological, pedagogical, and content knowledge. However, recent scholarship suggests that TPACK is not merely a static knowledge set but a contextualized and situated form of professional reasoning that unfolds through practice, negotiation, and reflection (Chai, Koh, & Tsai, 2013).

In vocational education, this situated nature becomes especially salient. Pre-service teachers must navigate highly specialized content, practical problem-solving, and the demands of instructional clarity. Yet, due to limited teaching experience, many struggle to enact TPACK in a purposeful and reflective manner. Studies have shown that meaningful TPACK development requires engagement in authentic teaching tasks, where technology is not taught in isolation but embedded within pedagogical decision-making processes (Angeli & Valanides, 2009).

This study builds on this perspective by framing TPACK not as a competence to be measured, but as a developmental trajectory revealed through how teachers talk about, justify, and reflect on their instructional choices—particularly when interacting with emergent technologies like generative AI.

2.2 Generative AI as Pedagogical Mediator and Ethical Disruptor

Generative AI tools—capable of producing text, images, code, and assessment content—are increasingly seen as promising supports for lesson design (Xie et al., 2023). For novice teachers, these tools offer accessible scaffolds for planning, visualization, and language refinement (Lo, 2023). However, researchers have raised critical concerns about the opacity, bias, and reliability of AI-generated content. AI systems often lack domain precision and may embed cultural or gendered stereotypes due to limitations in their training data (Floridi & Chiriatti, 2020).

More importantly, the process of interacting with AI itself becomes pedagogically consequential. Rather than simply enhancing productivity, AI tools shape how pre-service teachers frame instructional problems, imagine teaching scenarios, and construct knowledge. Holmes et al. (2022) suggest that AI may function as an "external cognitive agent," with the power to both extend and distort human reasoning. This calls for educators to approach AI not just as a tool, but as a pedagogical co-participant—one that requires interpretation, critique, and discernment. In response, recent literature advocates for embedding AI ethics and critical AI literacy into teacher education. Students must learn to ask: *What does the AI assume? Whose knowledge is being represented? How might these outputs shape learner understanding?* (Zawacki-Richter et al., 2019). These are not technical questions, but deeply pedagogical ones, and they must be addressed through dialogic, reflective instructional design experiences.

2.3 Self-Efficacy and Reflective Growth in AI-Supported Learning

Bandura's (1997) concept of self-efficacy offers a valuable lens to understand how pre-service teachers develop confidence in technology-mediated teaching. Self-efficacy arises not only from mastery experiences, but also from vicarious observation, social feedback, and emotional regulation. In the context of AI-supported instruction, efficacy is shaped by how students interpret their successes and failures when using unfamiliar tools in high-stakes learning design tasks (Teo, 2011).

However, elevated confidence in using AI does not always equate to pedagogical soundness. Research warns of the risk of overconfidence or uncritical dependence when students are not trained to evaluate or contextualize AI outputs (Lo, 2023). Therefore, self-efficacy in AI contexts must be developed alongside critical reflection, dialogic learning, and iterative redesign—practices more commonly found in qualitative, narrative-rich teacher education models.

This study thus positions self-efficacy not merely as a belief state, but as an emergent construct, visible through the language, struggles, and adaptive strategies students employ as they learn to use AI reflectively and responsibly in their teaching practice.

3. Instructional Design and Course Implementation

The instructional intervention in this study was grounded in a task-based learning (TBL) framework, designed not merely to teach pre-service teachers how to operate generative AI tools, but to immerse them in reflective, authentic experiences of instructional design. The goal was to cultivate both technical fluency and critical pedagogical reasoning within a situated, vocational education context.

3.1 Course Structure and Pedagogical Philosophy

The course was structured around the principle that teachers learn best by designing for real learners. Over a fifteen-week period, students were tasked with developing complete instructional units for vocational subjects (e.g., mechanical engineering, applied design, electronics), with generative AI used as a support rather than a directive force. Students were encouraged to make autonomous decisions about when, how, and why to incorporate AI-generated content into their lesson plans, materials, and assessments.

Each week introduced a new design challenge, accompanied by reflective prompts that asked students to evaluate their choices, difficulties, and discoveries. The learning environment emphasized creative experimentation, peer dialogue, and iterative revision.

3.2 Learning Phases and Activities

The course unfolded in three interrelated phases, each designed to scaffold both knowledge construction and reflective insight:

Phase 1: Exploration and Critical Familiarization

Students were introduced to a range of generative AI tools (e.g., ChatGPT for text generation, Bing Image Creator for visual design, and AI-based quiz generators). Rather than focusing solely on functionality, the instruction emphasized critical exploration: What kinds of knowledge can these tools generate? What do they obscure? Where might they mislead?

Students engaged in hands-on experiments with prompts, followed by group discussions about bias, accuracy, tone, and instructional applicability.

Phase 2: Design-in-Action

Each student selected a vocational topic and began constructing an instructional unit. AI tools were used to support:

- Drafting instructional goals and outlines,
- Generating teaching texts and diagrams,
- Designing formative assessment items.

However, students were explicitly encouraged to critique, adapt, or discard AI outputs as needed. This phase emphasized *productive struggle*—allowing students to encounter breakdowns, confront uncertainty, and engage in pedagogical decision-making.

Phase 3: Reflection and Iterative Redesign

Throughout the course, students maintained reflective journals, documenting their evolving beliefs, challenges, and strategies. Weekly peer review sessions were held, where students presented their AI-enhanced designs, received feedback, and discussed ethical or practical tensions encountered.

By the end of the course, each student submitted a comprehensive teaching unit along with a reflective narrative analyzing their use of AI, their reasoning behind instructional decisions, and their evolving understanding of technology's role in pedagogy.

3.3 Role of the Instructor

The instructor acted as a facilitator and provocateur, guiding students to not only use tools effectively, but to ask difficult pedagogical questions. When students struggled with AI-generated inaccuracies or ambiguous outputs, the instructor prompted deeper analysis:

- *What is this tool assuming about learners?*
- *How might this image reinforce stereotypes?*
- *Could this response mislead students?*

Rather than correcting students directly, the instructor modeled critical inquiry and design thinking, aligning with the course's broader goal of fostering adaptive, ethically aware teaching mindsets.

4. Research Methodology

4.1 Research Design

This study adopted a qualitative research design grounded in a phenomenological approach to explore how pre-service teachers construct their TPACK competencies and develop AI self-efficacy through the integration of generative AI tools in authentic instructional design tasks. By focusing on participants' lived experiences, the study aimed to understand how AI use shapes their pedagogical reasoning, instructional strategies, and reflective practices.

4.2 Participants and Context
The participants were 18 pre-service teachers enrolled in a vocational teacher education course at a university in Taiwan. The course was structured around a task-based learning model that required students to design a complete instructional unit with the aid of generative AI tools (e.g., ChatGPT, Bing Image Creator, AI quiz generators).

4.3 Data Collection
Multiple data sources were used to ensure credibility and triangulation:

- Reflective journals: Participants documented their experiences, challenges, and learning insights throughout the course.
- Teaching artifacts: Lesson plans, instructional materials, and AI-generated content served as evidence of instructional decision-making.
- Semi-structured interviews: Conducted with 12 representative participants to explore deeper perspectives on AI integration, instructional reasoning, and perceived growth.

4.4 Data Analysis
Thematic analysis was conducted following Braun and Clarke's (2006) six-phase process:

(1). Familiarization with the data;
(2). Generation of initial codes;
(3). Searching for themes;
(4). Reviewing themes;
(5). Defining and naming themes;
(6). Producing the report.

Coding was performed manually and iteratively. Three overarching themes and eight subthemes were identified to represent the trajectory of TPACK development and AI self-efficacy transformation.

5. Research Findings
Thematic analysis of reflective journals, interview transcripts, and teaching artifacts revealed three overarching themes that capture how pre-service teachers engaged with generative AI tools during instructional design. These themes illustrate a developmental trajectory from initial uncertainty toward empowered use, while also uncovering emergent tensions around ethics, content credibility, and professional identity.

5.1 Theme 1: From Tool Confusion to Pedagogical Confidence
5.1.1 Initial Uncertainty and Functional Struggles
Many students began the course with limited experience using generative AI. Early reflections expressed confusion, hesitance, and even frustration:
"I didn't know how to phrase my prompt. I asked it to make a quiz, but the questions didn't make sense for my topic."

(Participant C, Journal)
This unfamiliarity often led to reliance on default prompts or superficial applications of AI-generated outputs.
5.1.2 Confidence Through Iterative Design
As students engaged in repeated cycles of trial, critique, and refinement, they gradually developed confidence—not only in operating AI tools, but in deciding when and how to use them effectively:
"At first I used everything it gave me. But later, I started thinking like a teacher: 'Is this really what I want my students to learn?'"

(Participant L, Interview)
This transformation reflects a shift from passive tool usage to active instructional reasoning, marking an important phase in pedagogical growth.

5.2 Theme 2: Constructing Situated TPACK Through AI-Enhanced Tasks
5.2.1 Aligning Technology with Pedagogical Purpose
Students began recognizing that AI-generated content needed to be filtered through pedagogical intent:
"ChatGPT gave me a nice explanation, but I had to simplify it and add a visual so vocational students could understand."

(Participant A, Journal)
This illustrates the development of Technological Pedagogical Knowledge (TPK) in context—where teachers mediate between content, tools, and learners' needs.

5.2.2 Deepening Content Representations (TCK)
In designing materials for vocational subjects, students used AI to generate illustrations or analogies that clarified abstract or mechanical concepts. However, they often felt the need to correct or contextualize the outputs:
"The diagram looked polished, but the labeling was wrong. I had to edit it to match the actual machine structure."

(Participant F, Interview)
These moments reveal emerging Technological Content Knowledge (TCK), where students combine disciplinary accuracy with multimodal presentation.

5.3 Theme 3: Emerging Critical AI Literacy and Ethical Reflection
5.3.1 Questioning the Reliability of AI Outputs
While students appreciated the efficiency of AI tools, many expressed growing skepticism regarding accuracy and content validity:
"Sometimes it sounds confident but is actually wrong. I learned to double-check everything before using it in class."

(Participant D, Interview)
This cautious stance signified the beginnings of critical AI literacy, as students became more discerning evaluators rather than passive adopters.
5.3.2 Ethical Tensions and Representational Concerns
Several students raised ethical concerns about authorship and bias:
"The AI created a teaching story, but I felt uncomfortable—who owns it? Can I really say it's mine?"

(Participant K, Journal)
Others noticed stereotypical representations in AI-generated visuals:
"Most images showed men as engineers and women as assistants. I had to modify them to avoid reinforcing bias."

(Participant G, Interview)
These reflections indicate an evolving ethical awareness and a sense of responsibility toward inclusive and authentic educational representation.

5.4 Cross-Theme Synthesis: Becoming Reflective Instructional Designers
Across all themes, a consistent pattern emerged: students became more reflective, adaptive, and pedagogically intentional over time. They learned not just to use AI tools, but to interrogate them—to understand their affordances and limitations within specific teaching contexts:
"It's not about whether AI is good or bad. It's about how I, as a teacher, choose to use it—and why."

(Participant M, Final Reflection)
This evolving mindset aligns with the goals of teacher education in the digital age: to cultivate educators who are not only technologically capable, but critically aware, ethically grounded, and professionally self-directed.

6. Conclusion and Recommendations

6.1 Summary of Findings
This study explored how pre-service vocational teachers engaged with generative AI tools during a task-based instructional design course. Drawing on thematic analysis of reflective journals, interviews, and instructional artifacts, the findings reveal three key trajectories of learning and professional growth:

(1). From Tool Confusion to Pedagogical Confidence: Students initially struggled with prompt formulation and AI tool usage. However, through iterative experimentation and peer-supported reflection, they gradually developed confidence in using AI as a purposeful aid in teaching design.
(2). Situated Construction of TPACK: As students worked on authentic instructional tasks, they deepened their understanding of how technology intersects with pedagogy and content. Generative AI facilitated practical engagement with TPK and TCK, helping students internalize TPACK as a responsive framework rather than a static model.
(3). Emerging Critical AI Literacy and Ethical Awareness: Students became increasingly aware of issues related to content accuracy, algorithmic bias, and authorship. They expressed concern over stereotypical representations, questionable content credibility, and the ethical implications of using AI-generated materials in education.

6.2 Implications for Teacher Education
The findings underscore the need for a more reflective and ethically grounded approach to integrating AI in teacher education:

- Embed AI Use Within Authentic, Task-Based Contexts: Rather than teaching AI tools in isolation, they should be embedded in meaningful instructional design scenarios that require pedagogical reasoning and contextual decision-making.
- Emphasize Reflective Practice: Structured opportunities for self-reflection, peer feedback, and lesson redesign enable students to connect AI use with deeper insights into their teaching beliefs and design intentions.
- Integrate AI Ethics and Prompt Literacy into Core Curricula: Teacher preparation programs should systematically address AI-related issues such as bias detection, source transparency, and intellectual authorship, alongside developing skills in prompt design and content evaluation.

6.3 Recommendations for Future Research and Curriculum Design

(1). Broaden the Research Scope Across Contexts: Future studies can explore how AI-supported instructional design is experienced across general education disciplines and different stages of teacher development.
(2). Develop Scaffolded AI-TPACK Design Modules: Create progressive design templates and instructional materials that guide novice teachers from basic AI tool usage toward sophisticated, context-aware integration.
(3). Foster AI-Pedagogy Co-Design Communities: Establish communities of practice where pre-service teachers collaboratively explore, critique, and share AI-enhanced instructional strategies, fostering innovation through shared reflection.

6.4 Concluding Remarks

Generative AI offers powerful opportunities for teacher growth, but only when its use is embedded within pedagogically meaningful, ethically conscious, and reflective practices. This study demonstrates that pre-service teachers can evolve from tentative users to critically engaged designers through situated, AI-supported experiences. As the role of AI in education continues to expand, teacher education must prepare future educators not only to use these tools, but to do so with discernment, creativity, and professional responsibility.

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