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Enhancing Cognitive Skill Development in Science Education through Technology-Enhanced Inquiry-Based Learning

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ABSTRACT

Objective: The objective of this study was to investigate the relationship between technology-enhanced inquiry-based learning and the development of cognitive skills. **Methodology**: A survey-based data collection method was employed, utilizing a purposive sampling technique. The sample comprised 200 students from three schools in Aman, the capital city of Jordan. **Analysis**: Data were analysed using the JASP statistical tool, where descriptive statistics, factor loadings, Pearson correlations, and regression analyses were computed. The findings indicated a significant positive relationship between technology-enhanced inquiry-based learning and cognitive skills development. **Contribution**: This study contributes to the literature by affirming the importance of technology-enhanced inquiry-based learning in enhancing students' cognitive skills. **Implication**: The implications of these findings are practical, suggesting that such pedagogical approaches are essential for fostering students' cognitive skill development, which is crucial for their professional growth and advancement. Additionally, the study discusses its limitations and proposes avenues for future research.

Introduction

To enhance student performance, it is essential to provide reliable resources and integrate modern technology into their education. Effective performance relies on students' engagement with shared knowledge (Ginzburg & Barak, 2023) and can lead to significant improvements in strategic capabilities. Motivation plays a crucial role in the integration of technology, which benefits not only college and university students but also those at the school level (Yang et al.,

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2021). Effective technology use enhances students' behaviour and overall performance (Lu et al., 2023) while improving their cognitive skills, ultimately impacting their long-term success (Huang et al., 2024a). Teachers must support motivated students, and it is vital for students to acquire substantial knowledge about technology use (Campillo-Ferrer & Miralles-Martínez, 2023) to enhance their competitiveness and performance mechanics.

In Jordan, students are facing challenges in effectively utilizing technology in their educational settings (Huang et al., 2024b). Enhancing student performance is essential; however, the role of teachers in motivating students is equally critical (Kaldaras et al., 2024). When teachers demonstrate a strong commitment to student performance, they can effectively guide students in the proficient use of technology, which is vital for academic success. Moreover, teachers can further enhance their impact by encouraging students to cultivate positive behaviours (Wen et al., 2023). Despite the implementation of various technological tools in educational institutions, student performance remains limited. Additionally, the development of cognitive skills is crucial for students' learning and performance (Adhami & Taghizadeh, 2024). These skills can be fostered through motivation and effective training, enabling students to gain a deeper understanding that enhances their cognitive abilities. However, Jordanian school students continue to encounter difficulties related to their cognitive development (Novitra, 2021). Consequently, improving cognitive skills among school students in Jordan is essential for enhancing their overall performance. A robust understanding of how to develop cognitive skills can significantly contribute to students' academic success (Lu et al., 2021).

Previous research has focused on the role of technology in enhancing student learning and performance; however, it has largely overlooked the development of cognitive skills among school students. Kamarudin et al. (2024) emphasized the importance of motivation from parents and teachers in encouraging effective technology use for improved performance. Hinostroza et al. (2024) highlighted that cognitive development can enhance overall student performance when supported by technological interventions. Wu et al. (2021) noted the necessity of integrating technology into student learning to boost performance, while Kyza (2023) found that motivation is critical for advancing student performance. Additionally, Ješková et al. (2022) and Chen and Chen (2024) advocated for improving student learning through enhancements in cognitive abilities. Despite these insights, the literature lacks studies examining the relationship between technology-enhanced inquiry-based learning and cognitive skill development. Thus, a significant gap remains in the existing body of knowledge.

To address the gaps in the existing literature, this study aimed to examine the relationship between technology-enhanced inquiry-based learning and the development of cognitive skills. A survey-based data collection method was employed, utilising a purposive sampling technique. A sample of 200 students was drawn from three schools in Amman, the capital city of Jordan. The data were analysed using the JASP statistical tool, which provided findings related to descriptive statistics, factor loadings, Pearson's correlations, and regression analysis. The research identified a significant positive relationship between technology-enhanced inquiry-based learning and cognitive skills development. This study contributes to the literature by demonstrating the importance of technology-enhanced inquiry-based learning in fostering cognitive skills among students. The findings have practical implications for enhancing students' cognitive skill development, which is essential for their professional growth and advancement. The remainder of the study is structured into sections, including the literature review, research methodology, data analysis, findings, discussion, implications, and future directions.

Literature Review

Technology-based learning facilitates active participation among students (Campillo-Ferrer & Miralles-Martínez, 2023), enhancing their performance through group discussions and problem-solving activities (Kaldaras et al., 2024). When students are motivated to engage actively, they can better address real-world issues and improve their critical skills (Yin et al., 2024). Additionally, technology enables access to online discussions and task-oriented activities (Adhami & Taghizadeh, 2024), which are vital for enhancing performance. This approach helps students develop effective strategies essential for skill growth (Yeung & Sun, 2021). Moreover, shared digital platforms encourage active participation and improve communication during group projects, significantly contributing to learning outcomes (Ginzburg & Barak, 2023). Ultimately, the shift towards a technology-enhanced learning environment has a lasting positive impact on students' overall performance.

Furthermore, technology provides students with access to diverse tools essential for enhancing their performance (Huang et al., 2024b). The availability of digital learning platforms facilitates effective communication among students. Additionally, the incorporation of simulations and educational games significantly impacts students' overall performance (Kyza, 2023). However, student motivation is crucial when utilizing these online learning tools. Consequently, teachers should provide training to ensure effective use and optimal performance (Lu et al., 2023). Technology also fosters higher-order thinking skills, which are vital for academic success. Skills such as self-evaluation are critical for improving students' mental reasoning (Komalawardhana & Panjaburee, 2024). When students encounter changing environments and situations through technology, it becomes imperative for them to understand and assess their own performance (Kamarudin et al., 2024). In this manner, technology contributes to the overall enhancement of students' performance-related behaviours (Hinostroza et al., 2024). Nonetheless, active engagement from students is also necessary to improve their work performance.

Technology fosters a self-regulation attitude among students, enhancing their performance (Huang et al., 2024a). It enables learners to manage their performance over time and supports self-learning behaviours (Lu et al., 2021). Effective use of technology is facilitated by support from teachers and peers, which enhances students' mental abilities to tackle various tasks and challenges (Chen & Chen, 2024). Additionally, technology allows for the creation of personalised learning environments, utilising simulations to address performance issues (Yang et al., 2021). This strategic use of technology promotes self-evaluation, leading to critical improvements in learning. Overall, advancements in technology are essential for enhancing students' cognitive abilities through active discussion and engagement (Yun & Crippen, 2024). Thus, technology is a significant factor in the learning and performance of students.

The integration of technology in learning motivates students to engage with real-world problems and apply their knowledge effectively (Novitra, 2021). Simulations designed to address such challenges are crucial for helping students comprehend the relationships between various variables. It is essential for students to reflect on their overall behaviour concerning their performance (Lin et al., 2023). Moreover, the significance of technology can encourage students to utilise it further, thereby enhancing their overall learning performance. It is imperative for students to adopt positive attitudes and direct their learning strategies, while the judicious use of technology also encourages fairness in various working environments (Byukusenge et al., 2023). Consequently, as students confront real-world challenges facilitated by technology, they develop

rational and experiential responses. This fosters a positive understanding of technology among students, which in turn enhances their cognitive development and behavioural patterns (Ješková et al., 2022). Students who effectively incorporate technology into their education typically exhibit superior thinking skills and performance compared to their peers. Thus, technology is recognised as a significant factor in improving students' cognitive abilities and overall performance (Inel-Ekici & Ekici, 2022).

Immediate feedback facilitated by technology is crucial for enhancing students' overall performance (Srivastava et al., 2024). While students are motivated to excel, traditional feedback from teachers can hinder their progress due to procedural delays. In contrast, technology-driven learning modules offer real-time feedback, significantly improving students' learning experiences (Komalawardhana & Panjaburee, 2024). It is essential for students to engage critically in their learning, as their understanding of significant performance develops over time (Wen et al., 2023). Access to immediate responses through technology fosters overall cognitive development. Moreover, technology creates a multimodal learning environment that further advances student performance (Wu et al., 2021). By enhancing reliable learning methods, technology strategically supports students in improving their behaviour and addressing challenges (Li et al., 2024). Additionally, the use of technology encourages creative thinking, which is vital for cognitive skill development. Based on this discussion, the following hypothesis is proposed,

H1: *There is a relationship between technology enhanced inquiry based learning and cognitive skills development.*

Methodology

This study aims to examine the relationship between technology-enhanced inquiry-based learning and the development of cognitive skills. It is based on primary data, which was collected through direct engagement with respondents to gather relevant information pertinent to the research objectives. The study targeted students from various schools in Jordan, with data collected from three randomly selected institutions. A self-administered questionnaire, drawing on instruments from previous research, was utilised for data collection. Ethical standards were strictly adhered to throughout the process, with informed consent obtained from the participants prior to administering the survey. However, due to participants' hesitance to disclose demographic information, the data collected focused solely on responses derived from the established instruments.

This study gathered data from participants to validate the hypothesis. In social science research, data is typically collected from individuals to gain insights into their perceptions and behaviours, leading to informed findings. A sample of 200 students was drawn from three different schools in Amman, the capital city of Jordan, using a convenience sampling method. This method is commonly employed in social science studies requiring primary data, as it facilitates easy access to respondents based on their availability. It is particularly effective when targeting specific individuals who can contribute relevant data to the study. Data analysis was conducted using JASP statistical tools (Murad et al., 2024). The analysis commenced with descriptive statistics, followed by an examination of factor loadings. Subsequently, the residual variance for each indicator was assessed. The reliability of the scale was confirmed through the findings of Cronbach's alpha. Additionally, Pearson's correlations were analysed to explore the nature of relationships between variables. Finally, regression analysis was conducted to test the hypothesis.

Data Analysis and Findings

The findings of the descriptive statistics were utilised to assess the normality of the data distribution. The study revealed that the mean and standard deviation of all instruments were significant, falling within the range of -3 to +3, indicating a valid distribution of the data. Furthermore, skewness and kurtosis were evaluated against the threshold of -3 to +3, confirming that all values met the significance criteria (Royston, 1992). Consequently, the statistics presented in Table 1 substantiated that the data were normally distributed.

Table 1

Descriptive Statistics

	Mean	Std. Deviation	Skewness	Std. Error of Skewness	Kurtosis	Std. Error of Kurtosis
TEIBL1	3.190	1.228	-0.005	0.241	-1.108	0.478
TEIBL2	3.410	1.083	-0.201	0.241	-0.805	0.478
TEIBL3	3.300	1.168	-0.066	0.241	-1.093	0.478
TEIBL4	3.310	1.228	-0.050	0.241	-1.175	0.478
TEIBL5	3.350	1.175	0.007	0.241	-1.150	0.478
TEIBL6	3.460	1.068	-0.046	0.241	-1.240	0.478
CSD1	3.370	1.152	0.001	0.241	-1.196	0.478
CSD2	3.430	1.103	-0.049	0.241	-1.348	0.478
CSD3	3.370	1.203	-0.113	0.241	-1.158	0.478
CSD4	3.320	1.188	-0.169	0.241	-1.207	0.478
CSD5	3.350	1.140	-0.059	0.241	-1.210	0.478
CSD6	3.250	1.132	0.088	0.241	-1.203	0.478
CSD7	3.390	1.222	-0.214	0.241	-1.124	0.478
CSD8	3.340	1.174	-0.083	0.241	-1.071	0.478

TEIBL = Technology Enhanced Inquiry Based Learning and CSD = Cognitive Skills Development

An additional test was conducted to assess the factor loadings, which were accepted at a probability level of 95%. Consequently, p-values less than 0.05 were deemed significant (Hair et al., 2011). Table 2 indicates that all variables met this significant threshold, with no values exceeding 0.05; therefore, all instruments were retained for further analysis.

Table 2

Factor Loadings

						95% Confidence Interval	
Factor	Indicator	Estimate	Std. Error	z-value	p	Lower	Upper
TEIBL	TEIBL1	0.461	0.130	3.555	< .001	0.207	0.715
	TEIBL2	0.810	0.101	8.008	< .001	0.612	1.008
	TEIBL3	0.842	0.111	7.586	< .001	0.625	1.060
	TEIBL4	0.792	0.121	6.521	< .001	0.554	1.029
	TEIBL5	0.591	0.123	4.811	< .001	0.350	0.831
	TEIBL6	0.620	0.109	5.679	< .001	0.406	0.834

CSD	CSD1	0.590	0.114	5.164	< .001	0.366	0.814
	CSD2	0.826	0.098	8.413	< .001	0.633	1.018
	CSD3	0.890	0.107	8.334	< .001	0.681	1.100
	CSD4	0.924	0.104	8.874	< .001	0.720	1.128
	CSD5	0.775	0.105	7.407	< .001	0.570	0.980
	CSD6	0.838	0.101	8.328	< .001	0.641	1.035
	CSD7	0.676	0.119	5.667	< .001	0.442	0.910
	CSD8	0.682	0.113	6.015	< .001	0.460	0.905

Subsequently, the residual variance of the data was assessed. This refers to the portion of variance in the model that cannot be accounted for by the included variables. A higher residual variance indicates a diminished capacity of the model to explain the variation in the data. The results showed that the residual variance was statistically significant, with $p < 0.05$. Table 3 illustrates that all values were significant, as the p-values for all indicators were < 0.001. Therefore, the study's indicators demonstrated significant residual variance in the data.

Table 3

Residual Variances

					95% Confidence Interval	
Indicator	**Estimate**	**Std. Error**	**z-value**	**p**	**Lower**	**Upper**
TEIBL1	1.282	0.188	6.818	< .001	0.913	1.650
TEIBL2	0.506	0.100	5.033	< .001	0.309	0.702
TEIBL3	0.641	0.122	5.246	< .001	0.401	0.880
TEIBL4	0.867	0.150	5.798	< .001	0.574	1.161
TEIBL5	1.019	0.159	6.424	< .001	0.708	1.329
TEIBL6	0.744	0.122	6.081	< .001	0.504	0.984
CSD1	0.965	0.145	6.668	< .001	0.681	1.249
CSD2	0.524	0.090	5.794	< .001	0.347	0.701
CSD3	0.640	0.107	5.968	< .001	0.430	0.851
CSD4	0.545	0.099	5.511	< .001	0.351	0.738
CSD5	0.687	0.110	6.261	< .001	0.472	0.902
CSD6	0.566	0.095	5.938	< .001	0.379	0.752
CSD7	1.021	0.155	6.588	< .001	0.717	1.325
CSD8	0.899	0.138	6.515	< .001	0.628	1.169

Additionally, the reliability of the study scale was assessed using Cronbach's alpha. Values above 0.70 indicate reliability and validity (Hair et al., 2011). The study found that all variables exceeded this threshold, as reported in Table 4, confirming the scale's significance.

Table 4

Reliability

	Coefficient α
TEIBL	0.764
CSD	0.866
Total	0.884

Pearson's correlations were conducted to assess the nature and direction of relationships

within the model. The results indicated significance at $p < 0.05$ (Cohen et al., 2009). As shown in Table 5, most indicators demonstrated significant correlations with one another, validating the data for further analysis.

Table 5

Pearson's Correlations

Variable		TEIBL	CSD
1. TEIBL	Pearson's r	—	
	P-Value	—	
2. CSD	Pearson's r	0.584	—
	P-Value	< .001	—

Finally, regression analysis was conducted to evaluate the relationships between variables. The analysis was performed at a 95% confidence level, with significant relationships defined by a p-value of less than 0.05 (Hair et al., 2011). Hypothesis 1 (H1) was tested, revealing a positive and significant relationship between technology-enhanced inquiry-based learning and cognitive skills development. The t-value was 7.117, and a p-value of < .001 was obtained, indicating significance. The empirical findings are presented in Table 6.

Table 6.

Coefficients

Model		Unstandardized	Standard Error	Standardized	T	P
M_0	(Intercept)	3.270	0.113		29.019	< .001
M_1	(Intercept)	1.407	0.277		5.074	< .001
	TEIBL	0.571	0.080	0.584	7.117	< .001

Discussion and Conclusion

To achieve the objectives of this research, Hypothesis 1 (H1) was formulated and empirically validated. The findings indicated a positive and significant relationship between technology-enhanced inquiry-based learning and cognitive skills development. This study's results were compared with existing literature to contextualise its contributions to scholarly discourse. According to Yun and Crippen (2024), technology-based learning fosters active student engagement, which is essential for enhancing performance through participation in group discussions. Additionally, Adhami and Taghizadeh (2024) noted that incorporating technology into problem-solving exercises can further improve learning outcomes. When students are motivated to engage actively, their performance in real-world contexts improves. Lin et al. (2023) asserted that technology-based learning significantly enhances essential student skills. Furthermore, Byukusenge et al. (2023) highlighted that technology facilitates access to online discussions and task-oriented activities, both of which are vital for improving student performance. Long et al. (2024) emphasized that technology-based learning helps students develop effective strategies necessary for skill enhancement. Collaborative digital learning platforms promote active engagement and elevate students' performance capabilities. Moreover, Ginzburg and Barak (2023) identified effective communication in group projects as a critical factor that technology enhances to improve learning outcomes. In conclusion, the transition towards a technology-driven educational environment significantly impacts students' overall performance.

Li et al. (2024) assert that technology provides students with essential tools for performance enhancement and facilitates communication through digital learning platforms. The use of simulations and educational games engages students with technology, significantly impacting their overall performance. Byukusenge et al. (2023) highlight that student motivation is critical in utilising online learning tools, necessitating instructor training to improve efficacy and efficiency. Long et al. (2024) emphasise that technology fosters higher-order thinking skills, which are vital for student performance and self-evaluation. Wen et al. (2023) note the importance of students understanding and assessing their performance in a changing technological environment. Additionally, Lu et al. (2023) find that integrating technology improves students' performance-related behaviours, while support for students is crucial for enhancing academic achievement.

Hinostroza et al. (2024) suggest that technology cultivates a self-regulatory mindset in students, improving their performance by encouraging them to monitor their progress. Chen and Chen (2024) note that technological tools promote self-directed learning behaviours. Support from educators and peers is vital for equitable technology use and positive attitudes. Yin et al. (2024) conclude that technology enhances cognitive capacity, enabling students to manage tasks effectively. Wu et al. (2021) highlight that technology allows for personalised learning environments, utilising simulations to boost performance. Campillo-Ferrer and Miralles-Martínez (2023) assert that strategic efforts and technological use help identify performance deficiencies, fostering a culture of self-assessment and critical learning capabilities. Kamarudin et al. (2024) emphasise the importance of enhancing students' technology proficiency for improved learning outcomes. Overall, active discourse and technology use are essential for enhancing student learning and performance (Yeung & Sun, 2021).

Yang et al. (2021) assert that the integration of technology significantly enhances student motivation to tackle real-world challenges and apply their knowledge effectively. Simulations designed to address these issues are essential for students to understand the interconnections among various factors. Huang et al. (2024b) highlight that students must develop a comprehensive understanding of their behaviours in relation to performance. The motivational potential of technology encourages students to engage more deeply, thereby improving their overall academic achievement. Ješková et al. (2022) emphasise the need for students to actively participate in and direct their learning processes, with technology also promoting equitable practices across various contexts. Lu et al. (2021) further indicate that students cultivate rational thinking and practical experience to effectively address real-world problems anticipated by technology. Novitra (2021) notes that technology fosters a positive, technology-based understanding among students, enhancing both their behaviour and cognitive development. Research by Srivastava et al. (2024) shows that technology aids students in overcoming cognitive challenges and improving overall performance. Thus, the use of technology is recognised as a vital factor in enhancing students' cognitive abilities.

Huang et al. (2024a) highlight that timely feedback facilitated by technology is essential for improving students' overall performance. While feedback from teachers can sometimes hinder performance due to procedural delays, Kaldaras et al. (2024) emphasise that technology provides immediate feedback, significantly enhancing learning. As students' understanding of performance evolves, they must develop critical learning skills. Kyza (2023) notes that advanced technological tasks are crucial for cognitive development through prompt feedback. Additionally, Inel-Ekici and Ekici (2022) assert that technology enhances learning efficacy, strategically improving performance. According to Yun and Crippen (2024), technology integration fosters

student learning, facilitating behavioural improvements and effective challenge management while promoting creative thinking, essential for enhancing cognitive abilities.

Theoretical and Practical Implications

This research has substantial theoretical implications, contributing to the understanding that technology-enhanced inquiry-based learning plays a critical role in improving students' overall performance and developing their cognitive skills. The existing literature has largely overlooked this relationship, highlighting a significant knowledge gap. This study demonstrates that the integration of technology enhances students' cognitive skills, which are essential for their overall performance. The empirical findings of this research pave the way for further scholarly discussion on this important relationship. This study presents several practical implications. Firstly, it recommends that schools educate students about the relevance of technology in contemporary learning. Introducing students to technology can enhance their learning effectiveness. Consequently, teachers play a crucial role in motivating students to integrate technology into their daily practices. School administrations should ensure students have access to technology, which is vital for improving overall performance. Teachers must provide the necessary support and encouragement for effective technology use in learning. Additionally, students should be aware of their cognitive skill development and learning capabilities to effectively leverage technology for improved performance. Thus, collaboration between students and teachers is essential to foster an environment where technology-enhanced inquiry-based learning can significantly contribute to cognitive skill development.

Future Directions

This research contributes to the literature by establishing a positive and significant relationship between technology-enhanced inquiry-based learning and cognitive skills development. However, the study has several limitations. Firstly, data was collected from only three schools, limiting the generalizability of the findings to all of Jordan. Future research should aim for a larger sample size, ideally a minimum of 1,000 students. Additionally, as the data was solely from students, it may not provide a reliable basis for generalization; future studies should include data from teachers to gain a more comprehensive understanding of the relationships between variables. Lastly, the study did not account for gender differences among students. Future research should conduct a multigroup analysis to explore these relationships further, contributing to scholarly discourse. Addressing these areas will enhance the academic contribution of future studies.

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