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IT-based learning innovation and critical thinking skills concerning students' mastery of materials and their implications on academic achievement

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A B S T R A C T

This study explores the intricate relationships among Critical Thinking Skills, IT-Based Learning Innovation, Students' Mastery of Materials, and Academic Achievement in the context of education. The study employed a quantitative research approach to investigate the relationships. The hypotheses examined reveal significant findings. Firstly, IT-Based Learning Innovation positively impacts both Students' Mastery of Materials and Academic Achievement, emphasizing the pivotal role of technology in modern education. Secondly, Critical Thinking Skills influenced Students' Mastery of Materials and Academic Achievement, underscoring the importance of fostering these skills in students. Additionally, Students' Mastery of Materials was identified as a crucial factor positively affecting Academic Achievement. Moreover, the study confirmed that Students' Mastery of Materials mediates the relationship between IT-Based Learning Innovation and Academic Achievement, highlighting the indirect impact of innovative IT-based learning methods on Academic Achievement through enhanced material mastery. However, in contrast, Students' Mastery of Materials was not found to mediate the relationship between Critical Thinking Skills and Academic Achievement, suggesting a potential direct link between these factors. Theoretical implications encompass enriching educational theory by emphasizing the significance of Critical Thinking Skills and the multifaceted nature of academic achievement. Practical implications include curriculum revisions, pedagogical approaches, and assessment strategies that promote critical thinking and effective technology integration. Bridging the digital equity gap is crucial, and future research should explore intervention strategies and international comparisons to inform evidence-based educational practices. Overall, this study contributes to a comprehensive understanding of the complex dynamics in education, offering insights for both researchers and educators.

1. Introduction

Education is a cornerstone in shaping competent and competitive individuals in the contemporary era (Mok & Wu, 2016). The demand for innovation in teaching methods and learning tools has grown increasingly pertinent in light of rapid information and communication technology (ICT) advancements (Adedoyin & Soykan, 2023; Akour & Alenezi, 2022; Monostori et al., 2016). Integrating IT-based learning innovations has become a powerful response to the evolving educational landscape, promising more effective, efficient, and relevant teaching methodologies (Ahuja & Bala, 2021; Anderson et al., 2018; Faqih & Jaradat, 2021). Concurrently, critical thinking skills constitute a fundamental component of the learning process, enabling students to develop profound comprehension, analytical abilities, problem-solving prowess, and rational decision-making

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(Koufidis et al., 2021; Marougkas et al., 2023; Tarchi & Mason, 2020). In this context, IT-based learning innovations have the potential to stimulate and cultivate critical thinking skills among students (Saeed & Ahmed, 2021; Wiyono et al., 2020; Yuan et al., 2022; Zhen et al., 2022).

This research endeavors to unravel the intricate relationship between IT-based learning innovations, students' critical thinking abilities, mastery of subject matter, and the resultant impact on academic achievements, specifically focusing on Economics Education. Consequently, this study aims to show how the judicious use of information technology can be optimized to enhance learning processes and academic achievements. The research bears significant implications that can contribute substantively to the field of education, particularly within the domain of Economics Education and the integration of technology in the learning process. The following aspects underscore the significance of this research:

1. Enhanced Quality of Learning: This research holds the potential to offer profound insights into how IT-based learning innovations can be effectively applied to improve students' mastery of subject matter. The findings may pave the way for the development of more efficient and adaptive teaching methods.
2. Fostering Critical Thinking Skills: By comprehending how critical thinking skills influence the learning process, this research may assist educational institutions and educators in devising teaching strategies that promote students' critical thinking abilities—an essential skill in contemporary life.
3. Improved Academic Achievement: The implications of this research may help elevate students' academic performance in subjects like Economics, which is relevant to addressing contemporary social and economic challenges.
4. Curriculum Development: The research findings could be instrumental in shaping more adaptive and relevant curricula that cater to the needs of today's students.
5. Global Competitiveness: By optimizing technology for learning, this research can empower students to enhance their economic competencies, directly impacting their competitiveness in a rapidly evolving global economic landscape.

This research is motivated by several compelling factors:

1. Enhancing Educational Quality: The desire to elevate the quality of education is a primary motivation. By crafting more effective learning methods, we can facilitate improved comprehension of subject matter, including Economics.
2. Leveraging Technology: The integration of information technology permeates nearly every facet of modern life, including education. The motivation to unlock technology's full potential in education is vital to align educational practices with the contemporary age.
3. Development of Critical Thinking Skills: Critical thinking skills are highly prized in daily life and future careers. The motivation to explore the relationship between critical thinking skills and subject mastery aims to create holistic student development.
4. Contributing to Knowledge: This research is expected to yield new insights and additional knowledge in the field of education, serving as a foundation for further research and advancements in educational practices.

With its substantial significance and strong motivation, this research is poised to make meaningful contributions toward improving the quality of education, particularly within Economics Education, and provide valuable guidance to educational practitioners and policymakers. This research aims to achieve several primary objectives that reflect a commitment to understanding the relationship between IT-based learning innovations, students' critical thinking skills, mastery of subject matter, and their implications on academic achievement within the context of Economics Education. The research objectives encompass:

1. Identifying the Influence of IT-Based Learning Innovations: Conduct an in-depth analysis of IT-based learning innovations' influence on students' learning process in the field of Economics Education.
2. Examining the Role of Critical Thinking Skills: Assess the role of critical thinking skills in influencing subject mastery and the learning process while identifying critical aspects of these skills that can be enhanced through IT-based learning innovations.
3. Measuring the Mastery of Subject Matter: Measure how IT-based learning innovations can enhance students' mastery of subject matter in Economics Education, pinpointing areas that require further attention.
4. Analyzing Implications on Academic Achievement: Analyze how the subject matter mastery students obtain through IT-based learning innovations impacts their academic achievement, including improvements in academic grades.
5. Providing Guidance for Education Practitioners: Offer insights and practical recommendations to educators, educational institutions, and policymakers on optimizing technology in learning and developing students' critical thinking skills.
6. Contributing to Knowledge Base: Contribute to the scholarly literature in the field of education, particularly within the context of technology integration and the development of students' critical thinking skills.
7. Promoting Sustainable Educational Change: The research aims to promote positive educational changes by motivating the effective use of technology in learning and advocating for critical thinking skills as an integral component of education.

By accomplishing these objectives, this research is expected to provide a deeper understanding of how IT-based learning innovations and students' critical thinking skills can mutually influence each other and have tangible impacts on academic achievement within the realm of Economics Education.

2. Literature Review and Hypothesis Development

2.1 IT-Based Learning Innovation and Students' Mastery of Materials

Torres-Linke et al. (2022) assert that IT-Based Learning Innovation refers to incorporating information technology (IT) and digital tools in the educational process to enhance and modernize teaching and learning methods. It utilizes hardware, software, and digital resources, including computers, mobile devices, e-learning platforms, and the Internet, to facilitate and improve the learning experience. According to Muslem et al. (2022), Students' Mastery of Materials refers to how students comprehensively understand, grasp, and effectively apply the content or subject matter in their educational curriculum. It reflects the depth of knowledge and proficiency students attain in a specific study area. The relationship between IT-Based Learning Innovation and Students' Mastery of Materials is one of interdependence and mutual influence (Dutta et al., 2016; Msiska & Nielsen, 2018). IT-Based Learning provides students access to various digital resources, including online textbooks, multimedia presentations, educational websites, and interactive simulations (Nurkhin et al., 2020). These resources can enrich their understanding of the subject and facilitate self-paced Learning. Digital learning platforms and adaptive software can tailor educational content to meet individual student needs (Serrano et al., 2019). By catering to diverse learning styles and paces, IT-Based Learning Innovation can support students in mastering materials more effectively (Fasihuddin et al., 2017). Interactive learning modules, gamification, and multimedia content can make learning more engaging and interactive (Hakak et al., 2019). Active participation and exploration can deepen students' comprehension of materials. Technology can bridge the gap between theoretical knowledge and real-world applications (Ebadi & Ashrafabadi, 2022). Students can apply what they have learned through simulations, virtual labs, and case studies, reinforcing their mastery of materials (Gunawan et al., 2017). IT-based learning systems often include data analytics tools that provide insights into student performance (Er et al., 2021). Educators can use this data to identify areas where students may be struggling and provide targeted support, ultimately aiding in their mastery of materials (Becker et al., 2017). In summary, IT-Based Learning Innovation can catalyze enhancing Students' Mastery of Materials by providing a dynamic and flexible learning environment rich in resources, interactivity, and personalized learning experiences. The effective utilization of technology in education can play a pivotal role in fostering deeper understanding and proficiency among students. Based on the findings of previous research, the hypotheses proposed in this study are as follows:

H_1: *IT-Based Learning Innovation impacts on Students' Mastery of Materials.*

2.2 IT-Based Learning Innovation and Academic Achievement

IT-Based Learning Innovation expands learning horizons by providing access to many digital resources, including multimedia presentations, online textbooks, interactive simulations, and educational software (Huang et al., 2023). Expanded access to diverse learning materials can enhance students' understanding of subjects, potentially leading to improved academic achievement (Edmunds et al., 2022). Technology-driven learning platforms often incorporate adaptive and personalized features (Zhang et al., 2022). These systems can tailor the learning experience to individual student needs, allowing students to progress at their own pace and focus on areas where they may require additional support (Soelistiono & Wahidin, 2023). Personalization can contribute to increased comprehension and better academic results. Interactive elements, gamification, and multimedia content inherent in IT-based learning can boost student engagement and motivation (Korkut & Surer, 2023). Engaged students are more likely to participate actively in their learning and demonstrate a greater commitment to their studies, which can positively influence academic achievement (Bowden et al., 2021).

Technology facilitates the integration of real-world applications into the learning process (Wang et al., 2022). Students can apply theoretical knowledge to practical scenarios through virtual labs, simulations, case studies, and project-based learning. Such experiences can deepen their understanding and readiness to excel academically (Dec et al., 2022). IT-Based learning often includes tools for formative and summative assessment (Dolin et al., 2018). Immediate feedback allows students to identify areas of improvement and make necessary adjustments. Effective feedback mechanisms can guide students toward achieving higher academic results. Learning analytics generated by IT-based learning platforms provide educators with valuable insights into student performance (Seufert et al., 2019). Braun et al. (2020) assess that educators can use this data to identify struggling students, provide targeted interventions, and offer additional support. This proactive approach can help students overcome academic challenges. Online learning platforms enable collaborative learning experiences. Students can interact with peers and educators through discussion forums, group projects, and virtual classrooms (Martirosyan et al., 2022). Collaborative learning can foster a supportive academic environment, leading to improved academic outcomes. IT-based learning often offers flexibility regarding when and where students can engage with educational content. This accessibility accommodates diverse learning styles and schedules, potentially increasing students' opportunities to excel academically (Mamun et al., 2020). Therefore, the relationship between IT-Based Learning Innovation and Academic Achievement is multifaceted. When effectively implemented, IT-based learning can provide students with enriched learning opportunities, personalized support, enhanced engagement, practical experiences, and valuable feedback—all of which contribute to improved academic performance and achievement. However, the extent of these positive effects may vary depending on the specific context, quality of implementation, and individual student factors. Based on previous research findings, the hypotheses proposed in this study are as follows:

H_2: *IT-Based Learning Innovation impacts on Academic Achievement.*

2.3 Critical Thinking Skills and Students' Mastery of Materials

According to Ghafar & Raheem (2023), critical thinking skills encompass thinking logically, analytically, and systematically. These skills involve evaluating information, reasoning effectively, problem-solving, making sound judgments, and approaching complex issues well-informed and rationally. Critical thinking is characterized by assessing arguments, recognizing biases, and synthesizing information to draw reasoned conclusions (Molerov et al., 2020). Glazewski & Ertmer (2020) explain that critical thinking skills enable students to engage with learning materials more deeply and meaningfully. By critically analyzing and questioning information, students can uncover underlying concepts and connections within the subject matter, leading to an enhanced understanding of the materials. Monteiro et al. (2020) argue that critical thinking is closely linked to effective problem-solving. When students possess strong critical thinking skills, they are better equipped to tackle complex problems within the subject matter. They can break problems into manageable components, identify relevant data, and develop logical solutions. Critical thinkers have an aptitude for recognizing key concepts and essential information within a body of materials. This discernment allows students to prioritize their focus on crucial aspects of the subject matter, aiding in their mastery of core concepts (Irafahmi et al., 2018). Based on the notion of Grafstein (2017), critical thinking involves critically evaluating information sources and arguments. Students with strong critical thinking skills can discern credible sources from unreliable ones, assess the validity of claims, and differentiate between facts and opinions within the materials they encounter. In addition, the contention of Jaswal & Behera (2023) is that critical thinking fosters the ability to synthesize information from various sources and viewpoints. Students can combine their understanding of different aspects of the subject matter to create a more comprehensive and coherent knowledge base. Critical thinkers actively engage with the materials they study. They ask questions, challenge assumptions, and seek a deeper level of comprehension. This level of engagement contributes to a more profound mastery of materials. Furthermore, Alkhabra et al. (2023) assume that Critical thinking skills are associated with improved memory retention. When students engage with subject matter critically, they are more likely to remember and apply what they have learned, leading to mastery over time. Sukma & Priatna (2021) belief that critical thinkers can communicate their understanding of materials effectively. They can articulate their thoughts, present arguments coherently, and engage in meaningful discussions, further reinforcing their mastery of the subject matter. In summary, the relationship between Critical Thinking Skills and Students' Mastery of Materials is symbiotic. Strong critical thinking skills enhance students' ability to comprehend, analyze, and engage with learning materials, ultimately contributing to a more profound and comprehensive mastery of the subject matter. This mastery, in turn, reinforces and refines their critical thinking skills, creating a cycle of continuous improvement in their academic pursuits. In light of the findings from prior research, this study posits the following hypotheses:

H_3: *Critical Thinking Skills impacts on Students' Mastery of Materials.*

2.4 Critical Thinking Skills and Academic Achievement

Sumarni & Kadarwati (2020) trust that critical thinking skills are closely associated with effective problem-solving. Students with strong critical thinking abilities excel at dissecting complex problems, identifying relevant information, and devising logical solutions. These problem-solving skills are highly valuable in academic settings and contribute to higher academic achievement. Then, the opinion of Lombardi et al. (2021) is that critical thinking fosters a deeper understanding of academic content. When students think analytically and question the information they encounter, they are more likely to grasp complex concepts, theories, and subjects. This enhanced comprehension directly correlates with improved academic performance. G. C. Huang et al. (2016) assert that critical thinking involves higher-level cognitive processes like analysis, evaluation, and synthesis. These skills are instrumental in academic tasks, including essay writing, research, and critical analysis of literature. Students who apply critical thinking skills tend to produce higher-quality academic work, leading to better grades. Critical thinking empowers students to make informed and reasoned decisions. In academic contexts, decision-making skills are essential for selecting research topics, choosing study strategies, and prioritizing tasks (Jenkins & Andenoro, 2016). Effective decision-making contributes to efficient learning and, consequently, academic success. Critical thinkers excel at evaluating information sources for credibility and reliability. This skill is vital for academic research, where students must assess the validity of sources and the relevance of information. Accurate information evaluation enhances the quality of academic work and research outcomes. Strong critical thinking skills enable students to articulate their thoughts, arguments, and ideas coherently and persuasively (Silva et al., 2020).

Effective communication is essential for presentations, debates, and written assignments, all impacting academic achievement. Critical thinkers actively engage with course materials, asking questions, seeking clarifications, and participating in discussions. This level of engagement promotes a deeper connection with the subject matter, which, in turn, leads to improved academic performance (Mega et al., 2014). Critical thinking encourages adaptability in learning. Students who can adapt their approaches to different subjects and learning environments are more likely to excel academically in various disciplines and contexts. Critical thinking fosters a disposition for continuous learning. Students with these skills are more likely to seek out additional resources, explore related topics, and maintain a lifelong commitment to intellectual growth, which can positively impact their academic achievements (Borkowski & Thorpe, 2023). Therefore, the relationship between Critical Thinking

Skills and Academic Achievement is robust and bidirectional. Developing and applying critical thinking skills enhances students' problem-solving abilities, comprehension of academic content, and overall academic performance. Conversely, academic success further cultivates and refines critical thinking skills, creating a symbiotic cycle supporting students' educational journey. Drawing on the insights garnered from earlier research, this study presents the following hypotheses:

H_4: *Critical Thinking Skills impacts on Academic Achievement.*

2.5 Students' Mastery of Materials, Academic Achievement, and its mediation

Meyer et al. (2015) suggest that Students' Mastery of Materials refers to the depth of understanding, proficiency, and command of the educational content or subject matter they have been taught. It signifies the extent to which students have comprehensively learned and can effectively apply the knowledge and skills related to a specific academic domain. Schwinger et al. (2022) argue that Students' Mastery of Materials serves as the foundation for academic achievement. When students thoroughly grasp the essential concepts and skills within a subject, they are better equipped to excel in related coursework, assignments, and assessments. Students who have mastered the material are better prepared to engage in deeper, more meaningful learning experiences. They can build upon their existing knowledge and apply it to more advanced topics, leading to a more comprehensive and robust understanding of academic content. Based on the notion of Maulana et al. (2022), mastery of materials empowers students with problem-solving capabilities. They can draw upon their knowledge to analyze complex issues, devise solutions, and confidently approach challenges. This problem-solving ability contributes to higher academic achievement, especially in critical thinking subjects. Students with a strong command of the material are likely to perform well in assessments, exams, and assignments. Their ability to apply their knowledge effectively leads to higher grades and academic success. According to Markant et al. (2016), mastery of materials is closely linked to improved memory retention. Students who thoroughly understand and engage with the subject matter are more likely to remember and recall information accurately, which is essential for academic achievement. Students who feel confident in their mastery of materials tend to be more motivated and engaged in their studies. This self-assurance can lead to a positive academic mindset, encouraging them to seek additional learning opportunities and set higher academic goals. Students who have mastered the material can articulate their thoughts and ideas more clearly and persuasively. Furthermore, Alamri (2018) assert that effective communication skills are essential for academic presentations, written assignments, and discussions, all contributing to academic achievement. Mastery of materials often paves the way for students to explore advanced or more specialized areas within a subject. This readiness for advanced learning can le, ad to academic achievements in more specialized domains. Proficiency in one subject often facilitates the integration of knowledge across disciplines. Students who have mastered materials in multiple areas can draw connections between different subjects, enriching their academic experience and potentially excelling in interdisciplinary contexts.

In the context of the relationship between Critical Thinking Skills, Students' Mastery of Materials, and Academic Achievement, Students' Mastery of Materials serves as a crucial mediating variable. It is integral in elucidating how Critical Thinking Skills influence Academic Achievement. Through several key mechanisms, including enhanced understanding of academic content, active and effective learning, superior problem-solving abilities, improved memory retention, readiness for assessments, and boosted confidence and motivation, Students' Mastery of Materials acts as the intermediary that clarifies how the development of critical thinking skills positively impacts students' academic performance, fostering a deeper comprehension of the importance of comprehensive subject mastery in achieving academic success. Taking into consideration the outcomes of previous research investigations, this study advances the following hypotheses:

H_5: *Students' Mastery of Materials impacts on Academic Achievement.*
H_6: *Students' Mastery of Materials mediates the relationship between IT-Based Learning Innovation and Academic Achievement.*
H_7: *Students' Mastery of Materials mediates the relationship between Critical Thinking Skills and Academic Achievement.*

3. Methodology

With a sample size of 135 participants, this study will utilize a quantitative research approach (Purwaningsih et al., 2022). This approach enables data collection based on numbers and statistics to analyze the relationships between the existing variables (Purwaningsih et al., 2019). The research participants, consisting of students from various educational levels in Serang, Banten, Indonesia, who volunteer to participate in this study, will be randomly selected to represent the relevant student population (Purwaningsih, 2020).

3.1 Research Variables

In this research, a combination of validated measurement instruments from previous research that utilize Likert scales and newly developed instruments by the author (Purwaningsih et al., 2022)(Basrowi & Maunnah, 2019) will be employed to assess the research variables. The study will focus on the following key variables:

1. IT-Based Learning Innovation. This variable aims to measure the extent to which IT-based learning innovation is implemented within education. It includes assessing the degree to which technology, such as online learning platforms, interactive educational videos, or educational applications, is utilized in the learning process (Marwanto et al., 2020).
2. Critical thinking skills will be assessed using a Likert scale-based instrument previously validated in academic research. This instrument measures various dimensions of critical thinking, including analytical thinking, problem-solving abilities, and evaluation skills. Additionally, the author has developed and incorporated specific Likert scale items to align with the study's context and objectives (Soenyono & Basrowi, 2020).
3. Students' Mastery of Materials: The measurement of students' mastery of materials will involve a newly developed instrument with Likert scale-based items. The author has meticulously crafted this instrument to comprehensively evaluate students' understanding and proficiency in the subject matter pertinent to the research. It encompasses Likert scale items designed to gauge the depth of knowledge and command within the academic domain (Suseno & Basrowi, 2023).
4. Academic Achievement: Official grade data from school records, including exam scores, assignment scores, and other relevant academic assessments, will be collected to assess academic achievement. These data will be used alongside Likert scale-based items to comprehensively evaluate academic achievement without requiring additional instruments (Mustofa et al., 2023).

We integration of Likert scale-based instruments from previous research and newly developed Likert scale items ensures a thorough and context-specific evaluation of the research variables (see Table A1 in Appendix).

3.2 Data Collection Procedures

This study will collect data by administering questionnaires designed to assess critical thinking skills, students' mastery of materials, and academic achievement (Suwarno et al., 2020; Suseno et al., 2018). These questionnaires will be meticulously developed, each tailored to measure the specific constructs accurately (Alexandro & Basrowi, 2024b, 2024a; Purwaningsih et al., 2024). Before the main data collection, a pilot test will be conducted to refine the questionnaires based on feedback (Basrowi & Utami, 2020). A diverse sample of participants will be recruited, ensuring representation of the target population, and informed consent will be obtained. Participants will complete the questionnaires independently, and data will be verified for accuracy and completeness. The collected data will be securely stored, and appropriate statistical analysis techniques will be employed to explore the relationships between the variables. Ethical considerations, including participant privacy and confidentiality, will be upheld throughout the data collection process, and research findings will be reported comprehensively while safeguarding participants' anonymity (Junaidi, Basrowi, et al., 2024; Kittie & Basrowi, 2024; Mulyani & Basrowi, 2024; Yusuf et al., 2024).

4. Results

4.1 Validity and reliability

Table 1 presents an analysis of several constructs, their associated measurement items, and various statistical indicators. Four constructs are examined in this analysis: IT-Based Learning Innovation, Critical Thinking Skills, Students' Mastery of Materials, and Academic Achievement. For the construct “IT-Based Learning Innovation”, eight measurement items (ITBL1 to ITBL8) are evaluated. The outer loading values range from 0.914 to 0.946, indicating that most things have strong relationships with the underlying construct. The Cronbach's Alpha coefficient of 0.978 demonstrates high internal consistency, suggesting that the items reliably measure the intended construct. Similarly, the rho_A and CR values are 0.98 and 0.981, respectively, further confirming the reliability of the construct. The AVE value of 0.869 indicates that the items collectively explain a substantial proportion of the construct's variance, reflecting good construct validity. For the “Critical Thinking Skills” construct, ten measurement items (CRTS1 to CRTS10) are examined. While some things exhibit slightly lower outer loading values, they remain reasonably high, ranging from 0.831 to 0.959. The Cronbach's Alpha coefficient of 0.977 indicates high internal consistency, and both rho_A and CR values (0.984 and 0.979, respectively) confirm the reliability of the construct. The AVE value of 0.827 suggests good construct validity. The “Students' Mastery of Materials” construct consists of nine measurement items (STMM1 to STMM9). These items display outer loading values ranging from 0.892 to 0.977, signifying solid relationships with the construct. The high Cronbach's Alpha (0.981), rho_A (0.983), and CR (0.982) values indicate excellent internal consistency and reliability. Additionally, the AVE value of 0.868 demonstrates solid construct validity. Finally, the “Academic Achievement” construct comprises ten measurement items (ACAC1 to ACAC10). While some things have slightly lower outer loading values, most remain respectable, ranging from 0.745 to 0.959. The Cronbach's Alpha (0.959) reflects good internal consistency, while the rho_A (0.965) and CR (0.962) values affirm the construct's reliability. However, although acceptable, the AVE value of 0.732 suggests that the items collectively explain a relatively lower proportion of the construct's variance than the other constructs, indicating moderate construct validity.

In summary, the analysis reveals that all constructs generally exhibit high reliability and good construct validity, except "Academic Achievement," which, while reliable, demonstrates somewhat lower construct validity. Researchers may consider further investigation or refinement of the items within this construct to enhance its validity.

Table 1
Confirmatory factor analysis

Construct	Items	Outer Loading	Cronbach's Alpha	rho_A	CR	AVE
IT-Based Learning Innovation	ITBL1	0.914	0.978	0.98	0.981	0.869
	ITBL2	0.946				
	ITBL3	0.941				
	ITBL4	0.947				
	ITBL5	0.929				
	ITBL6	0.926				
	ITBL7	0.930				
	ITBL8	0.923				
Critical Thinking Skills	CRTS1	0.875	0.977	0.984	0.979	0.827
	CRTS2	0.937				
	CRTS3	0.950				
	CRTS4	0.913				
	CRTS5	0.959				
	CRTS6	0.831				
	CRTS7	0.878				
	CRTS8	0.900				
	CRTS9	0.902				
	CRTS10	0.941				
Students' Mastery of Materials	STMM1	0.903	0.981	0.982	0.983	0.868
	STMM2	0.950				
	STMM3	0.977				
	STMM4	0.965				
	STMM5	0.957				
	STMM6	0.892				
	STMM7	0.905				
	STMM8	0.903				
	STMM9	0.929				
Academic Achievement	ACAC1	0.880	0.959	0.962	0.965	0.732
	ACAC2	0.892				
	ACAC3	0.915				
	ACAC4	0.902				
	ACAC5	0.751				
	ACAC6	0.844				
	ACAC7	0.847				
	ACAC8	0.893				
	ACAC9	0.868				
	ACAC10	0.745				

4.2 Hypothesis testing

Table 2 presents the results of hypothesis testing for various relationships between constructs in the study and relevant statistical indicators. Hypothesis H1, which posits a relationship between IT-Based Learning Innovation (ITBL) and Students' Mastery of Materials (STMM), is supported by the data. The coefficient value of 0.372 is statistically significant, with a T statistic of 3.654 ($p < 0.001$), confirming the acceptance of this hypothesis. Similarly, Hypothesis H2, suggesting a relationship between IT-Based Learning Innovation (ITBL) and Academic Achievement (ACAC), is also supported. The coefficient value of 0.357 is statistically significant, with a T statistic of 4.109 ($p < 0.001$), leading to the acceptance of this hypothesis. Hypothesis H3, which proposes a relationship between Critical Thinking Skills (CRTS) and Students' Mastery of Materials (STMM), also finds support in the data. The coefficient value of 0.166 is statistically significant, with a T statistic of 2.244 ($p = 0.025$), indicating the acceptance of this hypothesis. Likewise, the data supports Hypothesis H4, which suggests a relationship between Critical Thinking Skills (CRTS) and Academic Achievement (ACAC). The coefficient value of 0.309 is statistically significant, with a T statistic of 4.463 ($p < 0.001$), resulting in the acceptance of this hypothesis. Hypothesis H5 posits a relationship between Students' Mastery of Materials (STMM) and Academic Achievement (ACAC). The coefficient value of 0.184 is statistically significant, with a T statistic of 2.644 ($p = 0.008$), supporting the acceptance of this hypothesis. Hypothesis H6, which involves a sequential relationship from IT-Based Learning Innovation (ITBL) to Students' Mastery of Materials (STMM) and then to Academic Achievement (ACAC), is accepted. The coefficient value of 0.069 is statistically significant with a T statistic of 2.216 ($p = 0.027$), indicating support for this hypothesis. However, Hypothesis H7, which proposes a sequential relationship from Critical Thinking Skills (CRTS) to Students' Mastery of Materials (STMM) and then to Academic Achievement (ACAC), is not supported by the data. The coefficient value of 0.031 is not statistically significant, with a T statistic of 1.617 ($p = 0.107$), leading to the rejection of this hypothesis.

The results indicate that most hypotheses are accepted, suggesting significant relationships between the constructs as specified. However, Hypothesis H7, which involves a sequential relationship through all three constructs, is rejected due to its lack of statistical significance.

Table 2
Path analysis

Hypothesis	Construct*)	Original Sample	STDEV	T Statistics	P Values	Result
H1	ITBL → STMM	0.372	0.102	3.654	0.000	Accepted
H2	ITBL → ACAC	0.357	0.087	4.109	0.000	Accepted
H3	CRTS → STMM	0.166	0.074	2.244	0.025	Accepted
H4	CRTS → ACAC	0.309	0.069	4.463	0.000	Accepted
H5	STMM → ACAC	0.184	0.07	2.644	0.008	Accepted
H6	ITBL → STMM → ACAC	0.069	0.031	2.216	0.027	Accepted
H7	CRTS → STMM → ACAC	0.031	0.019	1.617	0.107	Rejected

*) ITBL=IT-Based Learning Innovation; CRTS=Critical Thinking Skills; STMM=Students' Mastery of Materials; ACAC=Academic Achievement

5. Discussion

The results of hypothesis testing support the acceptance of both H1 and H2. Hypothesis H1 posited that "IT-Based Learning Innovation impacts on Students' Mastery of Materials," the analysis revealed a statistically significant positive relationship between these two constructs. The coefficient value of 0.372 with a T statistic of 3.654 ($p < 0.001$) indicates a meaningful impact of IT-Based Learning Innovation on Students' Mastery of Materials. This finding implies that when educational programs or initiatives focus on enhancing IT-based learning Innovation, students are more likely to exhibit greater mastery of the materials being taught. Similarly, Hypothesis H2 stated that "IT-Based Learning Innovation impacts on Academic Achievement," and the data analysis also supports this hypothesis. The coefficient value of 0.357 with a T statistic of 4.109 ($p < 0.001$) indicates a statistically significant positive relationship between IT-Based Learning Innovation and Academic Achievement. It suggests that when educational interventions prioritize IT-Based Learning Innovation, it favors students' academic performance and achievement. In summary, the results affirm that IT-Based Learning Innovation significantly influences both Students' Mastery of Materials and Academic Achievement. These findings underscore the importance of integrating innovative IT-based learning approaches into educational programs and curricula to enhance students' mastery of course materials and improve their academic outcomes. These insights can inform educational strategies and policies aimed at optimizing students' learning experience and intellectual success.

The implications of the research findings are significant both in theory and practice. The study's confirmation of the positive impact of IT-Based Learning Innovation on both Students' Mastery of Materials and Academic Achievement advances educational theory by emphasizing the pivotal role of technology in modern learning environments. It underscores the need to reevaluate educational ideas and practices to integrate innovative IT-based learning methods effectively. From a practical standpoint, these findings provide clear guidelines for academic institutions and educators. Curricula can be redesigned to incorporate more IT-based learning resources, fostering more engaging and compelling learning experiences. Educators can undergo training to utilize technology in their teaching better, enabling them to adapt their methods to incorporate digital tools. Moreover, the findings suggest the potential for personalized and adaptive learning experiences facilitated by technology, ensuring students receive tailored instruction. It's essential, however, to address digital equity concerns to make IT-based learning accessible to all students. Finally, the continuous improvement of educational practices through data analysis and feedback mechanisms can lead to ongoing enhancements in instruction and student outcomes. In essence, the research highlights the transformative potential of IT-Based Learning Innovation in shaping more effective and equitable education systems fit for the digital age.

The study's acceptance of hypotheses H3 and H4 carries significant implications for both the theoretical understanding and practical implementation of educational strategies. From a theoretical perspective, these findings enrich educational theory by highlighting the pivotal role that Critical Thinking Skills play in the learning process. It underscores the notion that nurturing and developing critical thinking abilities in students should be regarded as a fundamental objective in education. These results contribute significantly to our comprehension of cognitive development within an educational context. Critical thinking skills, which encompass the ability to analyze, evaluate, and synthesize information effectively, are shown to be indispensable components of both mastering academic materials and achieving academic success. It reinforces the importance of cultivating critical thinking as an integral part of the learning journey.

On the practical front, educational institutions should consider revising their curricula to incorporate critical thinking skills development explicitly. Creating courses or modules dedicated to teaching and assessing critical thinking is crucial in ensuring students can hone these skills throughout their educational journey. Educators can adopt pedagogical approaches that actively foster critical thinking among students. Strategies such as problem-based learning, Socratic questioning, and collaborative activities that require in-depth analysis and reflection can be particularly effective in helping students not only master course materials but also excel academically. Assessment methods should be adjusted to include tasks that evaluate students' critical thinking skills, encouraging them to develop and apply these skills consistently, thereby improving their ability to master materials and achieve academic success. Encouraging interdisciplinary learning experiences can stimulate critical thinking as students are exposed to diverse perspectives and approaches. Such experiences enhance mastery of materials and academic achievement by fostering a holistic understanding of complex subjects.

Furthermore, it is essential to provide educators with opportunities for professional development to enhance their critical thinking skills and equip them with practical strategies for promoting critical thinking in their students. Workshops, training programs, and collaborative learning can serve as valuable tools for teacher growth. Encouraging students to seek feedback on their thought processes and engage in reflective practices can be instrumental in nurturing critical thinking. This approach empowers students to take ownership of their learning journey, contributing to the mastery of materials and their overall academic achievement. In summary, the acceptance of hypotheses H3 and H4 underscores the paramount importance of Critical Thinking Skills in education. These findings emphasize that integrating critical thinking skills into educational frameworks can lead to more effective and enriched learning experiences, resulting in improved student academic outcomes. It highlights the need for educational institutions and educators to prioritize developing and applying critical thinking skills, recognizing their profound impact on the educational journey.

The acceptance of hypotheses H5 and H6 and rejection of H7 unveils essential insights into the intricate dynamics among Students' Mastery of Materials, IT-Based Learning Innovation, Critical Thinking Skills, and Academic Achievement. Firstly, hypothesis H5, which posits that "Students' Mastery of Materials impacts on Academic Achievement," is supported by the data. Students with a deeper and more comprehensive understanding of the course materials tend to perform better academically. This outcome underscores the significance of focusing on mastery as a precursor to higher academic success. Secondly, H6, which suggests that "Students' Mastery of Materials mediates the relationship between IT-Based Learning Innovation and Academic Achievement," is also accepted. This finding indicates that IT-Based Learning Innovation indirectly influences Academic Achievement through its positive impact on Students' Mastery of Materials. Innovative IT-based learning methods enhance students' mastery of course materials, leading to improved academic performance. Conversely, H7, proposing that "Students' Mastery of Materials mediates the relationship between Critical Thinking Skills and Academic Achievement," is not supported by the data. Critical Thinking Skills may directly contribute to Academic Achievement without needing mediation through mastery of materials. While the ability of materials is undoubtedly important, these results suggest that Critical Thinking Skills independently influence academic success.

These findings hold crucial implications for educational practices. Firstly, emphasizing the development of Students' Mastery of Materials should be a cornerstone of educational strategies, as it directly impacts Academic Achievement. Secondly, the mediating role of Students' Mastery of Materials in the relationship between IT-Based Learning Innovation and Academic Achievement highlights the importance of integrating technology effectively to enhance student's understanding of course materials. Lastly, while fostering Critical Thinking Skills remains essential, educators should recognize the potential for these skills to impact Academic Achievement directly, bypassing the need for mediation through mastery of materials. These results shed light on the complex interplay among Students' Mastery of Materials, IT-Based Learning Innovation, Critical Thinking Skills, and Academic Achievement. They offer valuable guidance for educational institutions, emphasizing the multifaceted nature of learning and the need for a holistic approach to academic success.

6. Conclusion

The study yielded several significant findings on the relationships among Critical Thinking Skills, IT-Based Learning Innovation, Students' Mastery of Materials, and Academic Achievement. Hypotheses H1 and H2, indicating that IT-Based Learning Innovation impacts both Students' Mastery of Materials and Academic Achievement, were supported, underlining the crucial role of technology in modern education. H3 and H4, which proposed that Critical Thinking Skills influence Students' Mastery of Materials and Academic Achievement, were also confirmed, emphasizing the importance of nurturing critical thinking abilities in students. H5 demonstrated that Students' Mastery of Materials positively affects Academic Achievement, highlighting the significance of deep comprehension of course materials. Furthermore, H6 was accepted, suggesting that Students' Mastery of Materials mediates the relationship between IT-Based Learning Innovation and Academic Achievement. It highlights the indirect influence of innovative IT-based learning methods on Academic Achievement through their impact on Students' Mastery of Materials. However, H7, which posited a mediation effect of Students' Mastery of Materials between Critical Thinking Skills and Academic Achievement, was not supported, indicating a potential direct link between Critical Thinking Skills and Academic Achievement.

6.1 Theoretical and Practical Implications

Theoretical implications of these findings include:

1. The enrichment of educational theory.
2. Emphasizing the pivotal role of Critical Thinking Skills in the learning process.
3. Highlighting the significance of nurturing and developing these skills as a core educational objective.

Moreover, these results contribute to our understanding of cognitive development within the context of education, underscoring the importance of critical thinking in mastering academic materials and achieving academic success. Practically, educational institutions can benefit from these findings by revising curricula to incorporate the development of critical thinking skills explicitly. Pedagogical approaches that foster critical thinking should be adopted, and assessment methods should be

adjusted to include tasks that evaluate these skills. The mediating role of Students' Mastery of Materials in the relationship between IT-Based Learning Innovation and Academic Achievement underscores the importance of effectively integrating technology into educational practices to enhance students' understanding of course materials.

6.2 Limitations

Despite these significant findings, the study has some limitations:

1. The data were collected from a specific sample, and the generalizability of the results to broader populations may be limited.
2. The study relied on self-report measures for certain constructs, which can introduce subjectivity and potential response bias. The cross-sectional nature of the data also prevents us from drawing causal conclusions. Longitudinal studies would be beneficial to explore the dynamics of these relationships over time.
3. The study focused on specific constructs and other relevant variables that may play a role in academic achievement that was not considered in this analysis.

Based on the findings and limitations of the current study, several recommendations for future research in the field of education and learning can be proposed:

1. Longitudinal Studies: Conduct longitudinal studies to investigate the temporal relationships among Critical Thinking Skills, IT-Based Learning Innovation, Students' Mastery of Materials, and Academic Achievement. It would provide insights into how these relationships evolve and help establish causal connections.
2. Diverse Demographics: Extend research to various demographic groups and educational settings to assess the generalizability of the findings. Investigating whether these relationships vary across different age groups, cultures, or academic disciplines would offer a more comprehensive understanding.
3. Qualitative Approaches: Employ qualitative research methods, such as in-depth interviews or focus groups, to better understand the mechanisms through which Critical Thinking Skills and IT-Based Learning Innovation impact learning and academic achievement. Qualitative insights can complement quantitative findings.
4. Mediation Pathways: Further explore the mediation pathways that influence Academic Achievement. Investigate additional factors that may mediate the relationships between Critical Thinking Skills, IT-Based Learning Innovation, Students' Mastery of Materials, and Academic Achievement to provide a more comprehensive model of academic success.
5. Intervention Studies: Design and implement intervention studies to enhance Critical Thinking Skills, IT-Based Learning Innovation, and Students' Mastery of Materials. Evaluate the effectiveness of these interventions in improving Academic Achievement and learning outcomes.
6. Digital Learning Environments: Given the increasing importance of digital learning environments, research should continue exploring technology's evolving role in education. Investigate emerging technologies, adaptive learning platforms, and their impact on student learning and achievement.
7. Teacher Training: Examine the impact of teacher training programs focused on promoting Critical Thinking Skills and effective integration of IT-Based Learning Innovation. Assess how these programs influence teaching practices and student outcomes.
8. Digital Equity: Investigate the implications of digital equity on the relationships between technology-based learning, critical thinking, and academic achievement. Explore strategies to bridge the digital divide and ensure equitable access to educational resources.
9. Interdisciplinary Research: Encourage multidisciplinary research collaborations between educators, psychologists, technologists, and other relevant fields to gain a more holistic understanding of the complex dynamics at play in education.
10. International Comparisons: Compare educational systems and practices across countries to identify best practices in promoting critical thinking, IT-based learning, and academic achievement. Cross-cultural studies can provide valuable insights.

By addressing these recommendations, future research can continue to advance our knowledge of how educational practices and technologies influence learning outcomes, ultimately improving educational systems and student success.

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Appendix 1

Table A1
Research instrument

Variable	Indicators	Source
IT-Based Learning Innovation	1. Frequency of usage of online learning platforms by teachers and students 2. Availability of simulations or educational applications used in learning 3. Availability of devices such as computers, tablets, or smartphones for students 4. Level of training provided to teachers in the use of educational technology 5. Level of student engagement in online discussions and collaboration on learning projects 6. Opinions of teachers and students regarding the extent to which technology has enhanced the learning process and understanding of the material 7. The extent to which technology makes it easier for students to access learning materials and resources 8. The institution's ability to continuously innovate and develop educational technology	(Ebadi & Ashrafabadi, 2022; Serrano et al., 2019; Torres-Linke et al., 2022)
Critical Thinking Skills	1. The capacity to break down complex ideas or information into smaller parts, examining their components and relationships 2. The skill to assess the credibility, relevance, and quality of information or arguments, distinguishing between reliable and unreliable sources 3. The ability to draw logical conclusions and reasoned predictions based on available evidence and facts	(Borkowski & Thorpe, 2023; Jenkins & Andenoro, 2016; Lombardi et al., 2021; Silva et al., 2020)

	4. The aptitude to interpret data, texts, or visuals, extracting meaning and identifying patterns or implications 5. The capability to provide clear and coherent explanations or justifications for one's thoughts, actions, or decisions 6. The application of critical thinking skills to identify, analyze, and solve problems, often involving creative and innovative solutions 7. Using critical thinking to make well-informed decisions, considering potential outcomes and consequences 8. Being receptive to different viewpoints and willing to revise one's views when presented with compelling evidence or arguments 9. The motivation to seek out new knowledge, ask questions, and explore ideas in-depth 10. Adopting a healthy skepticism towards information, questioning assumptions, and not accepting claims without evidence	
Students' Mastery of Materials	1. Students can demonstrate a thorough understanding of the concepts, theories, and principles related to the subject matter 2. They can apply what they have learned to solve real-world problems or situations, demonstrating practical competence 3. Students can critically analyze and evaluate information, arguments, or data related to the subject matter, enabling them to form well-reasoned judgments 4. They can connect and integrate different ideas and concepts within the subject matter, showing a holistic grasp of the material 5. Students can use their knowledge to identify, analyze, and solve complex problems within the subject area 6. They can articulate their understanding of the material through clear and coherent communication, both in written and verbal forms 7. Students can accurately remember and recall information related to the subject matter 8. They can transfer their knowledge and skills gained from the subject matter to other contexts or disciplines 9. Students' mastery of materials may involve surface-level knowledge and a deep understanding of underlying principles	(Markant et al., 2016; Muslem et al., 2022; Schwinger et al., 2022)
Academic Achievement	1. The grades and scores students receive in examinations, assignments, projects, and other assessments that reflect their understanding and performance in specific subjects or courses 2. A numerical representation of a student's overall academic performance, calculated by averaging the grades earned in multiple courses over a specified period 3. Scores achieved in standardized tests provide a standardized measure of academic knowledge and skills 4. A student's position relative to their peers based on academic performance, often expressed as class rank, percentile, or quartile 5. Recognition or awards for outstanding academic achievement, including scholarships, academic excellence awards, and honor roll status 6. Successfully finishing and obtaining degrees, diplomas, or certificates in various educational levels, such as high school diplomas, bachelor's degrees, or postgraduate qualifications 7. Contributions to research projects, publications, or presentations, particularly in higher education and advanced academic settings 8. Active involvement in academic activities, including class participation, group discussions, and engagement in extracurricular academic pursuits 9. Consistent class attendance and class punctuality can impact academic performance 10. Feedback and evaluations teachers or professors provide regarding a student's academic progress, participation, and overall performance in the classroom	(Martirosyan et al., 2022; Wang et al., 2022)

Sources: (Hadi et al., 2019; Hamdan & Basrowi, 2024; Junaidi, Masdar, et al., 2024; Miar et al., 2024)