J-PAI : Jurnal Pendidikan Agama Islam Vol. 12 No. 1 Juli - Desember 2025
P-ISSN 2355-8237 | e-ISSN 2503-300X http://ejournal.uin-malang.ac.id/index.php/jpai
DOI : 10.18860/jpai.v12i1.38584

AI-Enhanced TPACK with a Modeling the Way Approach for Conceptual Development and Strengthening Representational Fluency in Islamic Education

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Abstract. *Artificial Intelligence (AI) is increasingly reshaping pedagogical practices in higher education, yet its potential for conceptual restructuring in Islamic teacher education remains underexplored. This study develops and evaluates a model called Modeling the Way, based on AI-assisted TPACK learning, aimed at reducing conceptual misunderstandings and enhancing multi-representational skills among Islamic Religious Education students at UIN Maulana Malik Ibrahim Malang. Using a sequential exploratory mixed-methods design, qualitative findings from interviews and observations informed the development of AI-supported learning activities. A subsequent implementation demonstrated that AI-enabled modelling, guided practice, independent application, and reflective feedback facilitated cognitive conflict and strengthened representational fluency. Students shifted from relying on verbal recall to a flexible transformation of concepts across visual, symbolic, and contextual forms, while previously persistent misconceptions were reorganized into coherent conceptual structures. The findings suggest that when integrated intentionally, AI functions as a cognitive partner that amplifies pedagogical reasoning and conceptual development within the TPACK framework. This study offers theoretical insights and practical guidance for advancing technology-mediated learning innovations in Islamic teacher education. Broader application and longitudinal evaluation are recommended to examine long-term conceptual stability and ethical implications of AI in religious learning environments.*
Keywords. *Artificial Intelligence; TPACK; Conceptual Change; Modeling the Way; Islamic Teacher Education*

Abstrak. Perkembangan Artificial Intellegence (AI) mempengaruhi proses pembelajaran di lingkungan perguruan tinggi. Namun demikian, di dalam lingkup program studi Pendidikan Islam, masih diperlukan restrukturisasi konseptual yang sejauh ini masih belum banyak dieksplorasi. Studi ini mengembangkan dan mengevaluasi sebuah model yang diberi nama *Modeling the Way* berbantuan AI yang berbasis pendekatan TPACK. *Modelling the Way* bertujuan mengurangi miskonsepsi konseptual dan meningkatkan keterampilan multirepresentasi pada mahasiswa Pendidikan Agama Islam di UIN Maulana Malik Ibrahim Malang. Penelitian ini menggunakan desain *mixed-methods* sequential eksploratori. Tahap kualitatif digunakan untuk merancang aktivitas pembelajaran yang didukung AI, sedangkan tahap kuantitatif digunakan untuk mengevaluasi model pembelajaran. Hasil penelitian menunjukkan bahwa pemodelan dengan AI dapat memfasilitasi konflik kognitif dan memperkuat kemampuan representasional. Mahasiswa meninggalkan metode hafalan dan beralih mengembangkan pemahaman mendalam. Mahasiswa mampu mengubah konsep ke dalam bentuk gambar, simbol, dan situasi nyata, sekaligus meluruskan pemahaman salah yang selama ini menetap. Hasil penelitian ini menunjukkan bahwa integrasi Artificial Intelligence (AI) secara terencana menempatkan teknologi tersebut sebagai mitra kognitif yang memperkuat penalaran pedagogis dan perkembangan konseptual dalam kerangka

kerja TPACK. Studi ini memberikan kontribusi teoretis serta panduan praktis untuk mendorong inovasi pembelajaran berbasis teknologi dalam pendidikan guru Islam. Implementasi yang lebih luas serta evaluasi longitudinal direkomendasikan guna menguji stabilitas konseptual jangka panjang dan implikasi etis penggunaan AI dalam ekosistem pendidikan keagamaan.
Kata kunci. Artificial Intelligence; TPACK; Miskonsepsi; Modeling the Way; Pendidikan Agama Islam

A. INDTRODUCTION

The landscape of higher education has undergone significant changes globally since the advent of Artificial Intelligence (AI). Rapid developments in AI have transformed teaching methods into a more adaptive, data-driven, and multimodal learning ecosystem. One of the defining characteristics of Generation Z is their strong preference for interactive technology, flexible access, and rapid information processing in their academic experiences. This preference contrasts with the preferences of previous generations (Baidoo-Anu & Ansah, 2023; Hendrastomo & Januarti, 2023). As a result, universities are being asked to adapt their learning practices to suit Generation Z's learning behaviors. Despite the increasing digitalization of education, persistent conceptual misunderstandings remain, representing one of the most fundamental cognitive barriers to successful learning. Misconceptions are not merely wrong ideas, but deep-seated cognitive frameworks that are difficult to change even after exposure to correct instruction, ultimately hindering future knowledge transfer and reasoning (Potvin & Cyr, 2017; Swire et al., 2017).

For education students, the impact of misconceptions is even more immediate due to inaccurate conceptual understanding. These misunderstandings can persist into their future teaching careers. It's feared that students who have become teachers and experience misconceptions could pass these misconceptions on to students across generations. Initial findings among prospective Islamic religious teachers at UIN Maulana Malik Ibrahim Malang suggest that students frequently encounter conceptual ambiguity and confusion due to the monotonous nature of teaching practices. Students' overreliance on peer-to-peer presentations results in low learning engagement. These presentations, which often provide minimal feedback and limited instructor mediation, also contribute to the construction of inaccurate knowledge. These misunderstandings, in turn, indicate persistent misunderstandings in several core courses.

These findings reinforce global concerns that the absence of conceptual scaffolding in higher education perpetuates cognitive inaccuracies that hinder deeper learning (Adawiyah, 2023; Madeamin & Rimang, 2023). In addition to misunderstandings, limited multirepresentation abilities also contribute to superficial learning. Multirepresentation, the ability to transform knowledge through various forms, including textual, graphic, symbolic, and contextual, plays a critical role in promoting deep conceptual reasoning and cognitive flexibility (Li et al., 2022; Sutarto et al., 2018). However, recent studies highlight that students often struggle to integrate multimodal understanding because educational practices do not sufficiently encourage diversity of representation (Hidayat et al., 2022). Similar conditions were identified at UIN Maulana Malik Ibrahim Malang, where the multirepresentation skills of students enrolled in introductory Islamic education courses remained below the expected academic standards. These student conditions indicate that the learning design applied in Islamic education study programs may not yet fully provide the cognitive support necessary for multimodal concept formation.

To address this issue, researchers strongly advocate the adoption of integrated technology pedagogy. The TPACK (Technological Pedagogical Content Knowledge) framework emphasizes the reciprocal dependence of technological expertise, pedagogical

strategies, and content expertise in supporting meaningful learning in digital environments (Liando et al., 2023; Widiastuti, 2022). However, empirical evidence suggests that many teachers still utilize technology primarily as a medium of delivery, rather than as a cognitive tool capable of producing conceptual change and intellectual transformation (Arifa, 2024). The urgency of strengthening TPACK competencies is increasingly pressing in Islamic teacher education, where prospective teachers must master both subject-specific knowledge and pedagogy to convey Islamic principles using contemporary learning technologies accurately.

Artificial intelligence (AI) offers promising momentum to strengthen TPACK-based pedagogical innovation by supporting individualized guidance, generating multimodal explanations, detecting inaccurate reasoning patterns, and facilitating continuous assessment that triggers conceptual transformation (Akavova et al., 2023; Harry, 2023). Recent studies have shown that AI can create cognitive conflict, a core mechanism of conceptual change through automated feedback that challenges students' false assumptions and guides them toward a more scientifically accurate understanding (Ramsburg & Ohlsson, 2016). AI-supported learning tools have also proven effective in enhancing representational skills by enabling students to visualize, reinterpret, and manipulate knowledge structures in various forms more dynamically.

Despite its promising potential, current research shows significant gaps. Studies that explicitly integrate AI into learning models designed based on TPACK to reduce misconceptions while improving multifunctional representation skills are still minimal, especially in the context of Islamic teacher education. This field is severely underrepresented in the global education sector.

Therefore, this study aims to design and evaluate an AI-enhanced TPACK learning model to reduce conceptual misunderstandings and improve multifunctional representation skills among prospective Islamic teachers at UIN Maulana Malik Ibrahim Malang. This study aims to develop a theoretical discourse on AI-supported TPACK and provide practical strategies for reforming teacher education in a predominantly Muslim higher education environment. By positioning AI as a technological and cognitive partner in conceptual development, this study captures the ongoing digital transformation, yet pedagogical adaptation remains uneven.

B. RESEARCH METHODS

This study employed a sequential exploratory mixed-methods design, which prioritizes qualitative exploration as a basis for subsequent quantitative evaluation(Creswell & Plano Clark, 2018). This design was chosen to identify sources of conceptual misunderstandings and limited multirepresentational skills among pre-service Islamic teachers, as well as to evaluate the effectiveness of the developed learning model.

The development of the learning model followed the ADDIE framework (Analysis, Design, Development, Implementation, and Evaluation), which is widely used in instructional design research to ensure systematic and iterative model development (Branch, 2009; Molenda, 2015). The model integrated Technological Pedagogical Content Knowledge (TPACK) to align pedagogical strategies, content mastery, and AI-supported technology use (Mishra & Koehler, 2006).

During the qualitative phase, data were collected through semi-structured interviews and classroom observations involving purposively selected students from the Islamic Education Study Program at UIN Malang. This sampling strategy allowed the selection of participants who were directly involved in the learning context being examined (Patton, 2015). Qualitative data were analyzed thematically to identify instructional challenges, learning barriers, and opportunities for AI-based pedagogical intervention (Braun & Clarke,

2006).

The quantitative phase employed a pretest–posttest design to measure changes in students' conceptual understanding and multirepresentational abilities following the implementation of the AI-enhanced TPACK learning model. Data were analyzed using descriptive statistical techniques to examine learning improvements and shifts in conceptual accuracy (Fraenkel et al., 2019).

The study resulted in the development of AI-supported learning media, instructional strategies, and teaching materials grounded in the TPACK framework. Ethical considerations were addressed through informed consent, voluntary participation, and anonymization of participant data in accordance with educational research ethics standards (Cohen et al., 2018). This methodological approach ensured that the AI-enhanced TPACK learning model was systematically developed and empirically evaluated within the context of Islamic teacher education.

C. RESULT AND DISCUSSION

1. Improvement in Multirepresentational Ability

The study's results demonstrate a significant improvement in students' multirepresentation abilities following the implementation of the AI-supported TPACK learning model. Pretest data indicate that PAI students' competencies are strongest in verbal (63%), mathematical (58%), and symbolic (46%) aspects, with weaker competencies in graphic (32%) aspects. Based on the pretest data, students tend to rely more on verbal memory to transform knowledge into different semiotic forms. After the intervention, there was a significant increase in each domain. The verbal representation increased to 90%, the mathematical representation to 76%, the graphic representation to 82%, and the symbolic representation to 75%.

These significant changes indicate that AI-assisted TPACK learning design effectively strengthens the integration of representational competencies. The significant increase in graphic representation (+50%) is a positive sign. The significant increase is because the graphic aspect of visual reasoning is often associated with deeper conceptual processing and greater problem-solving flexibility. Similarly, the significant increase in symbolic expression (+29%) indicates better connections between abstract reasoning and visual-verbal forms. This figure confirms that the AI-enhanced TPACK model can overcome critical cognitive limitations, which were identified in the pretest as difficulties for students in switching between representation formats when understanding or explaining concepts.

From a theoretical perspective, these results support advances in contemporary claims regarding multimodal learning research. Students can learn more deeply when the ability to translate and synchronize understanding is performed across multiple representation systems (Department of Post Graduate Science Education, Jember University, East Java, Indonesia. et al., 2022). The role of AI in this study is central, namely as an intelligent tool that instantly generates graphics, diagrams, and symbolic transformations based on student input. In addition, AI also provides immediate representational feedback that is very difficult to provide manually within the limited time available for classroom learning. TPACK also ensures that these AI features are integrated into meaningful pedagogy, not just technology for technology's sake.

Qualitative feedback also indicates that visual outputs make abstract content more "real" and easier to understand, especially in subjects with a high level of abstraction, such as Theosophy. Observations also show that students become more willing to take cognitive risks by experimenting with different forms of representation. Therefore, this improvement represents a shift in cognitive habits from rote learning to representational reasoning.

The findings in this subsection confirm that the AI-enhanced TPACK model provides

effective scaffolding for the development of multirepresentational fluency. The AI-assisted TPACK learning model also represents a crucial step in preparing future Islamic teachers to communicate adaptively with diverse students.

2. Reduction in Conceptual Misconceptions

The intervention in this study has shown a significant positive shift in the conceptual profile of students. Before the application of the AI-enhanced TPACK model, misconceptions dominated in six core subjects in the Islamic teacher education study program. The pretest results showed that only 12 students were classified in the "lack of conceptual understanding" category, while 18 students had misconceptions, and nine students were classified in the "conceptual misconception" category. The students' patterns showed an inherent resistance to change, even after formal instruction. Misconceptions operate as stable but incorrect ontological categorizations, which learners consider coherent and correct until they are disrupted (Fuat et al., 2020).

After the intervention, conceptual accuracy increased significantly. The number of students categorized as having a complete conceptual understanding increased to 16. In contrast, the number of students with misconceptions decreased sharply to 9, and those categorized as not understanding decreased to 4. Meanwhile, the percentage of students with a "partial understanding" increased from 19% to 29%. This increase suggests that some students transitioned to partial restructuring, a typical intermediate stage in conceptual ecology, as described by Posner's theory of conceptual change (Posner et al., 1982).

In this study, AI plays a crucial role in facilitating cognitive shifts. One of the most important ways is through cognitive conflict induction, which is used to challenge students' false assumptions with instant counterevidence. AI is also used as multimodal feedback, transforming errors in one mode into multimodal corrections. Another role of AI in this study is as epistemic support prompts, guiding learners to articulate and justify their revised understanding.

Vosniadou's Framework Theory posits that conceptual change necessitates students' restructuring their internal conceptual frameworks, rather than merely modifying surface facts (Vosniadou, 2020). The reduction in misconceptions in this study demonstrates the success of AI-enhanced TPACK in facilitating students to move away from their initial naive theories and toward more accepted instructional knowledge.

The improvements are summarized in the following table:

Table 1. Distribution of Conceptual Understanding Before and After Intervention

Category	Pre-test (n)	Post-test (n)	Δ Change
Conceptually Sound	12	16	+4
Partially Understood	19	29	+10
Misconceptions	18	9	–9
No Conceptual Understanding	9	4	–5

Negative scores in the categories of misunderstanding and misinterpretation clearly indicate that students are shifting upward on the conceptual development continuum, approaching accurate knowledge, thus proving the effectiveness of the model in supporting conceptual restructuring. Qualitative results, as recorded in visual data, explain that students view AI tools as "clearer and more reasonable for explaining difficult concepts." Meanwhile, lecturers observed that AI provides "a quick way to identify conceptual errors." These results indicate an increase in cognitive and affective engagement, reinforcing the role of AI as a catalyst for corrective reasoning and the formation of epistemic trust. This study demonstrates that the

AI-assisted TPACK model has successfully addressed the challenge of misperceptions in education, particularly from both theoretical and practical perspectives, as observed in the experiences of students and teachers.

3. Integrated Interpretation: AI-Enhanced "Modeling the Way" as a Dual-Impact Learning Architecture

This research produced findings in the form of a learning model, utilizing a TPACK approach, called Modeling The Way - AI Assistant. Modeling the Way, reinforced by AI, successfully restructures the way knowledge is processed and represented cognitively. In the modeling stage, lecturers act as expert content creators, while AI generates visualizations and symbolic transformations. These two complementary elements make the thinking process visible, which is a core element of Cognitive Learning Theory (Hakimzadeh et al., 2021). Modeling the Way - AI Assistant positions AI as a thinking partner, not merely as a passive media delivery tool.

In the guided practice stage, learning becomes a process of representational negotiation. AI-supported transitions between verbal, visual, and symbolic formats activate integrated cognitive pathways. This step allows students to analyze the coherence between representations. The process that occurs in this stage aligns with Ainsworth's MER framework, which posits that diverse external representations serve to limit interpretation, deepen understanding, and facilitate abstraction (Ainsworth, 1997).

Conceptual restructuring occurs when AI output contradicts students' initial beliefs, creating epistemic conflict. This conflict aligns with Chi's theory of conceptual change, which states that misconceptions are deeply rooted ontological categorizations that require structural revision (Chiu et al., 2023). The cognitive dissatisfaction that arises in students leads them to adopt alternative explanations that are more understandable and useful through continuous comparison and reflection. This process meets Posner's criteria for stable conceptual change (Posner et al., 1982).

In the independent application phase, students adapt strategies for use in the classroom. There is a shift from content understanding to content transformation for learners, an essential dimension of Pedagogical Thinking and Action (Öztürk et al., 2023). Students use AI to practice selecting representations that maintain theological accuracy while maximizing clarity and accessibility. In this context, AI serves as a source of dynamic feedback (Barrat, 2023).

In the final stage, reflection takes place, developed with feedback refined by AI. This stage strengthens epistemic consolidation, ensuring that conceptual and representational improvements are lasting and transferable.

Students describe AI as a tool that requires them to justify and refine their thinking. The improvement is evidence of a developing professional identity in students' pedagogical competence (Arifa, 2024). Improvements in representational ability and conceptual understanding are mutually reinforcing processes within a cohesive instructional system.

Modeling the Way with the help of AI represents the TPACK-plus approach, namely, technology that is pedagogically designed to encourage conceptual restructuring and representational fluency simultaneously (Mayerhoefer, 2020). These findings are highly valuable in the PAI study program, as they convey the integrity of knowledge and the abilities of prospective teacher students. The classroom, as a place for learning, is where meaning is constructed, debated, and stabilized, placing prospective PAI teachers in a strategic position.

D. CONCLUSION

The AI-enhanced TPACK learning model demonstrated positive effects on improving conceptual understanding and multirepresentational abilities among pre-service Islamic

teachers. By positioning AI as a cognitive partner within a structured *Modelling the Way* approach, the learning process encouraged deeper reasoning, facilitated cognitive conflict to address misconceptions, and supported flexible expression of knowledge across multiple representational forms.

These findings indicate that intentional integration of AI within a TPACK-based framework can strengthen pedagogical reasoning and support the development of accurate and adaptable understanding of Islamic concepts. However, this study was conducted within a single institutional context and over a relatively short intervention period, which limits the generalizability of the results.

Despite these limitations, the study offers valuable insights for technology-mediated instructional reform in Islamic teacher education, particularly in the design of AI-supported learning activities that promote conceptual change. Future research is recommended to implement the model across diverse contexts, examine its long-term impact on conceptual stability, and further explore the ethical and epistemic implications of AI use in religious learning environments.

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