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Article

The Role of Artificial Intelligence in Enhancing Creative Thinking among Students of the Departments of Quranic Sciences and Islamic Education

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Abstract

The present study seeks to examine the influence of artificial intelligence (AI), specifically machine learning (ML) and deep learning (DL), on the development of creative thinking (CT) among female students enrolled in the Departments of Quranic Sciences and Islamic Education. The significance of this research lies in the capacity of AI to cultivate a learning environment that promotes innovation. Data were gathered from female students attending Islamic educational institutions in Iraq through structured survey questionnaires. The study employed smart-PLS to assess the relationships between the examined variables. Findings indicated that AI technologies, including ML and DL, improve students' comprehension of academic content and simultaneously foster CT through innovative processes. The integration of AI applications can therefore support the advancement of CT among students by stimulating innovation. These insights provide guidance for policymakers aiming to formulate strategies to enhance students' creative thinking via AI.

Keywords

Artificial Intelligence, Deep Learning, Machine Learning, Creative Thinking, Islamic Education.

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Introduction

AI is a domain within computer science dedicated to creating systems capable of performing tasks traditionally requiring human intelligence, such as learning, reasoning, problem-solving, and understanding natural language (Albakry, Hashim, & Puandi, 2025). It comprises technologies that allow machines to emulate human behaviours, including learning from prior experiences, making decisions, and interacting with their environment. AI systems can process information, identify patterns, enhance performance, and provide effective solutions to complex problems (Chang & Tsai, 2024). CT is a cognitive process involving the generation of novel and unconventional ideas by connecting concepts and knowledge innovatively. It refers to the capacity to produce unique solutions or ideas that surpass conventional thinking, aiding problem-solving and fostering innovation. This skill relies on imagination and critical analysis to generate ideas and support non-linear thinking (Abu Owda et al., 2023).

AI represents one of the most significant technological advances in contemporary society, exerting a notable influence across various sectors, particularly in education. Its impact is especially relevant in teaching humanities and religious studies, such as Quranic sciences and Islamic education, where AI applications can support the development of CT among students (Saritepeci & Yildiz Durak, 2024). The core research problem centres on understanding how female students in the Departments of Quranic Sciences and Islamic Education can utilise AI tools to enhance their CT capabilities. These students often encounter obstacles that may restrict CT development, including traditional pedagogical methods, limited curricula, and insufficient access to modern educational resources. This study investigates the potential of AI to enhance CT and to provide solutions to the challenges faced by female students in this context. The anticipated findings aim to offer insights for educators and curriculum planners regarding the integration of AI technologies into religious education, ultimately improving students' creative capacities and enriching their learning experience. Therefore, the primary research question is: What role does AI play in fostering CT through innovation among female students in the Departments of Quranic Sciences and Islamic Education?

Exploring AI's contribution to enhancing CT in these departments is crucial for understanding the intersection of technological advancement and educational processes. Its significance lies in offering innovative educational tools, enabling educators and students to employ advanced systems such as intelligent platforms and interactive programmes. These tools support active learning approaches, allowing students to develop CT skills more effectively, engage with educational material in depth, and generate novel ideas. AI further cultivates a learning environment that encourages innovation. By leveraging technologies such as personalised learning and adaptive systems, AI can provide tailored educational experiences (Al Ka'bi, 2023). This facilitates the exploration of new concepts and the creation of innovative solutions to academic challenges, thereby promoting a culture of innovation. Additionally, AI can analyse extensive educational datasets, aiding teachers in understanding student needs and designing customised programmes that foster CT (Dainys & Jašinauskas, 2023). The present study aims to examine the role of AI in enhancing CT through innovation among students in the Departments of Quranic Sciences and Islamic Education.

Literature Review

AI is defined as the discipline concerned with engineering intelligent machines, particularly intelligent software systems. In essence, AI enables machines to emulate human cognitive processes through computer programming. It encompasses the capacity of computers or other devices to execute tasks that typically require human intelligence (Lin & Chang, 2024). This domain focuses on creating machines endowed with such capabilities and can be regarded as a branch of computer science that emphasises symbolic reasoning through computational methods. AI can also be interpreted as an endeavour to replicate aspects of human thought within computer systems. Since its inception in the 1950s, AI has provoked debate regarding the trajectory of such innovations, with concerns that sufficiently advanced AI could approach human-level intelligence, potentially achieving self-awareness and autonomous control, posing significant ethical and societal challenges (Hu et al., 2022).

Modern conceptions of AI involve constructing machines capable of performing tasks that require human-like intelligence. AI entails designing systems that display cognitive attributes, including problem-solving and the capacity to generate CT (Gupta et al., 2021). It seeks to model diverse aspects of human mental processes—such as understanding, creativity, learning, perception, problem-solving, and emotional responses—

and implement these capabilities within computers. Accordingly, AI, including ML, represents a relatively recent subfield of computer science aimed at developing intelligent systems that emulate human cognitive patterns (Wang & Wang, 2024). These systems are designed to perform functions typically executed by humans, simulating their reasoning and abilities using logical, mathematical, and qualitative frameworks. AI and ML involve reproducing human intelligence within machines (Xue, 2025). ML, specifically, focuses on designing computational systems capable of performing at levels comparable to expert human practitioners, replicating both cognitive and motor functions (Lin & Chang, 2024). Such systems operate by analysing information, making inferences, responding to stimuli, and utilising prior experiences. Intelligent systems interpret external data accurately, learn from it, and adapt dynamically to achieve defined objectives and tasks (Bharathi et al., 2024). Based on these theoretical foundations, the present study has formulated the following hypothesis:

H1: *AI such as machine learning has a positive association with CT in the students of Islamic education.*

Deep learning, a relatively recent branch of computer science, concentrates on understanding and emulating human intelligence to develop advanced systems capable of executing complex tasks requiring sophisticated reasoning, inference, and perception (Li, Ortegas, & White, 2023). This form of AI is often regarded as embodying attributes traditionally associated with human cognition, which were previously beyond the reach of machines. Deep learning systems are designed to mimic human learning and comprehension, providing functions such as educational support, guidance, and user interaction (Zhao et al., 2021). Deep learning represents a broad area of AI with diverse applications, offering substantial benefits through the utilisation of advanced modern technologies. Its impact on enhancing and developing multiple domains of human activity is demonstrated by computer systems operating with efficiency comparable to expert human performance (Chiu & Hwang, 2024). As an applied science, deep learning has moved beyond theoretical discussion to become an integral part of contemporary life, especially amid rapid technological advancement. Computers have become central to everyday activities, reflecting the transformative influence of AI across various sectors, while also facilitating social, cultural, and technological connectivity on a global scale (Alam, 2022).

In education, deep learning exhibits several key features that enhance learning processes and student engagement. ML, as a core aspect of AI, enables systems to analyse educational data, acquire knowledge autonomously, and develop experiential understanding. This capability supports personalised learning tailored to the specific needs of each student. Deep learning utilises deep neural networks to examine and interpret educational data, allowing for the assessment of student performance and the provision of customised guidance to optimise learning outcomes (Liu, Chen, & Yao, 2022). The primary characteristics of AI in education constitute a significant advancement, as they enable the enhancement of students' learning experiences and the development of their academic competencies in innovative and effective ways. By integrating AI into educational practices, traditional learning can be transformed into an interactive, technology-driven environment. These capabilities facilitate substantial improvements in educational quality and support the objectives of digital transformation within the educational sector (Yim & Su, 2025). Based on this literature, the present study has formulated the following hypothesis:

H2: *AI such as deep learning has a positive association with CT in the students of Islamic education.*

AI has the potential to transform educational practices, as technologies such as personalised learning algorithms and virtual or augmented reality offer opportunities to enrich the learning experience through innovation. These tools foster interactive learning, increasing student engagement (Albakry et al., 2025). AI systems can analyse data, learn from experience, and make decisions in ways comparable to human cognition. This includes ML, which can be applied to enhance educational quality and improve the learning experience. The applications of AI in higher education are extensive and cover several key areas (Chang & Tsai, 2024). Firstly, AI can support personalised learning by examining students' learning patterns and delivering tailored educational content to meet individual needs. Such personalisation improves learning effectiveness and promotes superior academic outcomes. Secondly, AI functions as an effective academic support tool, providing immediate assistance by responding to queries and directing students to appropriate educational resources (Abu Owda et al., 2023).

AI has emerged as a highly impactful technology, influencing numerous sectors including industry, services, healthcare, education, and sports training. To explore this, the researcher analysed studies demonstrating the effects of AI on productivity and innovation. For example, Fan and Zhong (2022) investigated

how AI applications enhance learning and innovation skills, accelerate decision-making, and facilitate data analysis, emphasising their role in guiding research and developing educational and training strategies, particularly within sports. Similarly, Muthmainnah, Ibna Seraj and Oteir (2022) concluded that AI technologies contribute to quality and progress across multiple domains by improving innovation and cognitive skills. Consequently, this study aims to provide evidence-based recommendations for optimising AI applications in various contexts, recognising their capacity to achieve desired outcomes such as reducing time, effort, and costs. Based on this literature, the present study has formulated the following hypothesis:

H3: *Innovation significantly mediates among AI such as machine learning and CT in the students of Islamic education.*

AI is a key driver of growth and innovation across various sectors, and education is no exception. Although AI solutions have been gradually introduced into educational technologies, their adoption remained slow until the global pandemic in late 2019, which dramatically transformed the educational landscape. This shift positioned AI as an essential component of learning processes, with smart platforms facilitating communication and interaction among educational stakeholders (Ameen et al., 2022). The use of AI-powered learning management tools is projected to increase by more than 47% over the next three years, highlighting the need for adherence to core principles of AI integration in education, while ensuring that technological disparities are not exacerbated. These tools can become vital instruments for addressing major educational challenges and for informing policies that advance sustainable scientific development (Lin & Chen, 2024).

Given rapid technological advancements, an educational revolution is required to keep pace with progress. This study emphasises the significance of identifying AI systems and their role in enhancing the educational process during crises. The adoption of e-learning and distance learning solutions has proven particularly effective in responding to challenges such as the COVID-19 pandemic (Huang & Qiao, 2024). Among anticipated future trends is the widespread expansion of e-learning and AI technologies. The study addressed the theoretical and conceptual framework of AI and employed an open-ended questionnaire to identify the primary challenges facing education and the potential role of AI applications in addressing them (Ivcevic & Grandinetti, 2024). AI applications integrated into distance learning environments aim to replicate real-world educational experiences. Moreover, the adoption of AI in education requires the promotion of technological literacy among educators, institutions, and society at large, raising awareness of the positive impacts of AI on learning outcomes (Jia et al., 2024). Based on this literature, the present study has formulated the following hypothesis:

H4: *Innovation significantly mediates among AI such as deep learning and CT in the students of Islamic education.*

Drawing on the reviewed literature and the study's objectives, the research framework for the present study is illustrated in Figure 1.

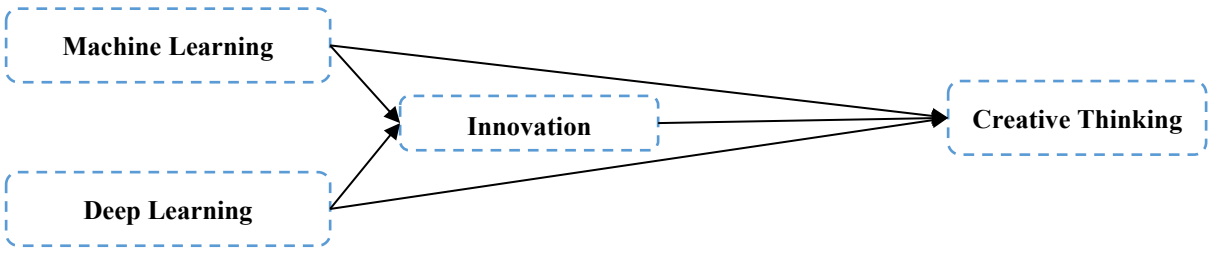

Figure 1: *Research Framework.*

Research Methodology

The present study aims to investigate the impact of AI dimensions, specifically ML and DL, on the CT of students in Islamic educational institutions. In addition, the study examines the mediating role of innovation between ML, DL, and CT. In methodological terms, generalizability refers to the extent to which the study's findings can be applied to a broader population (Elliott-Sale et al., 2021). To obtain a representative sample, the target population must first be clearly identified. For this study, the population comprised students enrolled in the College of Education for Girls, within the Departments of Quranic Sciences and Islamic Education. Data were collected using structured questionnaires. The researchers selected students as respondents and distributed

the surveys by visiting their institutions directly. A total of 534 questionnaires were distributed, of which 357 were completed and returned, yielding a response rate of approximately 66.85 percent. Standardised instruments were employed to measure the study variables. Specifically, ML was assessed using seven items adapted from Ho, Cheong and Weldon (2021). Table 1 presents the items used to measure ML.

Table 1: *Machine Learning Items.*

Items	Questions	Sources
ML1	I am comfortable with the required technologies.	(Ho et al., 2021)
ML2	I am clear which technologies and applications I am required to use.	
ML3	I have no difficulty accessing reliable communication software.	
ML4	I can always access specialized software for my study.	
ML5	I can always access library resources.	
ML6	I can always find time to participate in synchronous classes.	
ML7	I can always find time for class meetings and schedules.	

In addition, the study considers DL as an independent variable. DL was measured using six items adapted from Lau, Liem and Nie (2008). Table 2 presents the items used to assess DL. Moreover, the study includes innovation as the mediating variable. Innovation was measured using five items adapted from Oduro (2020). Table 3 presents the items used to assess innovation. Furthermore, the study considers CT as the dependent variable. CT was measured using five items adapted from Fadhil et al. (2021). Table 4 presents the items used to assess CT.

Table 2: *Deep Learning Items.*

Items	Questions	Sources
DL1	I question what I hear or read to decide if I find them convincing.	(Lau et al., 2008)
DL2	I check to make sure that it is correct before I accept it.	
DL3	When I study Islamic studies, I try to connect new ideas to what I already know.	
DL4	I apply ideas from my Islamic studies class to other subjects.	
DL5	When I study the Islamic studies textbook, I take notes and write down the main ideas.	
DL6	When I study the Islamic studies textbook, I write an outline to help me organize my thoughts.	

Table 3: *Innovation Items.*

Items	Questions	Sources
IN1	We adopt innovation to improve our internal (R&D) and innovation process.	(Oduro, 2020)
IN2	We use the innovation to gain knowledge and expertise that we do not have internally.	
IN3	Our institution uses innovation to reduce the high cost of innovating alone.	
IN4	We use innovation to counter balance our lack of capacity.	
IN5	We use the innovation to secure market share growth and global market reach.	

Table 4: *Creative Thinking Items.*

Items	Questions	Sources
CT1	The pre-test and post-test questions are easy for me to understand.	(Fadhil et al., 2021)
CT2	The learning was carried out very interesting and fun.	
CT3	The learning that was carried out encouraged me to cooperate with friends.	
CT4	This learning makes it easy for me to express ideas or opinions about a given problem.	
CT5	The learning that was carried out encouraged me to be independent.	
CT6	This study can make it easier for me to draw conclusions.	
CT7	I am very motivated to learn about vibration and wave material.	
CT8	The assignments in the worksheets gave me a challenge in learning.	

In addition, the study employed smart-PLS to assess both the measurement and structural models. The measurement model includes convergent and discriminant validity. Convergent validity evaluates the correlations among items, which should be high. It is assessed using factor loadings, which must exceed 0.50 (Hair & Alamer, 2022), average variance extracted (AVE), also above 0.50 (Hair Jr., Gabriel, & Patel, 2014), Cronbach's alpha, which should exceed 0.70, and composite reliability (CR), also required to be greater than 0.70 (Hair et al., 2017). Discriminant validity examines correlations among variables, which should be low. This is evaluated using the Fornell-Larcker criterion, where the first value in each column should be greater than all other values, and via the Heterotrait-Monotrait (HTMT) ratio, which should be less than 0.90 (Hair, Howard, & Nitzl, 2020). The associations among variables were also analysed, with significance determined by p-values below 0.05, indicating statistically significant relationships (Hair et al., 2021).

Research Findings

The study assessed convergent validity, which evaluates the correlations among items and requires these correlations to be high. Convergent validity was examined using factor loadings, which should exceed 0.50 (Hair & Alamer, 2022); the results indicated that all loadings were above this threshold. Additionally, AVE values were required to be greater than 0.50 (Hair Jr. et al., 2014), and the findings confirmed this criterion was met. Cronbach's alpha values were expected to exceed 0.70, and the results were higher than the threshold. Finally, CR values should be greater than 0.70 (Hair et al., 2017), and all observed values satisfied this requirement. Table 5 and Figure 2 illustrate the results of the convergent validity assessment.

Table 5: *Convergent Validity.*

Constructs	Items	Loadings	Alpha	CR	AVE
Creative Thinking	CT1	0.693	0.893	0.914	0.573
	CT2	0.670			
	CT3	0.711			
	CT4	0.724			
	CT5	0.791			
	CT6	0.814			
	CT7	0.842			
	CT8	0.792			
Deep Learning	DL1	0.801	0.901	0.927	0.718
	DL3	0.879			
	DL4	0.853			
	DL5	0.891			
	DL6	0.809			
Innovation	IN1	0.870	0.857	0.898	0.641
	IN2	0.804			
	IN3	0.860			
	IN4	0.801			
	IN5	0.649			
Machine Learning	ML1	0.868	0.915	0.933	0.666
	ML2	0.848			
	ML3	0.797			
	ML4	0.805			
	ML5	0.868			
	ML6	0.852			
	ML7	0.649			

The study also assessed discriminant validity, which evaluates correlations among variables and requires these correlations to be low. Discriminant validity was examined using the Fornell-Larcker criterion, where the first value in each column should exceed all other values. The results confirmed that the first values were greater than the remaining values in their respective columns, indicating low correlations among variables. Table 6 presents the Fornell-Larcker results. Furthermore, discriminant validity was evaluated using cross-loadings. The results indicated that the correlations of each item with its own construct were higher than the correlations with other constructs, confirming low correlations among variables. Table 7 presents the cross-loading results. Finally, discriminant validity was also assessed using the HTMT ratio, which requires values to be below 0.90 (Hair et al., 2020). The results confirmed that all values were below this threshold. Table 8 presents the HTMT ratio results.

Table 6: *Fornell Larcker.*

	CT	DL	IN	ML
CT	0.757			
DL	0.690	0.847		
IN	0.595	0.460	0.801	
ML	0.583	0.556	0.469	0.816

Table 7: *Cross-Loadings.*

	CT	DL	IN	ML
CT1	**0.693**	0.541	0.540	0.450
CT2	**0.670**	0.541	0.668	0.463
CT3	**0.711**	0.461	0.441	0.531
CT4	**0.724**	0.489	0.423	0.489
CT5	**0.791**	0.545	0.332	0.403
CT6	**0.814**	0.519	0.327	0.361
CT7	**0.842**	0.551	0.403	0.427
CT8	**0.792**	0.483	0.355	0.351
DL1	0.517	**0.801**	0.292	0.461
DL3	0.632	**0.879**	0.383	0.458
DL4	0.625	**0.853**	0.373	0.473
DL5	0.604	**0.891**	0.458	0.521
DL6	0.535	**0.809**	0.428	0.443
IN1	0.539	0.443	**0.870**	0.389
IN2	0.447	0.358	**0.804**	0.301
IN3	0.471	0.318	**0.860**	0.388
IN4	0.419	0.259	**0.801**	0.310
IN5	0.472	0.417	**0.649**	0.456
ML1	0.526	0.481	0.417	**0.868**
ML2	0.512	0.457	0.430	**0.848**
ML3	0.475	0.431	0.390	**0.797**
ML4	0.450	0.457	0.338	**0.805**
ML5	0.463	0.466	0.374	**0.868**
ML6	0.440	0.442	0.356	**0.852**
ML7	0.445	0.435	0.358	**0.649**

Table 8: *Heterotrait Monotrait Ratio.*

	CT	DL	IN	ML
CT				
DL	0.760			
IN	0.654	0.509		
ML	0.635	0.614	0.521	

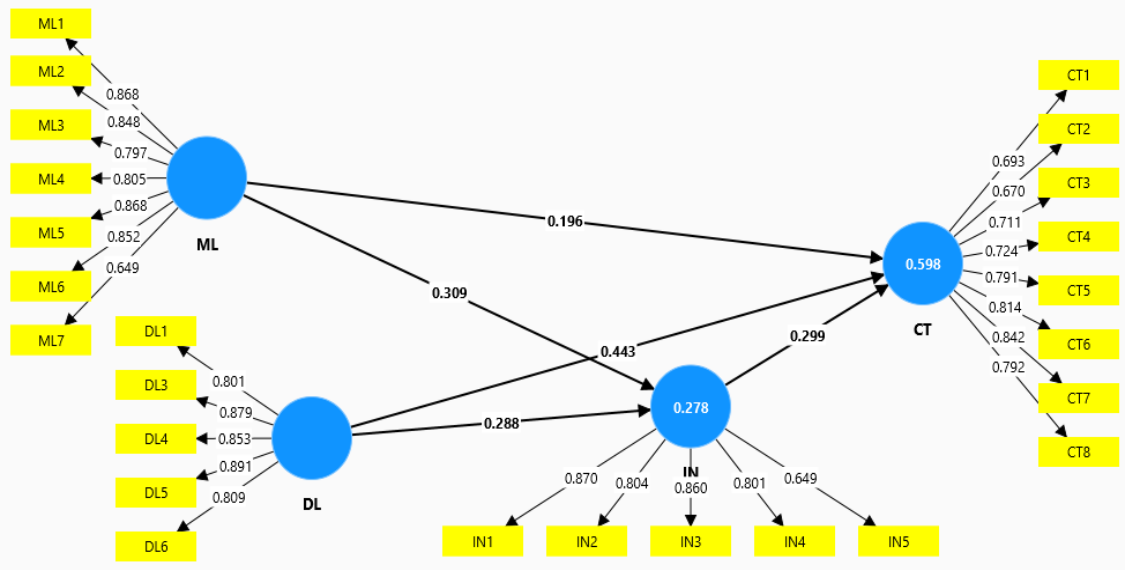

Figure 2: *Measurement Assessment Model.*

The study assessed the relationships among variables using path analysis. The results indicated that AI dimensions, including ML and DL, improve students' understanding of content and enhance CT, supporting H1 and H2. Additionally, the findings revealed that innovation significantly mediates the relationships between ML, DL, and CT. Table 9 and Figure 3 present the path analysis results.

Table 9: *Path Analysis.*

Relationships	Beta	Standard Deviation	T Statistics	P Values
DL -> CT	0.443	0.049	8.993	0.000
DL -> IN	0.288	0.056	5.121	0.000
IN -> CT	0.299	0.049	6.084	0.000
ML -> CT	0.196	0.039	5.064	0.000
ML -> IN	0.309	0.055	5.662	0.000
ML -> IN -> CT	0.093	0.022	4.276	0.000
DL -> IN -> CT	0.086	0.024	3.610	0.000

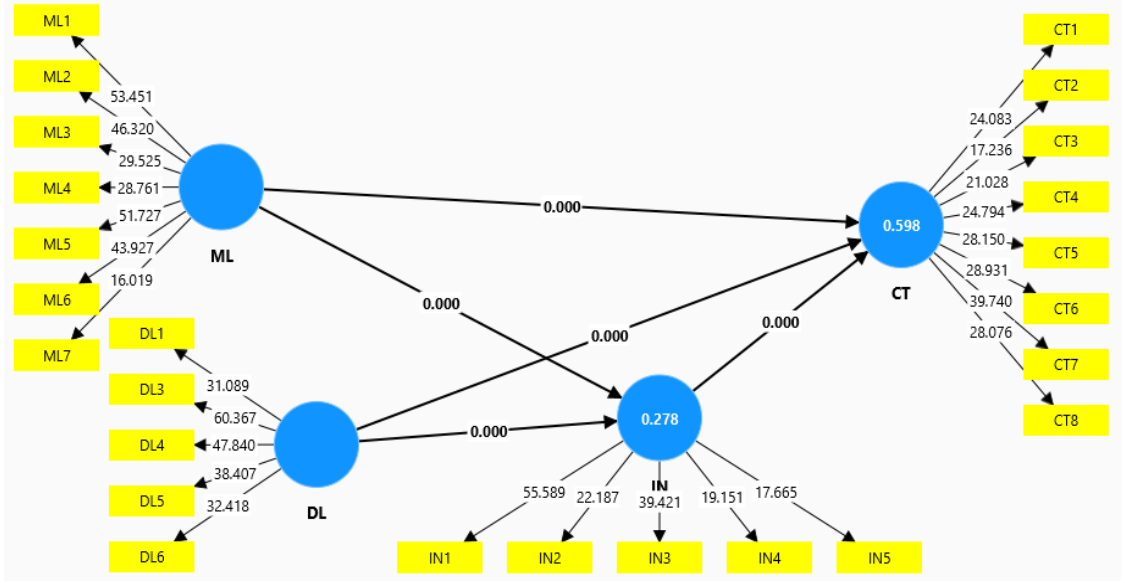

Figure 3: *Structural Assessment Model.*

Discussion

The study findings indicated that ML, as a dimension of AI, has a positive effect on CT. These results are consistent with Stevens and Zabelina (2020), who note that ML processes large datasets, examines issues from multiple perspectives, and generates insights akin to personalised experiential knowledge. By exploring diverse trends, possibilities, and opportunities, ML enables users to develop CT. Similarly, Xue (2025) reports that adopting AI-driven ML allows users to think beyond conventional boundaries and generate novel ideas, thereby enhancing CT. In line with Mateja and Heinzl (2021), ML extends beyond conventional teaching resources, with AI tools acting as collaborative partners. These tools not only explain concepts but also provide suggestions, highlight challenges, and encourage users to resolve problems creatively.

The results further demonstrated that DL positively influences CT. Zhao et al. (2021) support these findings, observing that when users have limited understanding of a concept or event, DL models can recognise patterns from minimal input and deliver comprehensive, universally applicable information. This facilitates broad thinking and the generation of innovative ideas. Dainys and Jašinauskas (2023) similarly highlight that DL, with its capacity to process large, complex, and dispersed datasets using artificial neural networks, enables users to respond effectively to challenges and display creative capabilities. Al Ka'bi (2023) also confirms that interaction with DL provides supportive guidance that enhances CT. The study also revealed that innovation has a positive relationship with CT. Arici and Uysal (2022) emphasise that creativity involves generating new ideas, implementing innovative thought, and producing more useful outcomes. Exposure to innovation within an organisation allows users to learn about new techniques and resources, which promotes creative problem-solving. Similarly, Siyal et al. (2022) note that as community needs and trends evolve, adopting innovative strategies and resources offers faculty and learners opportunities to broaden their thinking and enhance CT. Rampa and Agogué (2021) further suggest that in institutions where service improvement and innovation are prioritised, both faculty and students expand their knowledge and creative capacity in response to change.

Regarding mediation, the study found that innovation significantly mediates the relationship between ML and CT. Moruzzi (2020) supports this finding, noting that interacting with AI-driven DL models updates organisational technologies and resources, facilitating innovation. The application of innovative resources in response to changing trends enhances knowledge, training, and experience, thereby promoting CT. Ilić et al. (2021) also report that introducing ML into organisations and training employees in its use fosters innovation in management and service processes, altering thinking patterns and promoting creativity. Botega (2021) similarly highlights that ML facilitates automation and process improvement, driving organisational innovation and encouraging learners to actively engage in CT. The study additionally showed that innovation mediates the relationship between DL and CT. Ameen et al. (2022) emphasise that AI tools incorporating DL act as knowledge hubs, providing extensive and relevant information that enhances organisational innovation and, consequently, CT. Jia et al. (2024) confirm that DL within AI promotes innovation across departments, easing learning processes and improving CT. Vinchon et al. (2023) also note that innovation facilitated by DL enhances technical knowledge and skills, leading to improved CT outcomes.

Implications

The present study holds considerable significance for contributing to the literature on education, with CT as its primary focus. It explores the role of AI in the education sector, specifically examining how AI promotes CT within educational institutions. The study investigates the impact of ML and DL on students' CT. While prior research has examined the relationship between ML or DL and CT, these studies typically considered each factor independently rather than as integral dimensions of AI. By evaluating ML and DL simultaneously as AI dimensions and their collective influence on CT, the present study extends existing literature. Furthermore, whereas previous studies primarily addressed the direct relationship between innovation and CT, this study examines the mediating role of innovation between AI dimensions and CT, thereby providing an additional contribution. The study is also novel in focusing on female students in the Departments of Quranic Sciences and Islamic Education. The study carries significant implications not only for Islamic education in Iraq but also for educational systems globally. It offers guidance for students' parents, institutional administrators, and educational policymakers. The findings recommend introducing ML into the curriculum and providing training

for both faculty and students to enhance CT. In teaching and learning environments, emphasis should be placed on DL through AI models to foster CT. Additionally, educational institutions are encouraged to implement policies that integrate innovation into resources and processes, which in turn can strengthen CT. Training initiatives should promote the use of ML tools to support innovation and enhance students' CT. Moreover, effective educational policies should prioritise the adoption of DL within AI frameworks to motivate faculty and students toward innovation, ultimately leading to improved CT outcomes.

Conclusion

The study was designed to investigate the impact of AI dimensions, specifically ML and DL, on students' CT. A further objective was to examine the mediating role of innovation in the relationships between ML, DL, and CT. To provide empirical evidence, data were collected from female students enrolled in the Departments of Quranic Sciences and Islamic Education in Iraq. Quantitative analysis revealed that both ML and DL are positively associated with innovation and students' CT. The findings indicate that educational institutions utilising ML within AI frameworks enhance organisational operations, teaching practices, and student engagement. ML facilitates knowledge acquisition and practical experience, enabling students to interact effectively with modern technologies to address challenges, thereby fostering CT. Moreover, institutions that integrate DL models and provide faculty-led instruction along with student training create opportunities for in-depth exploration of subjects. This approach allows students to analyse concepts from multiple perspectives, generate innovative ideas, and perform tasks more effectively, promoting CT. Additionally, the study demonstrates that innovation serves as a significant mediator between ML, DL, and students' CT. The results suggest that the adoption of ML and DL within institutions stimulates innovative practices, which in turn encourage CT among both faculty and students.

Limitations

The present study has certain limitations that warrant attention in future research. First, the study focuses on a model with a limited set of variables, specifically AI dimensions, ML, and DL, in relation to the development of CT. Other influential factors, such as competitive programs, leadership styles, employee training, and learning and development initiatives, may also significantly impact CT. Consequently, future research should consider extending the scope of the model to incorporate these additional factors. Second, while this study examined innovation as a mediator between ML, DL, and CT, it could also be conceptualised as a moderator in this relationship, which may provide additional insights into the dynamics of CT development. Third, the study is based solely on female students from the Departments of Quranic Sciences and Islamic Education in Iraq. Since the dataset is drawn exclusively from the Islamic education system in Iraq, the findings may not be directly generalisable to other educational contexts or disciplines. Therefore, it is recommended that future research collect data from multiple countries and broader educational systems to enhance the generalizability and applicability of the results.

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