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AI-Assisting Technology and Social Support in Enhancing Deep Learning and Self-Efficacy among Primary School Students in Mathematics in China

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Abstract. The extant literature highlighted the significant relationship between artificial intelligence (AI)-assisting technology and deep learning in mathematics among primary school students in China, with learning self-efficacy emerging as a mediator and social support emerging as a moderator. However, the relationships with and their effects on primary school students' deep learning with AI-assisting technology and social support remain less explored. This study aims to address this gap by (a) examining the differential effects of AI-assisting technology on deep learning and (b) determining whether these relationships and effects operate via mediator and moderator, in this case, learning self-efficacy and social support, respectively. Based on a sample of 387 respondents from four primary schools in China, this study examined the underlying causal links among key variables using structural equation modeling (SEM). The findings demonstrate that AI-assisted technology has a significantly positive influence on primary school students' deep learning. Learning self-efficacy supports deep learning improvements within this study's framework. Social support fosters student participation and academic progress, leading to a more enriching learning process. The results strongly validate the proposed theoretical assumptions, demonstrating a clear correlation between the conceptual model and research findings. This study provides valuable perspectives on AI's role in education, emphasizing the necessity of adopting AI-powered educational tools to enhance deep learning among primary school students.

Keywords: Artificial intelligence assistant; deep learning; learning self-efficacy; social support

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1. Introduction

Mathematics is an indispensable subject in global education and essential for cultivating logical reasoning, problem-solving, and analytical thinking skills. Although mathematics is important, many students find it challenging because it is abstract and requires precise calculations and multi-step reasoning. Mathematics is part of the formal education system globally, which uses symbols as a language to represent numbers and amounts. Mathematics is a complex subject that constantly challenges the students who take it (Thanheiser, 2023). The students will be challenged for their calculation and problem-solving skills. Previous studies found that students commonly need critical calculation and problem-solving skills when dealing with challenging mathematics problems and questions, specifically complex mathematics questions that involve multiple steps or equations. They found that students needed help completing most questions (Kaitera & Harmoinen, 2022). From the outcomes of previous studies, many researchers and instructors have attempted to create different learning methods by adopting various advanced technologies that can help to enhance and improve students' learning of complex and challenging courses, such as engineering and mathematics, to help the students achieve better academic performance. Previous researchers also found that students who take mathematics or complex courses usually suffer from learning stress and burnout as they need to maintain or achieve better academic performance (Gao, 2023).

The main issues from the students are due to a lack of prior knowledge and customized help in learning specific knowledge such as mathematics. In the advanced technological era, artificial intelligence (AI) has been focused on academicians and educators, especially for complex and challenging courses. AI has created a mechanism to help educators and academicians to improve their teaching and enhance the students' learning process (Igbokwe, 2023). Moreover, AI is an advanced technological application that can make intelligent networks that can help individuals work on and complete tasks that need partial human intelligence, such as virtual reality and interaction skills, language communication skills, and complex decision-making analysis (Ahmad et al., 2023). However, AI is not new in this advanced technological era; many industries have used AI to transfer and learn new knowledge. Most of the learning and knowledge-transferring processes through AI happen in multinational corporations, where knowledge is transferred from one region to another, facilitating employees' self-paced learning (Olan et al., 2023).

AI applications in education systems are still new for teaching and learning, especially for assisting and facilitating students with complex and challenging courses such as mathematics and engineering. According to most recent studies, AI can play various roles in the education system, facilitating innovative teaching and learning, providing simple feedback and comments to students, and providing in-depth analyses for academic-related policies to academicians and educators. More and more learning institutions use AI as an intelligent learning assistant. Previous studies indicated that AI technological applications can replace real teaching instructors and deliver teaching to students (U.S. ED, 2023). In addition, AI instructors can customize and individualize each student's advice, feedback, and comments according to their learning ability in the course in which they are enrolled. Previous studies reported that to understand the current need for AI and other advanced technologies in education, using AI in educational instructions based on intelligent adjustment can further facilitate students' personal growth and academic achievement (Zhang & Aslan, 2021).

Using AI in complex and challenging subjects or courses can also promote self-efficacy in students, reduce learning burnout and anxiety, and increase motivation to learn. There are two types of AI in the market: AI operating as the brains of logical flow, allowing virtual responses and calculation to act as the virtual human personal assistant, and AI operating as robotics, allowing AI to act as physical individuals and serve to help humans in work and in teaching (Huawei Technologies, 2023). The technological system in AI helps to generate a readily modifiable technological system to address various issues and challenges in the real world, such as nuclear boom exploration estimation, earthquake estimation, volcano eruption estimation, and heatwave estimation (Sheikh et al., 2023). In the modern technological era, the increasing usage of AI in various industries may demonstrate the development of more complex systems that can understand and resolve difficult tasks at higher speeds and at a very challenging level that humans are hardly able to achieve, such as resolving complicated mathematical equations and military strategies planning.

According to previous studies, students' learning and developing new knowledge and information are heavily influenced by the AI available in the market. AI in the education system can be substantially automated in helping the system determine which students need academic support to achieve better academic performance (Rodway & Schepman, 2023). It might be difficult for real human instructors or teachers to meet each student's needs. However, AI can perform tasks by processing millions or billions of data and graphical algorithms to determine the differences and issues. Teachers or instructors can understand the needs of the students through the in-depth analysis of the AI assistant, thereby helping to enhance and improve the teaching based on most of the needs of the students or pupils (Essel et al., 2022). Moreover, the AI is not only able to analyze data from the students, but can also evaluate the most appropriate teaching methods and techniques. It can help the instructors or teachers to assess students' performance while at the same time, generating grades, and reporting with substantial feedback and comments based on the students' performance in class (Seo et al., 2021).

Furthermore, educational institutions that use AI as a teaching assistant can facilitate the deep learning of students in complicated subjects such as mathematics in both primary and secondary schools. Students sometimes become disengaged when learning complicated knowledge, such as mathematical equations, at both primary and secondary level (Bekker et al., 2023). The instructors or teachers often use games such as chess or puzzles to motivate students to learn mathematics and keep them focused. However, the physical games will not help so much. Hence, many teachers use AI-integrated chess or puzzle games to motivate students. AI can calculate millions of steps ahead of the next step, increasing the difficulty level of the games and keeping the students focused. Furthermore, AI can gather and analyze the cognitive and critical thinking of the students in resolving complex mathematics-related questions and tasks, which leads to further deep learning of the students in mathematical-related courses or subjects (Huang & Tu, 2021). For instance, intellectually stimulating strategy games can help students develop their logical reasoning skills across different learning stages. AI is an excellent motivator that enhances students' ability in education, which can improve their rational and academic understanding at higher levels of study (Rodway & Schepman, 2023).

As such, this study aims to explore the impact of AI technology on deep learning and determine whether this is mediated by learning self-efficacy and moderated by social support. The relevance of using AI assistants in mathematics to enhance the deep learning skills of pupils in primary schools in China was investigated, guided by the following research questions and hypotheses:

RQ1: Is there a positive relationship between self-efficacy and students' deep learning of mathematics in China?

RQ2: Is self-efficacy a mediator in the relationship between AI-assisted technology and deep learning in mathematics among students in China?

RQ3: Is AI-assisted technology directly associated with students' deep learning of mathematics in China, independent of self-efficacy?

RQ4: Is social support a moderating factor in the relationship between AI-assisted technology and students' self-efficacy in deep learning of mathematics in China?

H1: AI-assisting technology positively correlates with self-efficacy among students in China.

H2: Self-efficacy positively influences students' deep learning of mathematics in China.

H3: Self-efficacy among students in China mediates the relationship between AI-assisting technology and deep learning in mathematics.

H4: The higher the level of social support, the better the relationship between AI-assisting technology and learning self-efficacy students' deep learning of mathematics in China.

Figure 1 shows how the AI-assisting technology affects self-efficacy (H1) and, in turn, students' deep learning of mathematics (H2). The figure also indicates how self-efficacy mediates (H3) and social support moderates (H4) the causal relationships between AI-assisting technology and the primary dependent variable, namely students' deep learning.

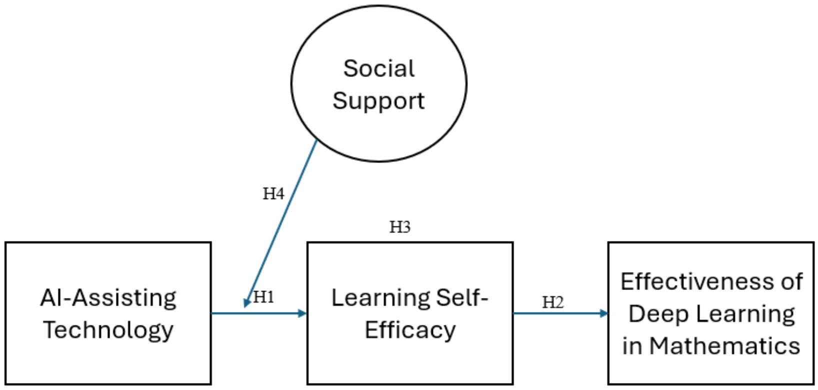

Figure 1: Theoretical Framework

2. Literature Review

2.1 AI Assisting Tools in Education

The first researcher who created the term "artificial intelligence" (AI) was McCarthy in his 1955 study. McCarthy defined AI as the intelligence that allows machines to behave like humans. Other researchers and scholars subsequently proposed different definitions for AI alongside the development of AI. However, there has yet to be consensus among researchers and scholars on AI as many kinds of AI technology exist worldwide. However, a standard agreement among researchers and scholars is that AI-related technologies are widely used to help humans resolve problems, especially human-related problems such as learning, calculating, and deep understanding (Ahmad et al., 2023).

According to the study, AI is a human-created technology built to think and act like natural humans to achieve targeted goals (Akgun & Greenhow, 2022). Another survey on AI and cognition defined AI as a computer system created to perform cognitive tasks. Baker et al. (2019) also mentioned that AI's primary functions are to perform tasks related to human thinking, especially critical thinking, knowledge learning, deep thinking, and problem-solving tasks. AI technology differs from traditional computers, which provide fixed algorithms and sequences to solve fixed questions and issues without considering humans' personal needs and learning knowledge (Sheikh et al., 2023).

In the educational setting, AI can analyze and interpret the pattern and logic of the collected data and information and provide suggestions, feedback, and comments for further improvement. Furthermore, AI technology is based on continuous learning for improvement. AI is constantly improving the thinking process as it evaluates strategies in the past and present and adapts them for future use. Hence, AI can influence students' academic performance and achievement through continuous innovation and creativity in assisting the student, positively affecting student thinking and problem-solving skills (Salido, 2023). Previous studies have shown that AI positively affects mathematics learning as it can improve the cognitive abilities of students as well as their learning development.

AI technology also helps students develop and enhance their learning attitudes on complex subjects such as mathematics, increasing their engagement in learning mathematics (Sheikh et al., 2023; Xu & Ouyang, 2022). Students can concentrate on complicated mathematics equations and models as AI technology makes learning mathematics more fun, much the same as playing games or chess. Therefore, students are more eager to spend more time, focus, concentration, and effort on learning mathematics with AI technology as their learning assistant (Wardat et al., 2024).

However, several studies have shown that AI technology does not significantly influence students' academic performance. The reason is that students need to be active in learning to manage their learning process with AI assistants, and not all students can access good network connectivity. Learning with AI assistants requires more time to understand the technology with some support from the teacher or instructors. Hence, owing to the complications in getting help from instructors and requiring better network connectivity, some students may not be prepared to put in more time and effort to master the learning process with AI technology assistants. Thus they become demotivated and lose interest in learning (Seo et al., 2021).

Several types of AI assistants are widely used in education systems for learning, such as adaptive learning systems and robotics (Chu et al., 2022). Previous studies have shown that adaptive learning systems have been widely adopted to improve student academic achievement and performance in mathematics. The adaptive learning system provides individualized and customized learning based on each student's needs (Peng et al., 2019). Moreover, the adaptive learning system is a powerful AI assistant for learning mathematics as it clearly displays the content of the subject. It can evaluate student progress and provide feedback and comments to each student based on their progress (Gligorea et al., 2023). In addition, the adaptive learning system also acts as a bridge between teacher and student engagement in mathematics learning (Kabudi et al., 2021). In the adaptive learning system, teachers or instructors can check the students' progress any time, monitor their progress and achievement analysis outcomes from the system and make suggestions or recommendations for each student to further enhance the students' learning activities (El-Sabagh, 2021).

For instance, instructors or teachers can use the analysis outcome from the adaptive learning system and revise teaching strategies to improve and enhance student engagement through supportive learning (El-Sabagh, 2021; Gligorea et al., 2023). Another advantage of using an adaptive learning system in mathematics is that it contains both learning tasks, namely ordinary and game-based lessons (Bang et al., 2023). On the other hand, robotics allows students to explore and engage in learning more deeply (Kyprianou et al., 2023). For instance, robotics can help students explore different mathematical ideas by manipulating the tools used in mathematics learning. Using robotics for mathematics learning can provide interactive feedback and comments to students and further help develop the students' cognitive, critical thinking and reasoning skills (Ching & Hsu, 2023).

2.2. Deep Learning

Although deep learning has been mentioned in previous studies since the 1970s, until 1976 scholars or researchers only focused on the words “deep learning” (Taye, 2023). Geitz et al. (2015) explained that deep learning is all about understanding and responding cognitively to the learning content. Subsequently, previous studies commonly mentioned and expanded the deep learning concept. Deep learning has now been defined as the process of organizing, synthesizing, and transferring learning knowledge and ideas (Sarker, 2021). Deep learning is highly related to both analytical and critical thinking and independent learning and thinking (Zhao & Liu, 2022). It also includes cross-referencing and imaginative reconstruction thinking.

The student learns through deep learning, aiming to understand and facilitate analytical and critical thinking (Kovac et al., 2023). This helps connect existing ideas and previous knowledge to generate innovative ideas or find the relationship between existing and current ideas to form long-term memory and a deep understanding of knowledge. Hence, students’ understanding of the learning and reaction toward the comprehensive learning quality can be observed from the online or learning platform's deep learning status (Shi et al., 2023). This is facilitated by AI-assisting technology such as adaptive learning systems or robotics. AI can collect and gather all the student learning data from the online learning platform integrated with the adaptive learning system and analyze the data to provide feedback to the students and instructors on how well the students are progressing as well as offering suggestions for further deep learning (Gligorea et al., 2023).

Even though AI assistant technology can help students better understand academic achievement and improve deep learning performance, learning self-efficacy is necessary for students to have more learning motivation (Essel et al., 2022). In order to achieve better academic performance with AI assisting technology and deep learning performance, educators or instructors need to increase student learning self-efficacy to achieve better learning outcomes. Previous studies show a positive relationship between student learning experience and self-efficacy. Results show that self-efficacy can positively influence the learning outcome (Hayat et al., 2020). Hence, this study used learning self-efficacy to mediate the relationship between AI-assisting technology and deep learning effectiveness in mathematics among Chinese students.

2.3. The Mediating Role of Learning Self-Efficacy

Self-efficacy refers to individuals’ believing they have the ability to complete given tasks to produce expected outcomes (Schunk & DiBenedetto, 2021). Previous studies found that self-efficacy can influence students’ academic motivation, which determines students’ academic achievement. Moreover, it can also affect the students’ academic learning with predicted academic achievement. Numerous studies have examined the impact of self-efficacy on students' learning experiences in online platforms and virtual environments. For instance, a study shows a positive correlation between learning self-efficacy and students’ academic performance in online learning (Hayat et al., 2020). The study also reported that learning self-efficacy significantly impacts academic performance and heavily influences learning outcomes.

Many studies have been conducted on different aspects of self-efficacy. For example, a study conducted by Chang et al. (2024) indicated that a lack of self-efficacy in a network of students significantly affects students' academic performance negatively. In contrast, a study conducted by Tsai et al. (2020) reported that self-efficacy positively influences the online learning experience and learning satisfaction in the online environment for students in the United States of America (USA). Many studies have been conducted on the relationship between self-efficacy and the learning process, self-efficacy and learning outcome, learning efficacy and student academic achievement, self-efficacy and student learning motivation, and self-efficacy and other learning performance-related studies (Fakhrou & Habib, 2022). However, there are limited or no studies on the relationship between self-efficacy mediating the relationship among AI-assisted technologies, such as adaptive learning platforms, AI tutors, and automated assessment systems, and deep learning effectiveness in mathematics education. Therefore, this study investigates learning self-efficacy as a mediator, exploring whether specific AI-assisted technologies in online learning platforms can influence students' deep learning in mathematics through learning self-efficacy, thereby improving deep learning effectiveness.

2.4. The Moderating Effects of Social Support

In a study, a moderator functions to influence, adjust, or modify the association between the independent and dependent variables (Cortes & Ooi, 2023). This study determines whether social support affects students' deep learning in mathematics in China. Social support is crucial for online learning environments, especially in new learning styles, such as learning with AI-assisting technology. Previous studies found that social support moderates technology-related tools in online learning environments. AI-assisting technology requires high levels of learning self-efficacy and motivation to minimize the negative impact on students with high levels of social support from parents and peers (Asghar et al., 2021). Hogh levels of social support also serves as the main factor influencing the effectiveness of AI-assisting technology operating in online learning environments. Researchers argue that social support improves students’ deep learning as students use technology in education to facilitate learning and academic performance efficiency. Moreover, Chen et al. (2023) contend that the higher the level of social support, the greater the students' learning performance in online learning environments.

Similarly, Ahmed and Opoku (2022) demonstrate that social support moderated technological tools in diverse educational institutions. Social support can enhance the students’ self-efficacy by actively participating in learning and by enabling students to understand the usage of AI-assisting technology in learning. This can enhance the effectiveness of student deep learning in complex courses such as mathematics (Liang et al., 2023). Moreover, social support plays a moderating role in deep learning through advanced technological tools such as AI-assisting technology. Hence, this study investigates AI-assisting technology and social support that may affect self-efficacy and student deep learning performance. Building on prior research that has demonstrated a significant correlation between the usage of technological tools and the learning performance of the students, this study examines the impact of social support as a moderating factor in student deep learning constructs (AI-assisting technology) and, eventually, the overall deep learning performance and success of the students.

3. Methodology

3.1. Research Participants

This research was authorized by the Human Research Ethics Committee of Universiti Sains Malaysia (JEPeM-USM) and granted the study protocol code USM/JEPeM/PP/23090665. This study confirms that informed consent was obtained from all participants and the person in charge of the primary schools. The sample population consisted of students from four primary schools in Fujian, China who experienced AI-assisting technology in mathematics classes. These participants were identified from the list provided by the school or instructors. After filtering targeted participants, the lists were sent back to the instructors for uploading to the learning system used in the course for survey participation. This research employed a web-based questionnaire to investigate different hypotheses. The survey was conducted between January and February 2024. The respondents were primary school students from four targeted schools in Fujian, China, selected from a sample of 1,755 students. Based on experience criteria in AI-assisted technology and deep learning performance, only 756 met the selection requirements, while 387 individuals participated in the online survey, resulting in a 51.19% response rate. Survey Monkey developed the questionnaire, which is available in simplified Chinese and English. Participants' identities were fully protected by the use of pseudonyms. Of the sample, 53% were male, and 47% were female. Most participants were between 9–10 years (39%) and 11–12 years (34%). To reduce potential method bias, participants were informed of the survey's voluntary nature and assured of confidentiality. Harman's single-factor test was evaluated to assess common method bias. The test results revealed that the primary factor accounted for less than 50% of the overall variation, indicating that bias was not a substantial concern in the dataset.

3.2. Data Analysis

The latent variables of this study were modified from existing literature (see Appendix 1 for the questionnaire) and measured using a five-point scale to measure the variables, where 1 indicates complete disagreement, 2 slight disagreements, 3 neutrality, 4 slight agreement, and 5 indicates complete agreement. The analysis was gathered via an online questionnaire and analyzed using SPSS and AMOS software. The analysis process involved two stages: (a) conducting confirmatory factor analysis (CFA) to evaluate the alignment between the indicators and the latent structure and (b) structural equation modeling (SEM) to verify the research hypothesis relationship. According to Collier (2019), the statistical indicators of CFA model fit assessment include absolute fit index (CMIN/df and RMSEA) and incremental fit index (CFI and NFI). CMIN/df should be less than 3.0, RMSEA should be less than 0.08, and CFI and NFI should be greater than 0.90 to ensure a good model fit.

A five-item scale measures the AI-assisting technology (AIT) construct. For example, items measuring AIT are "If I invest the necessary effort, I can solve most technical problems using AI-assisting technologies." and "Learning with AI-assisting technology makes me feel very comfortable". A five-item scale measures the learning self-efficacy (LSE) latent variable (SE). For example, items measuring in LSE were "Before the start of each online course, I will make a complete study plan and be sure to complete it" and "I think I can think and master in-depth knowledge in an online learning environment". A five-item scale measured the social support (SC) construct. For example, items measuring SC were "I think positive feedback from classmates online helps me think and learn" and "I think the support of classmates can make me feel relaxed in the online learning environment".

Based on earlier studies by Zhao and Liu (2022), deep learning (DL) is measured by five questions indicating its effectiveness. Item examples included "I can synthesize and organize thoughts, information or experience to form new and more complex explanations and relationships", "I can analyze the basic elements of thought, experience or theory, such as the in-depth study of a specific situation and considering its components", "I can recall facts, opinions, or methods from the course and readings and repeat them similarly" and "I can judge the value of information, arguments, or methods, such as evaluating how others collect online data and verifying their conclusions' reliability".

This study conducted data analysis using SPSS and AMOS statistical software. SEM was used to verify the research hypothesis relationship. At the same time, CFA assesses the relationships and correlations between variables, ensuring the validity of the measurement model. Indicators such as CMIN/df, RMSEA, CFI, and NFI were utilized to evaluate model fitness to evaluate model fitness, guaranteeing the reliability and appropriateness of the data.

4. Results

4.1. Cross-correlations among the four latent variables

Table 1 displays the summary statistics and intercorrelations among the four underlying variables: AI-assisting technology (AIT), learning self-efficacy (LSE), social support (SC), and deep learning (DL). The inter-correlations among all variables were positive and statistically significant at the 0.01 level (two-tailed).

Table 1: Descriptive Statistics and Latent Variable Correlations (n=387)

Latent	M	SD	AIT	LSE	SC	DL
AIT	4.1220	0.3681	1.000	0.572***	0.478***	0.398***
LSE	4.2375	0.3325		1.000	0.462***	0.475***
SC	4.1122	0.3652			1.000	0.512***
DL	4.2071	0.3821				1.000

Note: ***p < 0.01. Latent -> Latent Variable, M -> Mean, SD -> Standard Deviation, AIT -> AI-assisting technology, LSE -> Learning Self-Efficacy, SC ->Social Support, and DL -> Deep Learning.

4.2. Measurement Model Results

This study used the confirmatory factor analysis (CFA) before analyzing the SEM model to understand how well the indicators measure the variables. Various tools were used to test the stability of the four underlying constructs such as Cronbach's alpha, AVE, and CR, as shown in Table 2. The Cronbach's alpha has to exceed 0.7, and this study has an alpha value ranging from 0.801 to 0.841. In addition, the CR values of the three constructs were all above the minimal value of 0.70. The AVE values have to be higher than the threshold value of 0.5, and this study has an AVE value ranging from 0.7922 to 0.8567. All the test values from Cronbach's alpha, CR, and AVE indicate and support the strong unidimensional validity of the latent constructs. Furthermore, based on the Fornell and Larcker criterion, the discriminant validity assessment results demonstrated that each latent construct is unique and differentiated from the others (Cortes & Ooi, 2023).

Table 2: Latent Construct Quality (n=387)

Latent Construct	AVE	CR	Cronbach's Alpha
AIT	0.8567	0.8421	0.801
LSE	0.8225	0.8112	0.812
SC	0.8023	0.7815	0.841
DL	0.7922	0.7623	0.823

Note: AIT -> AI-assisting technology, LSE -> Learning Self-Efficacy, SC -> Social Support, and DL -> Deep Learning.

4.3. Hypotheses testing on the relationship among AI-assisting technology, deep learning in mathematics, self-efficacy and social support

The primary hypotheses of the complete SEM model were evaluated using SPSS-AMOS 29. Table 3 displays the results of the analysis. Regarding direct influences, H1 is confirmed, indicating that AI-assisted technology exerted a positive and statistically significant, albeit modest, effect on self-efficacy (H1: $\beta = 0.382$, $t = 2.254$). The AI-assisting technology explained 38.2% of the variance in learning self-efficacy. The outcomes supported H2, indicating that learning self-efficacy directly and significantly affected learning burnout (H2: $\beta = 0.475$, $t = 8.552$). Learning self-efficacy explained 47.5% of the variance in deep learning. Following Collier (2019), the CFA metrics utilized to evaluate model fitness comprise absolute fit indicators (CMIN/df and RMSEA) along with incremental fit criteria measures. The acceptable thresholds require CMIN/df to be under 3.0, RMSEA to be less than 0.08, and CFI to exceed 0.90. (Cortes & Ooi, 2023). The model in this study was an absolute fit where the RMSEA value was 0.032, the CFI value was 0.913, the IFI value was 0.921, and the CMIN/df value was 1.412.

Table 3: SEM Test Results

Hypothesized Relationships	Standardized Estimates	t-Values	Hypothesis Supported
H1: AI-assisting Technology → Learning Self-Efficacy	0.382 ***	2.254	Supported
H2: Learning Self-Efficacy → Deep Learning	0.475 ***	8.552	Supported
Squared Multiple Correlations:			
Deep Learning	0.325		
Model Fit Statistics:			
CMIN = 1.412, CFI = 0.913, IFI = 0.921, RMSEA = 0.032			

Significance levels: * $p < 0.05$, *** $p < 0.001$.

4.4. Effects of AI technology on deep learning, self-efficacy and social support

4.4.1. Mediation test analysis

The mediating role of learning self-efficacy in the relationship between AI-assisted technology and deep learning was analysed. The outcomes tabulated in Table 4 show that the intermediary role of learning self-efficacy on the relationships of AI-assisting technology on deep learning was significant. This study's immediate and mediated impacts were significant, suggesting a partial mediating role of the learning self-efficacy variable.

Table 4: Mediation Tests

Relationships	Direct Effect	Indirect Effect	p-Value	Conclusion
H3: AI-assisting technology → Learning Self-Efficacy → Deep Learning	0.141 (2.445)	0.572 (6.765)	<0.003	Partial Mediation

Note: t-values in parentheses.

4.4.2 Moderating effects

A framework incorporating the moderation effects of social support on the AI-assisting technology to learning self-efficacy relationships was defined and evaluated using SPSS-AMOS 29. It was conducted to examine whether the moderating factor (social support) impacted the mediated connections between the exogenous latent structure (AI-assisted technology) and the outcome variable (deep learning). As presented in Table 5, the findings revealed that social support had a significant moderation effect, confirming the hypothesis.

Table 5: Moderation Tests

Hypothesis	Path	Standard Error	t-Value	p-Value	Result
H4	**Social Support → AI-assisting technology → Learning Self-Efficacy → Deep Learning**	**0.042**	**4.652**	***	**Supported**

Note: *** p < 0.001 (t-statistic > 3.090, two-sided), with bootstrapping (n = 5000).

5. Discussion

The impacts and advantages of AI-assisting technologies on student academic performance in Western and some Asian countries have been extensively studied and well-supported. Beyond their direct effects, AI-assisting technologies offer additional benefits, including adaptive learning systems, improved learning management control, and enhanced student learning self-efficacy, particularly among school students. A sample of 387 primary school students studying mathematics in Fujian, China, was analyzed using SEM to examine these relationships. The empirical findings demonstrate that AI-assisted technology significantly and positively impacts students' deep learning. Furthermore, these effects are mediated by learning self-efficacy and moderated by social support.

5.1. Relationship between AI-assisting technology and deep learning in mathematics

This study investigated the intricate relationship between AI-assisting technology, learning self-efficacy, social support, and deep learning among primary school students in China. It emphasized that AI-assisted technology, both directly and indirectly, improves deep learning effectiveness by enhancing students' self-efficacy and social support. Learning self-efficacy was a key mediator in this relationship, reducing the negative impact of AI-assisted technology on students' deep learning performance. At the same time, social support moderated the relationship between AI-assisted technology and learning self-efficacy, influencing students' overall deep learning engagement. El-Sabagh's (2021) research suggests that AI-based adaptive learning environments can deliver personalized instruction, fostering deeper cognitive engagement. Similarly, research in Western countries demonstrates that AI-powered learning systems enhance metacognitive awareness and promote autonomous learning, essential components of deep learning (Rodway & Schepman, 2023).

This study focuses on primary school students' deep learning performance. One possible reason for this focus is that primary school students exhibit lower levels of self-efficacy and are easily influenced by external distractions owing to a lack of AI-assisted learning support and social support. Students striving for success in online learning environments may experience disengagement; thus shifting their interest toward AI-assisted learning will facilitate deeper cognitive processing. The combined influence of learning self-efficacy and social support plays a crucial role in fostering deep learning, particularly when students have access to AI-assisted technology. Students with high levels of self-efficacy are more likely to take control of their learning, adapt to technological tools, and manage more significant academic challenges. In contrast, students with lower self-efficacy may struggle to engage in complex learning tasks. The findings of this study align with this hypothesis.

5.2. Effects of AI technology on deep learning, self-efficacy, and moderated by social support

This study finds that learning self-efficacy mediates the relationship between AI-assisted technology and deep learning. This conclusion supports the findings by Chang et al. (2023) and Hayat et al. (2020), who determined that students with higher levels of self-efficacy are more inclined to adopt deep learning strategies. Hayat et al. (2020) found that self-efficacy was a key determinant of academic success in online learning environments, highlighting the significance of both cognitive and motivational factors in deep learning. Although AI-assisted learning can boost self-efficacy, educators should still guide students in building self-discipline and critical thinking skills. This way, students can take advantage of AI's benefits while developing the independence needed for long-term academic success.

Additionally, this study identifies social support as a key moderating factor in the relationship between AI-assisted technology and deep learning. This finding aligns with research in both Western and Asian contexts, which underscores the critical role of parental and peer support in fostering academic resilience and perseverance (Huang & Tu, 2021). For instance, Fakhrou and Habib (2022) reported that students with strong social support networks demonstrated greater self-efficacy when facing academic challenges, increasing their willingness to persist in completing complex tasks. Additionally, research indicates that AI-assisted technology alone cannot ensure deep learning unless students receive sufficient social support (Taye, 2023). In China's fast-paced academic environment, parents' investment in their children's education is critical in shaping how students view and engage in AI-assisted learning. However, economic disparities may create barriers to widespread AI adoption, potentially exacerbating the achievement gap between students with and without access to AI-enhanced learning tools. Thus, policymakers should address these digital divides by ensuring equitable access to AI-assisted technologies. AI-assisted technology can be a powerful intervention tool, fostering social support and self-expression in learning environments. By integrating AI-assisted technology with structured support systems, educators can enhance student support systems, increase student participation, boost academic performance, and foster a more inclusive learning environment. Schools should implement AI-driven strategies that improve self-efficacy and cultivate a supportive academic environment that nurtures students' long-term cognitive development.

6. Conclusion

This study explores the complex relationship among AI-assisted technologies, learning self-efficacy, social support, and deep learning for Chinese primary school students when learning mathematics. The study highlights the importance of considering distinct cultural factors in China, including conventional standards, societal values, and education practices tailored to local contexts. The findings emphasize the important role of AI-assisted technologies in improving students' learning self-efficacy, promoting better and more effective deep learning outcomes, and enhancing technology acceptance in educational settings. They also influence the implementation and success of AI-assisted technologies, emphasizing the need for a supportive learning environment to enhance their benefits. This study addresses multiple issues, such as AI-assisted technology influencing students' learning self-efficacy, the role of social support in regulating students' use of AI-assisted technology, and AI-assisted technology facilitating deeper and more effective learning in educational settings.

This research had certain constraints. To begin with, it concentrated on the deep learning of primary school students in mathematics in China. Second, the survey respondents were primarily primary school students in four primary schools in Fujian, China, with experience using AI-assisting technology in online learning, especially in mathematics. Finally, the study framework and proposed hypotheses were evaluated using cross-sectional data collected at a single point in time. Future research can build on these findings to refine AI-assisted learning strategies and optimize their effectiveness across diverse educational settings.

7. References

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