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The mediating role of critical thinking skills in the relationship between technology-based learning, digital competence, and academic achievement

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ABSTRACT

Teaching and learning approaches have developed alongside the growing adoption of digital technologies in higher education. However, the effect of these technologies on students' academic achievement remains unclear. Previous research has yielded mixed findings. Several studies suggest that digital competence and technology-based learning enhance academic performance, while others report only marginal advantages, especially for students with lower cognitive abilities. These discrepancies highlight a notable gap in the literature, as previous research has largely concentrated on academic performance, digital learning, and digital competence separately without sufficiently explaining the mechanisms that link them. This limitation leads to an incomplete understanding of how digital technologies improve learning outcomes and may contribute to inefficient implementation in educational settings. Therefore, there is a need for a more integrated framework to clarify these relationships. This study proposes a model that views critical thinking as a crucial mediating mechanism that connects digital competence and technology-based learning to academic achievement. This study employs a survey of 264 purposively selected undergraduate students from a university in Makassar, with data analyzed using SEM-PLS. The findings demonstrate that technology-based learning and digital competence significantly affect academic achievement, both directly and indirectly through critical thinking as a mediating variable. Overall, this study emphasizes the importance of incorporating critical thinking into technology-based learning to promote academic achievement in higher education and provides empirical evidence of the role of cognitive processes in shaping digital learning outcomes.

Keywords: academic achievement; critical thinking skills; digital competence; higher education; technology-based learning

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INTRODUCTION

Contemporary education systems have experienced profound shifts driven by the accelerated advancement of digital technology (Bond et al., 2021). Efforts to respond to demands of 21st-century learning increasingly emphasize integration of technology-oriented instructional models, including

blended learning strategies, interactive digital media, and online-based educational frameworks within academic settings (Organization for Economic Co-operation and Development, 2021). Expanding scholarly evidence reveals that educational institutions are "increasingly employing technology in their teaching and learning processes, demonstrating its effectiveness in improving learning outcomes, student engagement, and interaction" (Ardhiani et al., 2023; Chikileva et al., 2023; Kusumo et al., 2024). Concept of digital competence is described as capability to utilize digital tools appropriately and responsibly for purposes of learning, communication, and problem-solving among both instructors and learners. Recognition of this competence continues to grow as a critical determinant of meaningful participation in digitally enriched learning environments (González-Zamar et al., 2020). Effective engagement, however, emerges not solely from technological adoption but from interplay between digital competence and pedagogical, technological, as well as motivational dimensions.

Integration of technology-based learning commonly involves utilization of learning management systems, video conferencing platforms, multimedia resources, and instructional software within instructional processes. Adoption of such tools broadens accessibility to educational materials while fostering inclusive learning conditions by enabling participation across varied temporal and spatial contexts (Kusumo et al., 2024). Digital competence, in this regard, encompasses skills required to design learning activities, retrieve and manage digital information, and collaborate through information and communication technologies. Prior empirical findings indicate that learners possessing advanced digital competence tend to demonstrate superior academic outcomes, largely due to enhanced capacity for self-regulated learning, systematic knowledge organization, and increased productivity (Ardhiani et al., 2023; Eluemuno, 2025).

Despite rising awareness regarding the importance of digital literacy and technology-based education in Indonesia, student performance in these domains remains relatively limited. Persistent challenges related to digital competence continue to hinder optimal academic development. Although internet penetration reached 80.6% in 2025 (Asosiasi Penyelenggara Jasa Internet Indonesia, 2025), many students still lack proficiency required to effectively employ digital tools for academic purposes. Difficulties in utilizing productivity applications, navigating digital learning platforms, and accessing global academic resources have contributed to suboptimal academic performance. Empirical studies confirm that insufficient digital competence is associated with lower academic achievement and reduced engagement within higher education contexts (Ardhiani et al., 2023; Suhartono et al., 2025). Additional evidence from World Bank (2022) indicates that only a limited proportion of Indonesian students demonstrate ability to independently identify problems and generate innovative solutions. Findings highlight urgent necessity for improved instructional strategies aimed at strengthening digital literacy, critical thinking, and technology-supported learning.

Numerous investigations have explored relationships among technology-based learning, digital competence, critical thinking, and academic achievement. Several studies report significant positive influence of technology-based learning on student performance (Ahmad et al., 2024; Kusumo et al., 2024). Findings related to digital competence, however, remain inconsistent. Research conducted by Karafil and Uyar (2023) as well as Suhartono et al. (2025) identifies a strong correlation between digital competence and academic success. Conversely, other studies emphasize that although digital competence contributes to the development of technical abilities, it does not necessarily lead to improved academic outcomes in the absence of adequate critical thinking skills (Ng et al., 2023). Such inconsistencies suggest that academic achievement cannot be explained solely through digital competence. Consideration of mediating factors, particularly critical thinking and problem-solving abilities, becomes essential since these competencies enable learners to interact with technology in a more strategic, reflective, and effective manner (Adeoye, 2023; Putera et al., 2024).

Divergent findings across prior studies concerning digital competence, technology-based learning, and critical thinking indicate the absence of consensus regarding their combined influence on academic performance. Existing literature has yet to sufficiently investigate the mediating role of critical thinking, especially within the Indonesian higher education context. Most prior research examines these variables independently without adequately addressing their integrative or interactive

effects. Evidence suggests that critical thinking contributes significantly to academic performance (Akpur, 2020), explicit reading comprehension (Heidari, 2020), and analytical-reflective reasoning (Valencia & Shodiq, 2024).

Previous research consistently demonstrates that Indonesian students encounter substantial difficulties in developing higher-order cognitive skills, particularly critical thinking abilities. Limitations in these competencies are associated with lower academic achievement, challenges in explicit reading comprehension, and weak analytical-reflective thinking capacities (Akpur, 2020; Heidari, 2020; Valencia & Shodiq, 2024). Such conditions indicate that increased access to digital technologies has not been accompanied by adequate development of cognitive skills required to process, evaluate, and apply information effectively in academic contexts. Government initiatives in Indonesia have emphasized importance of integrating digital literacy and higher-order thinking into educational systems. Implementation across higher education institutions, however, remains uneven, with many institutions yet to adopt pedagogical approaches that effectively combine technological integration with critical thinking development.

Focus of this study centers on critical thinking as a mediating variable due to its essential role in enabling students to assess digital information, engage in reflective reasoning, and generate well-founded academic conclusions within technology-based learning environments. Contribution of this research lies in offering new insight into mediating function of critical thinking in relationship between technology-based learning, digital competence, and academic achievement among university students in Makassar. Research question guiding this study is formulated as follows: "To what degree does critical thinking mediate relationship between students' academic accomplishment and technology-based learning and digital competence."

LITERATURE REVIEW

Technology-oriented learning

Technology-oriented learning has become an integral component of modern instructional practices, particularly within higher education contexts. Rapid evolution of digital innovations has motivated educators to embed diverse technological instruments into curriculum planning, teaching delivery, and evaluation mechanisms (Wen & Walters, 2022). Various tools—including learning management systems, virtual meeting platforms, multimedia materials, and interactive instructional applications—support creation of flexible and learner-centered environments. Integration of such technologies expands access to educational content while enabling participation without constraints of time or place. Consequently, this approach fosters development of an adaptive and inclusive educational framework aligned with demands of 21st-century education.

Role of technology-based learning also extends to strengthening essential student competencies, including problem-solving, communication, collaboration, and creativity. Digital platforms allow learners to engage in dynamic activities such as developing digital products, participating in virtual discussions, and collaborating on online assignments (Aslam et al., 2024). Engagement in these activities stimulates deeper cognitive processing and active participation, which contribute positively to academic performance. Access to diverse information sources through digital means further enhances knowledge acquisition and analytical capability. Effective incorporation of technology in instructional settings therefore supports not only content mastery but also advancement of higher-order thinking skills required for academic success.

Digital competence

Concept of "digital competence" encompasses a broad spectrum of abilities, attitudes, and knowledge necessary for effective utilization of digital technologies across various domains, including education. Vuorikari et al. (2022) identify multiple dimensions of this competence, such as data and information literacy, communication and collaboration, digital content creation, safety awareness, and problem-solving capacity. Within academic environments, digital competence enables learners to navigate digital systems, optimize use of technological tools, and critically evaluate online information.

Increasing expansion of digital ecosystems in higher education highlights importance of this competence as a fundamental requirement for both academic achievement and continuous learning. Capacity to actively engage in meaningful digital learning experiences represents a central element of digital competence.

This involves "building, managing, and assessing knowledge through the efficient use of digital resources, online collaboration tools, and virtual learning platforms" (Kallas & Pedaste, 2022; Yang et al., 2021). Implementation of technology in teaching practices frequently enhances development of such competence by providing hands-on exposure to digital applications (Bojórquez-Roque et al., 2024). Elevated levels of digital competence support students in regulating their own learning processes, structuring information effectively, and participating actively in academic tasks. Accordingly, digital competence is regarded as a critical factor that facilitates both academic performance and cognitive growth within technology-enriched learning environments.

Academic achievement

Academic achievement is commonly viewed as a primary indicator reflecting learning outcomes and overall academic success of students. Conventional measurement approaches rely on grades, examination scores, and other formal assessment tools to evaluate student performance (Cutumisu et al., 2020; Zhang & Zeng, 2024). Such measures indicate extent to which learners understand, retain, and apply knowledge within specific subject areas. Contemporary educational perspectives, however, have expanded this concept beyond mere test results to include broader competencies that contribute to holistic student development. Recognition has grown that abilities such as critical thinking and adaptability in applying knowledge across contexts are equally important components of academic success.

From a broader standpoint, academic achievement incorporates not only intellectual mastery but also competencies related to critical reasoning, interpersonal interaction, and readiness for professional environments (Luo et al., 2023; Wang et al., 2022). Higher education institutions increasingly prioritize cultivation of these capabilities to prepare students for complex real-world challenges. As a result, academic achievement is now understood as a multidimensional construct representing both mastery of knowledge and ability to apply it effectively in diverse situations. This expanded perspective underscores significance of integrating cognitive, technological, and social competencies to enhance overall academic performance. Advancement of digital technology in education further enriches this concept by embedding digital literacy and self-regulated learning as essential dimensions of student achievement.

Critical thinking skills

Advanced cognitive skills, particularly critical thinking, hold a central role within technology-supported higher education contexts. Critical thinking is characterized as a reflective and self-regulated process that involves "analysis, evaluation, and inference to guide decision making" (Ennis, 2011; Facione, 1990). As a complex and multidimensional construct, it encompasses interpretation, analysis, evaluation, and self-regulation, allowing learners to engage with information in a deep and critical manner. Within digital learning settings, this capability becomes especially essential for assessing credibility of information and for constructing knowledge in an effective way. Empirical findings from previous research demonstrate that digital competence and technology-based learning contribute to enhancement of students' critical thinking through active participation and inquiry-driven learning strategies (Fernández-Gutiérrez et al., 2020; van Laar et al., 2017).

Critical thinking also functions as a significant determinant of academic achievement, as it facilitates problem-solving processes, logical reasoning, and application of knowledge (Abrami et al., 2015; Halpern, 2014). More importantly, its role extends as an intermediary variable that explains connection between academic performance, digital competence, and technology-based learning. Recent empirical studies reveal that critical thinking reinforces relationship between digital learning practices and academic outcomes by promoting deeper cognitive engagement (Sánchez-Caballé et al.,

2020; van Laar et al., 2020). Limited attention in earlier studies toward this mediating function suggests necessity for a more comprehensive conceptual framework that explicitly positions critical thinking as a fundamental mechanism within technology-based learning environments.

METHOD

Research participant

Population of this study consisted of undergraduate students in Makassar City who were enrolled during the 2022–2025 academic period. Selection of respondents applied purposive sampling by considering several inclusion criteria, namely active status as undergraduate students within that period, involvement in technology-oriented organizations both inside and outside campus, participation in technology-related courses, and demonstrated engagement in digital learning activities. Such engagement was reflected through participation in online learning platforms, frequency of technology use in academic tasks, and self-reported digital competence. Total of 300 students completed an online questionnaire. Data screening process resulted in elimination of 36 responses due to incomplete submissions and fulfillment of one or more predefined criteria. Final dataset therefore consisted of 264 valid responses that were subsequently utilized for further analysis.

Research instrument

Design of this research is grounded in principle that methodological approach must align with characteristics of variables examined and nature of data required to answer research questions. Investigation of relationships among technology-based learning, digital competence, critical thinking skills, and academic achievement requires careful consideration of construct measurability, inter-variable relationships, and extent to which findings can be generalized within defined population. Systematic and structured data collection procedure is essential, particularly as study aims to capture students' perceptions and experiences within technology-enhanced learning environments.

Research activities were undertaken within multiple higher education institutions in Makassar City, focusing on undergraduate students who demonstrate consistent involvement in digitally supported learning environments. Context of this investigation offers important insights into application of educational technology; however, scope of findings remains limited to specific institutional and regional settings, reducing broader applicability. Adoption of a cross-sectional framework further constrains interpretation, particularly in identifying cause-and-effect relationships among studied variables. Accordingly, "it is recommended that future research employ longitudinal or experimental methods and involve more varied groups in order to improve the robustness and generalizability of findings."

Choice of a quantitative methodology aligns with the objective of producing structured and statistically testable evidence through numerical data grounded in empirical and systematic principles (Apuke, 2017). Measurement of constructs relied on a five-level Likert scale, where responses ranged from 1 ("strongly disagree") to 5 ("strongly agree"). The development of the research instrument involved modification of previously established indicators that had demonstrated acceptable levels of validity and reliability in earlier investigations.

An analytical process applied "Structural Equation Modeling Partial Least Squares (SEM PLS)" with support from Smart-PLS software. Initial stage focused on examining measurement model (outer model) through evaluation of construct reliability "(Cronbach's alpha and composite reliability), discriminant validity, and convergent validity testing (loading factor and AVE)." The subsequent stage assessed structural relationships (inner model) using path coefficients along with the coefficient of determination (R-squared). Final analytical step employed a bootstrapping procedure to test significance and mediation effects, enabling identification of both direct and indirect influences among variables. Formulation of this study includes five hypotheses: "(H1) implementation of technology-supported learning is expected to produce a positive and statistically significant contribution to improvement of students' academic outcomes in Makassar City, (H2) higher levels of digital competence are anticipated to be associated with better and more significant academic performance

among students in Makassar City, (H3) stronger critical thinking abilities are predicted to positively and significantly enhance students' academic achievement in Makassar City, (H4) influence of technology-based learning on academic performance is expected to occur not only directly but also indirectly through enhancement of critical thinking skills as an intervening variable, and (H5) impact of digital competence on academic achievement is also assumed to be transmitted through development of critical thinking abilities as a mediating factor."

FINDINGS

Respondent descriptive

Descriptive analysis results of respondents are presented in subsequent tables. Characteristics examined in this study include gender distribution, academic major, and year of enrollment

Table 1

Distribution of Participants by Gender Category

Gender Category	Number of Participants	Proportion (%)
Male Students	45	17%
Female Students	219	83%
Overall Total	264	100%

Source: Processed data from survey findings, 2025

Table 1 shows a strong female majority in the sample (83%), compared to 17% male respondents.

Table 2

Characteristics of Respondents based on Majors

Majors	Frequency	Percentage
Business Administration	52	20%
Indonesian Language and Literature Education	132	50%
Public Administration	25	9%
Management	55	21%
Total	264	100%

Source: Research results, 2025

Table 2 indicates that most respondents are from Indonesian Language and Literature Education (50%), with smaller proportions from Management (21%), Business Administration (20%), and Public Administration (9%).

Table 3

Characteristics of Respondents based on Year Class

Year Class	Frequency	Percentage
2022	107	41%
2023	54	20%
2024	95	36%
2025	8	3%
Total	264	100%

Source: Processed data from survey findings, 2025

Table 3 shows a dominance of the 2022 cohort (41%), with smaller proportions from 2024 (36%), 2023 (20%), and 2025 (3%).

Table 4

Characteristics of Respondents based on Institution

Year Class	Frequency	Percentage
Universitas Negeri Makassar	90	34%
Universitas Hasanuddin	35	13%
Universitas Sawerigading	120	45%
Universitas Patompo	19	8%
Total	264	100%

Source: Processed data from survey findings, 2025

Table 4 shows that Universitas Sawerigading contributes the largest share of respondents (45%), with smaller proportions from Universitas Negeri Makassar (34%), Universitas Hasanuddin (13%), and Universitas Patompo (8%).

Outer model

Preliminary analysis within "Structural Equation Modeling Partial Least Squares (SEM PLS)" emphasizes evaluation of measurement model (outer model) to ensure that all constructs fulfill established criteria of reliability and validity. This stage plays a critical role in confirming that each indicator accurately captures and consistently represents its associated latent construct. Assessment procedure incorporates examination of both convergent validity and discriminant validity to verify measurement quality. In this research, four latent variables were operationalized through sixteen observed indicators. Outcomes of this evaluation demonstrate that all constructs meet required measurement standards, indicating that model specification is adequate and can be confidently extended to structural model estimation and hypothesis verification.

Convergent validity

Examination of convergent validity is intended to assess how well observed indicators are represented by their underlying latent constructs. In this research, evaluation relied on two main measures, namely "Average Variance Extracted (AVE) and outer loading values." Acceptability of each indicator is determined by its loading magnitude, which should reach or exceed a threshold of 0.7 to indicate a strong association with its construct. Furthermore, the adequacy of convergent validity at the construct level is confirmed when AVE surpasses 0.5. A value above this benchmark signifies that more than half of the indicator variance is captured by the construct, reflecting sufficient explanatory strength.

Table 5

The Loading Factor Value

Variable	Indicator	Outer Loading	AVE Value	Variable	Indicator	Outer Loading	AVE Value
Technology based-learning	TBL1	0.768	0.625	Critical thinking skills	CTS1	0.803	0.701
	TBL2	0.830			CTS2	0.847	
	TBL3	0.776			CTS3	0.850	
	TBL4	0.788			CTS4	0.849	
Digital competence	DC1	0.842	0.683	Academic achievement	AA1	0.794	0.708
	DC2	0.864			AA2	0.858	
	DC3	0.849			AA3	0.839	
	DC4	0.745			AA4	0.872	

Source: Processed data from survey findings, 2025

All indicators in this study are legitimate because Table 5 demonstrates that each indicator's outer loading value is larger than 0.7 and the AVE value is greater than 0.5.

Discriminant validity

Verification of discriminant validity is intended to demonstrate that each latent construct reflects a unique concept and does not share substantial overlap with other constructs in a structural model.

Analytical procedure in this study incorporated two complementary techniques, namely "cross loadings and the Fornell-Larcker criterion." In cross loading evaluation, each measurement item must display its highest association with the construct it represents, while showing lower associations with all other constructs. Furthermore, "Fornell Larcker criterion examines interrelationships among latent variables by contrasting square root of the AVE value with correlations between constructs," thereby confirming that variance explained by a construct's own indicators exceeds variance shared with other constructs.

Table 6

Cross Loading Value

Indicator	Variable			
	Technology Based-Learning	Digital Competence	Critical Thinking Skills	Academic Achievement
TBL1	0.768	0.676	0.484	0.584
TBL2	0.830	0.504	0.492	0.617
TBL3	0.776	0.436	0.444	0.558
TBL4	0.788	0.556	0.440	0.518
DC1	0.627	0.842	0.488	0.539
DC2	0.631	0.864	0.572	0.582
DC3	0.530	0.849	0.541	0.575
DC4	0.473	0.745	0.443	0.519
CTS1	0.488	0.517	0.803	0.498
CTS2	0.495	0.519	0.847	0.594
CTS3	0.460	0.551	0.850	0.574
CTS4	0.530	0.495	0.849	0.610
AA1	0.638	0.631	0.546	0.794
AA2	0.532	0.473	0.600	0.858
AA3	0.616	0.591	0.551	0.839
AA4	0.633	0.553	0.595	0.872

Source: Processed data from survey findings, 2025

All indicators in the study are deemed legitimate since Table 6 demonstrates that each indicator has the highest loading factor value for the intended construct in comparison to the loading factor value for other constructs.

Table 7

Fornell-Larcker Criterion

Variable	Academic Achievement	Critical Thinking Skills	Digital Competence	Technology Based-Learning
Academic Achievement	0.841			
Critical Thinking Skills	0.681	0.837		
Digital Competence	0.671	0.621	0.826	
Technology Based-Learning	0.722	0.589	0.686	0.791

Source: Processed data from survey findings, 2025

It can be inferred that the model in this study has a good discriminant validity value as Table 7 demonstrates that all AVE root values of all variables have the highest correlation values with other variables.

Reliability test

To confirm the consistency and dependability of the latent variable, reliability testing measures Cronbach's alpha and Composite Reliability. If both Cronbach's alpha and composite reliability above 0.7, a latent variable is considered to have good reliability.

Table 8
Reliability Test

Variable	Composite Reliability	Cronbach's Alpha
Technology Based-Learning	0.870	0.800
Digital Competence	0.896	0.844
Academic Achievement	0.906	0.862
Critical Thinking Skills	0.904	0.858

Source: Processed data from survey findings, 2025

Every single latent variable tested in this study had composite reliability and Cronbach's alpha values more than 0.7, as Table 8 demonstrates; hence, all latent variables can be considered "reliable."

Inner model

"Internal model testing is the next step in the SEM PLS analysis process. R-square values and direct and indirect hypothesis testing techniques can be used to assess the performance of the internal model."

R-square

"A higher R-squared value gives a better predictive capability of the proposed research model."

Table 9
R-Square Value

Variable	R-Square
Academic Achievement	0.645
Critical Thinking Skills	0.436

Source: Processed data from survey findings, 2025

Results displayed in Table 9 reveal that the coefficient of determination for academic achievement reaches 0.645, while the value for critical thinking skills is recorded at 0.436. Interpretation of these values indicates that digital competence and technology-based learning explain 43.6% of the variance in critical thinking, whereas 64.5% of the variation in academic achievement is accounted for by variables included in this model. Remaining unexplained portions, amounting to 56.4% for critical thinking and 35.5% for academic achievement, are attributed to additional factors beyond the scope of this study.

Magnitude and direction of direct relationships among variables are reflected through path coefficient estimates. Indirect influences are identified using specific indirect effect analysis, which captures the role of mediating variables in transmitting effects from independent variables to dependent outcomes. The decision regarding hypothesis testing is based on statistical indicators such as p-value, T-statistic, and significance level. Values obtained from the bootstrapping procedure serve as a basis for evaluation, where acceptance criteria require a positive coefficient direction, a T-statistic exceeding 1.96, and a p-value lower than 0.05, indicating statistically significant relationships.

Hypothesis testing

Testing the hypothesis evaluates whether path coefficients are statistically significant, with a P-value less than 0,05 typically used to indicate a significant correlation (Hair et al., 2011).

Table 10
Path Coefficients

Relationship between Variable	Original Sample	T Values	P Values	Decision
Technology Based-Learning (X1) -> Academic Achievement (Y)	0.357	4.539	0.000	Significant
Digital Competence (X2) -> Academic Achievement (Y)	0.198	2.884	0.004	Significant

Critical Thinking Skills (Z1) -> Academic Achievement (Y)	0.271	3.699	0.000	Significant

Source: Processed data from survey findings, 2025

Table 11
Specific Indirect Effects

Relationship between Variable	Original Sample	T Values	P Values	Decision
Technology Based-Learning (X1) -> Critical Thinking Skills (Z1) -> Academic Achievement (Y)	0.084	2.582	0.010	Significant
Digital Competence (X2) -> Critical Thinking Skills (Z1) -> Academic Achievement (Y)	0.111	3.425	0.001	Significant

Source: Processed data from survey findings, 2025

Statistical testing outcomes demonstrate that each direct linkage within the proposed model exhibits a positive direction and achieves significance. Evidence confirms that "technology-based learning (H1) contributes positively and significantly to students' academic performance" ($\beta = 0.357$, $t = 4.539$, $p < 0.001$). Influence of digital competence (H2) is likewise supported, as it "provides a meaningful positive contribution to academic achievement" ($\beta = 0.198$, $t = 2.884$, $p = 0.004$). In addition, "critical thinking skills (H3) significantly enhance students' academic outcomes" ($\beta = 0.271$, $t = 3.699$, $p < 0.001$).

Examination of mediated pathways reveals additional insights. "Fourth hypothesis (H4) evaluates indirect contribution of technology-based learning to academic performance through critical thinking skills." Findings from SEM-PLS indicate that this pathway is statistically significant, confirming the existence of mediation ($\beta = 0.084$, $t = 2.582$, $p = 0.010$). Similarly, "fifth hypothesis (H5) assesses the indirect effect of digital competence on academic outcomes through critical thinking." Results indicate a positive and significant mediated relationship ($\beta = 0.111$, $t = 3.425$, $p = 0.001$), highlighting the function of critical thinking as a key intermediary variable.

DISCUSSION

This research deepens insight into the roles of digital competence and technology-based learning in shaping academic achievement by positioning critical thinking as a fundamental explanatory mechanism. Findings move beyond simple confirmation that technology integration enhances academic outcomes, revealing instead that effectiveness emerges from stimulation of active cognitive involvement. Technology-supported learning environments facilitate interaction, exploration, and autonomous learning, which subsequently activate higher-order thinking processes such as evaluation and analysis (Chikileva et al., 2023). From a constructivist standpoint, improvement in learning outcomes is not determined by the presence of technology itself, but by the extent to which it enables meaningful engagement with academic content. Within this framework, technology-based learning operates as a transformative driver that shifts passive participation into cognitively intensive activities, ultimately strengthening academic performance. Contribution to existing literature lies in clarifying that the effectiveness of digital learning environments depends on their ability to cultivate critical thinking rather than merely expanding access to information (Wang et al., 2022).

The second hypothesis is also supported, indicating that digital competence exerts a positive and significant influence on academic achievement. Evidence from this study demonstrates that "students who possess higher levels of digital competence are more adept at navigating digital learning environments, assessing online content, and making efficient use of digital resources for academic reasons. Previous studies have shown that students' learning success in technologically advanced classrooms is significantly influenced by their level of digital competency" (Hatlevik & Christophersen, 2013; Tee et al., 2023). Strong digital capability enables learners to manage academic tasks more efficiently, organize information systematically, and achieve higher levels of academic success, reinforcing its importance as a determining factor in educational outcomes.

Findings further confirm the third hypothesis, showing that critical thinking skills significantly and positively affect students' academic performance. Alignment with cognitive learning theory is evident, as the theory emphasizes the importance of higher-order thinking processes in fostering deep comprehension and knowledge transfer. Students equipped with advanced critical thinking abilities demonstrate a stronger capacity to interpret complex information, resolve academic challenges, and apply knowledge effectively, all of which contribute to improved performance. Empirical evidence from higher education research consistently identifies critical thinking as a reliable predictor of academic success (Kallas & Pedaste, 2022).

More importantly, results indicate that critical thinking functions as a mediating variable in the relationship between "Technology-Based Learning and academic achievement," thereby supporting the fourth hypothesis. Technology-based learning enhances academic outcomes not only through direct influence but also indirectly by strengthening students' critical thinking abilities. Properly designed digital environments stimulate the development of critical thinking by encouraging engagement with content in an active and reflective manner (Luo et al., 2023). Improvement in these cognitive skills leads to deeper interaction with academic materials, which ultimately translates into higher academic achievement. This outcome emphasizes that technological tools alone are insufficient to improve learning results without integration of pedagogical strategies that nurture higher-order cognitive processes.

The fifth hypothesis is likewise validated, demonstrating that critical thinking mediates the relationship between digital competence and academic achievement. Students with strong digital competence are better positioned to evaluate the credibility of digital information, select reliable sources, and utilize technology strategically for academic purposes. "These abilities contribute to the development of critical thinking skills, which in turn enhance academic performance." Such findings are consistent with previous research indicating that digital competence indirectly influences academic success through cognitive and metacognitive mechanisms, particularly critical thinking (Bojórquez-Roque et al., 2024).

Overall interpretation suggests that both technology-based learning and digital competence play significant roles in determining academic achievement in higher education; however, the magnitude of their impact increases substantially when supported by well-developed critical thinking skills. Implications for higher education institutions in Makassar City highlight the necessity of aligning technological investment with instructional strategies that deliberately integrate critical thinking into course design. Educators are encouraged to adopt problem-based learning approaches, case analysis methods, and activities that emphasize evaluative reasoning. Structured online discussion forums requiring argument justification, peer critique, and evidence-based reasoning can further strengthen cognitive engagement.

Reflective practices, including learning journals and electronic portfolios, may also be incorporated into digital platforms to enhance metacognitive awareness. Institutional initiatives should include professional development programs aimed at equipping lecturers with skills to design technology-enhanced instruction that integrates higher-order questioning techniques, assessment rubrics for critical thinking, and interactive learning tools. Systematic implementation of these strategies enables universities to improve academic outcomes while preparing students to meet cognitive challenges associated with 21st-century education.

CONCLUSION

The results show that technology-based learning greatly improves students' academic performance, proving that using digital tools like learning management systems, online platforms, and multimedia materials improves learning experiences and outcomes. Digital competence, which emphasizes the significance of students' capacity to use digital tools, evaluate online content, and engage effectively in digital learning environments, also has a major impact. Additionally, critical thinking skills mediate the connections between digital competency, technology-based learning, and academic success and are crucial for academic success. This implies that both the indirect and direct effects of technology on

learning outcomes are improved by higher-order cognitive skills. These results show that merely offering digital infrastructure is not enough; Makassar City institutions should adopt teaching strategies that incorporate technology with activities that foster critical thinking, like inquiry-based and problem-based learning. Despite this contribution, there are a few things to be aware of. First, it is more difficult to determine causal links between variables when a cross-sectional design is used. Second, the study's geographic limitations to Makassar City institutions may limit how far the results may be applied. Lastly, rather than using objective markers (such as GPA or institutional records), academic progress was judged based on perceived outcomes, which could have an impact on the accuracy of the results. Therefore, to improve the robustness and extent of the results, future research is encouraged to use longitudinal or experimental designs, incorporate multi-source or objective data, employ a probability sampling technique, and look at additional variables like learning motivation and self-regulated learning.

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CONFLICT OF INTEREST STATEMENT:

The authors report no competing interests associated with the research presented in this manuscript.

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