

The Effect of AI Based Scaffolding on Problem Solving and Metacognitive Awareness in Learners

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ARTICLE INFO			ABSTRACT
Article History:			<i>This study examined how students' problem-solving abilities and metacognitive awareness—more especially, their capacity to organize, track, and assess their own learning—were affected by AI-based scaffolding. The main goal was to ascertain how learners' knowledge of their own thought and learning processes was improved by structured support utilizing artificial intelligence. A quasi-experimental design was employed involving 300 students, aged 15–22, from secondary schools and undergraduate institutions in Lahore, Pakistan. Participants were divided into two equal groups: one received instruction using AI-assisted scaffolding tools, while the other was taught using traditional methods. Data were collected using standardized pre-tests, post-tests, and structured questionnaires. The results showed a strong favourable relationship between metacognitive awareness and AI-based scaffolding. Students who used AI-assisted learning showed improved ability to efficiently solve issues, organize their thoughts, and self-regulate their learning processes. Additionally, the study discovered that female students outperformed male students in terms of metacognitive awareness, pointing to a potential gender-based difference in the way students used metacognitive techniques and interacted with AI tools. Additionally, learning regulation improved more for pupils who had previously used AI tools. These findings corroborated other studies that shown how well intelligent tutoring programs enhance self-regulated learning. The study came to the conclusion that there was a great deal of promise for improving students' cognitive and metacognitive abilities through the use of AI technologies in the classroom. In both traditional and digital learning contexts, these technologies provide a more efficient, personalized, and interactive learning experience.</i>
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Introduction

In recent years, artificial intelligence (AI) has made its way into education, changing both how teachers and students learn. The capacity of AI to help students when they run into problems is one of the biggest advantages of AI in education; this kind of support is called scaffolding. Students benefit from AI-based scaffolding, which guides them through activities by giving them timely hints, feedback, and detailed instructions. When taking on difficult subjects, this individualized support makes sure that students don't feel overwhelmed or stuck. By reacting to students' activities in real time, AI systems can also improve problem-solving skills (Roll & Wylie, 2016). Furthermore, by tailoring the degree of difficulty to each student's aptitude, AI can maintain students' motivation and engagement (Holstein et al., 2019). It is crucial to take into account how these technologies affect the learning process as more colleges and universities use AI in the classroom. The term "thinking about thinking" refers to metacognition, which includes abilities including problem-solving strategy planning, self-assessment, and modification. These abilities are necessary for successful learning. Because they know how to manage their time and effort, learners with high levels of metacognitive awareness typically solve problems more quickly. By giving prompt feedback, assisting students in their activities, and encouraging them to consider their ideas, AI-based scaffolding can aid in the development of these abilities. Students who receive this kind of astute support grow more self-reliant, self-assured, and self-directed learners. According to research, AI applications can raise pupils' understanding of their thinking. Students who receive this kind of astute support grow more self-reliant, self-assured, and self-directed learners. According to research, AI applications can help students become more conscious of their own learning choices and processes (Azevedo et al., 2022).

Additionally, AI systems help with tracking students' progress and making appropriate revisions to instructions (Winne et al., 2013). By using AI, teachers are able to effectively help and mentor their students by gaining insightful knowledge about their learning. The purpose of this study is to examine how learners' problem-solving abilities and metacognitive awareness are affected by AI-powered scaffolding. It is anticipated that online learning environments will increasingly employ AI-based scaffolding. By decomposing difficult problems into smaller, more manageable steps, these approaches help guide students through them. In order to keep students interested and involved in the learning process, they can also allude to or imply more complex techniques without giving away the solutions outright. This method promotes psychological safety and confidence in pupils while they learn by lowering anxiety when they encounter challenging assignments. According to studies, scaffolding can greatly improve students' capacity for sustained attention and help them comprehend the material more thoroughly (van de Pol et al., 2014). Because AI-based support is dynamic and responsive to the unique needs of each student, it is especially beneficial (Knoop-van Campen et al., 2024). These intelligent learning settings give students the chance to investigate, make wise decisions, and practice critical thinking and self-monitoring—all of which are crucial abilities for resolving issues in the real world.

Understanding Metacognitive Awareness and Its Importance

Metacognition refers to the process of thinking about the process of thought. It helps the students to be aware of their learning methods. When they would like to solve a problem, test their performance and then think critically, students use metacognitive skills. All of these are the roads to improvement of learning and good performance. A number of the learners drop out because either there is no planning or they leave when they are asked to work hard. The metacognitive awareness can help the student become more active learners rather than passive learners. It educates them as a series of questions like is it working or should I take a different strategy. This way, such practices give them the chance to be on track when learning. The research has shown

that students who are more conscious of the amount of their intellectual skills achieve a higher grade at school and cope more effectively with tasks (Taufiqurachman, 2021). These learners are much more able to choose their strategies and change them in case of need. They do not guess blindly and follow the steps without thinking. On the contrary, they reflect on what they are doing, and why.

Scaffolding with the use of AI may help develop the sphere of metacognition with the provision of smart and prompt assistance. Such AI tools orient learners when performing learning activities. The questions they pose force the learners to think. As an example, the prompt asking why a choice has been made will be thought-provoking. AI systems can also know the response of the students and adapt to their support. These types of assistance will enhance better metacognition by reminding the learners to reflect on what they do. Studies have demonstrated that these reflective prompts makes one more cognizant and self-controlled (Greene et al., 2021). Students can also get hints or feedbacks depending on their progress with the help of AI tools. Students get a lesser chance feeling lost or frustrated when the concerned support is given to them at the right time. They start to know how to control their own thinking. This helps in resolution of problems and improvement of learning skills. When students are still using such systems, they begin to pose reflective questions by themselves.

The metacognition of students that involves understanding the problems also becomes very effective as their awareness grows. They are even able to learn how to apply the most effective techniques, to proof-read their writing and to revise it where it is necessary. The scaffolding by the use of AI assists in this as it gives feedback based on the level and according to the needs of the student. Students are made to notice what they are lapsing on and are made to learn by this feedback. It makes the learners more independent and assertive as time progresses. They begin to solve problems themselves and they are not always helped. In the researches, it is discovered that learners acquire better guidelines and regulations of making successful decisions and self-control with the particular provision of assistance to them through the AI-powered instruments (Hadwin et al., 2025). They not only tell the students what to do but how to think too. It is an excellent solution in the encouragement of lifelong learning. In this study, the researchers will also look at the role of AI-based scaffolding in the creation of metacognitive awareness within it. We would want to see how it helps in bringing out students as a certain thinker but not mainly as a learner. As long as AI will have the capability of helping in such developments, it can play a great role in the education field.

Role of AI-Based Scaffolding in Problem Solving

Artificial intelligence-based scaffolding is another important aspect using which students are able to respond to difficult questions. These programs are not the ones to provide students with the correct answers. Instead, they offer step by step tricks and guide the learners through the solution of a problem. By doing this, the students remain interested in the task. They are not alone and lonely. The AI tools can also be used to diminish stress by providing support when needed. The students are less pressurized the moment they receive help at the right time and can be motivated to move forward. This will make them concentrate and learn more. It has been determined by researchers that learners fare better when support in such a manner is given to them (Reiser, 2018). The AI scaffolding can help the students think in terms of how they are getting along rather than guessing. It also assists them in the development of their thinking abilities. This way, students not only obtain the information but also acquire procedures to tackle such issues in the future. This is the reason why this kind of learning support comes in very handy. It makes students ready to cope with problems independently. They are also more sure and content with their study results.

The second benefit of AI scaffolding is its adaptability based on the student behavior. These instruments observe the task that the learner is involved in and then conclude what volume of assistance to avail. In case of a student who is not performing, the system offers extra help. The AI will give less assistance in the cases of good performance of the student and leave the student to work independently. This is accompanied by a feeling of the support and freedom. It also helps the students have the control of learning. This gives one more confidence and learns how to solve problems step by step. Adaptive scaffolding has been discovered as effective because since the learner is at a particular level, corresponding support will be made (Campen & Molenaar, 2020). The after-learning is also the option through which the AI can make a comment concerning the student progress. They begin to think about what tactics were successful and which tactics were not. It enhances the thinking process. It will also help students in applying such skills in other situations.

As students get exposed to routine use of AI-based scaffolds, they will develop better skills at making decisions when going through the process of solving problems. They are taught to make the correct choices and how to verify their work and attempt a new strategy when the time comes. This makes them become more independent in solving problems. Other traits that AI fosters and are crucial in real life, are self-monitoring and reasoning. Some of the questions that the system can ask include; what will you do next or is this the best way. These are questions that encourage students to reason. There is research to support that such kind of prompts keep the students on focus and establish better thinking patterns (Chi & Wylie, 2014). AI scaffolding can assist students with a particular task and, in this way, instill habits that can last with them. They become less dependent on the system with time and they become self-reliant. This can demonstrate that AI is not replacing thinking instead it is used to make students develop their own skills. In the present inquiry, we shall discuss the enhancement in the problem solving capacity in the students using AI-based scaffolding.

Research objectives

1. To examine the relationship between AI-based scaffolding and students' problem-solving skills.
2. To assess the impact of AI-based scaffolding on learners' metacognitive awareness.
3. To explore differences in problem-solving and metacognitive awareness based on learners' academic background or experience with AI tools.

Problem Statement

The ability to solve problems and take control of learning has become difficult to many students in the current classrooms. Because they lack critical metacognitive skills like planning, monitoring, and reflecting on their learning processes, many students in today's classrooms struggle with problem-solving and self-directed learning. These abilities are essential for developing metacognitive awareness, which helps students become more self-reliant and productive. Without them, students frequently feel overburdened, disinterested, and incapable of finishing challenging assignments. At the same time, teachers struggle to give each student personalized instruction due to time and resource constraints. This disparity emphasizes the necessity of scalable technologies that provide learners with real-time assistance. The use of artificial intelligence (AI)-based scaffolding, which provides learners with dynamic help through reminders, feedback, and hints throughout learning exercises, is one potential strategy. Instead of providing straight answers, these resources assist students in structuring their ideas and coming to well-informed conclusions.

Although artificial intelligence (AI) is becoming more prevalent in educational settings, little study has been done on how AI-based scaffolding especially aids in the growth of students' metacognitive abilities. The majority of current research focuses on broad learning objectives, paying little attention to AI's potential to promote self-regulation and metacognitive awareness. By examining the effects of AI-supported scaffolding on students' metacognitive growth and problem-solving skills, this study fills that knowledge vacuum.

Significance of the Study

This study's importance stems from its emphasis on how artificial intelligence (AI) might improve students' ability to solve problems and think critically. Students in many courses find it difficult to handle challenging difficulties or intellectually taxing assignments. They frequently lack critical metacognitive abilities that are necessary for both academic performance and lifetime learning, such as organizing, tracking, and assessing their learning. These abilities could be fostered by timely, tailored support from AI-based scaffolding systems. These resources encourage students to remain involved and reflect critically on their learning processes by providing hints, prompts, and strategic direction without giving out answers outright. With this kind of help, students can manage their academic assignments more independently and with greater self-awareness. Even while AI is being used in education more and more, nothing is known about how it specifically affects students' capacity for metacognition and problem-solving. By investigating how AI-based scaffolding affects learners' capacity for autonomous thought and learning regulation, this study seeks to close that gap. It is anticipated that the results will provide educators with important information about how to successfully include AI tools in the classroom to improve both cognitive and metacognitive outcomes.

Literature Review

Over the years, educationists have been struggling to acquire the most suitable tool which they hope to use to make the students become independent and strong in learning. One of the concepts that have been crucial is the aspect of the metacognition which translates to the ability of individuals to reflect, understand and govern the learning of the individual. When the students employ metacognitive strategies, planning before an assignment, monitoring during an assignment, and reflection on the outcome attained by both the strategies adopted and those failed are involved. These processes can help the students to solve problems more effectively since they do not indulge in mindless activities anymore but they do have a rational approach to problems. The level of metacognitive awareness and its greatness results in the students doing better in their works, being greatly motivated, and having a more organized thought process. To some extent, the metacognitive awareness enables the students to be responsible as far as their learning is concerned. According to these researchers, metacognition skills are vital skills, which can aid in achievement of improved academic performance, and problem-solving aptitude (Liu & Liu, 2020).

Over the past few years, technology has started to transform the process through which students consume learning material and Artificial Intelligence (AI) is just one of the recent innovations to look particularly promising. AI has also become important to learners with a process called scaffolding, which entails providing step-by-step hints, prompts or feedback which guide the students through an area where they are stuck with some difficulties. As opposed to direct instruction, scaffolding encourages the learners to develop problem solving styles. AI-based scaffolds are dynamic, AI-based scaffolding systems examine the behavior of the students in real time and alter the degree of support offered etc. more when a student is not performing and less when the student is performing well. Such one-on-one treatment encourages long-term

involvement and reduces the likelihood of frustration and occurrence of dropouts. It has also been perceived that students as well as their understanding and motivation can be greatly increased with the help of such intelligent tutoring systems (Aleven et al., 2023). The tools are not only beneficial in content delivery but also affect the cognitive and metacognitive engagement.

Though the popularity of AI in education keeps increasing, there is still a quip in studies as to how and to what extent students could be influenced by it as opposed to metacognitive awareness. Most of the available material focuses on the effectiveness of AI tools in improving learning outcomes like the grades, test results, or the level of engagement. Nonetheless, very little research is conducted concerning whether these tools truly develop the capacities of the learners to think of and control their learning processes. It is an essential split as metacognitive processes that encompass planning, monitoring the understanding, and reflection of performance functionality is essential to life-long learning and learning resiliency. AI-driven scaffolding has a potential to develop such skills and assist students with self-questioning, representing feedback on time, and reflective questions. The methods can be used to enable students to be more purposeful and self-conscious learners. The evidence on AI and its role in contributing to self-regulated learning has also been mentioned by (Azevedo & Wiedbusch, 2023), who brought up the idea that it may help learners be more mindful of their thinking process, but emphasized more empirical research as well. As such, there is a need to investigate on the AI scaffolding effect on metacognitive development in addition to content acquisition.

Intelligent Scaffolding through Artificial Intelligence

Artificial Intelligence (AI) is transforming the learning behavior of students by presenting high-end support systems offering feedback according to the need of the individual learner. The conventional teaching normally brings up the same lesson to every student but irrespective of the learning capability. Such a practice, which can be referred to as intelligent scaffolding, is meant to assist students to accomplish their tasks when they are not able to do them solo. An example of this is that when a student has a hard time on a math problem the AI may provide a slight hint or ask a question that will lead the student to ask a question so the right answer can be found. The AI provides less assistance as the student learns and builds up his confidence. This makes the learning more individual and so the students do not become lost or frustrated. After a period of time, they would be more independent learners. (VanLehn et al., 2024), suggests that intelligent tutoring systems have demonstrated their capacity to enhance the performance of students by providing them with the form of step by step assistance that is similar to that by human tutor.

Such systems do not only pass provisions; they aid the method of learning, thinking, and problem solving among students. Such technology enables teachers to teach at a higher level with students playing a part of the role since the process is done at their own level. It should, therefore, be understood that AI is not discharging teachers but making them deliver in a more focused and efficient manner. Finally, AI-scaffolding can also play an important part in the creation of the student-based studying contexts. In the past, learning was always together with the course rooms that were mostly teacher-centred and passive learners. Nevertheless, nowadays, through the latest AI innovation, students are becoming increasingly self-regulating through AI support in the education process. The learners are energized and more engaged, in case they can choose their progress, the hours, and the form of assistance (Jackson & McNamara, 2017).

This has been achievable through AI scaffold that resorts to the data of individual students and forms itself in real time. This will make the system to discover when to stand out and when to retire. The research carried out by (Holmes & Porayska-Pomsta, 2023), shows that adaptive technologies, including AI, encourage learners to be more active and engaged and improve the

significance of the learning process and the level of confidence. These aids assist in encompassing a learning cycle that entails a process of planning, an action and a reflection all of which are key processes in good learning. Other than that, as schools become more and more stuffed with technology, AI apps can be useful in helping instructors reduce the workload, providing consistently individual feedback. In conclusion, smart scaffolding does not merely help the students to solve the academic problems, but also to come out to be mature, considerate learners, who are in a much better position to tackle the challenges and problems in future. AI would make an immensely suitable companion in the process of schooling especially since it is developed in such a way that it reinforces not merely intellectual but also metacognitive prowess (Hutson & Plate, 2023).

Impact of AI on Metacognitive Skill Development

Artificial Intelligence (AI) is stereotypically thought of as something that leads to higher grades or results of different tests in a broad way when students are capable of obtaining better grades. The other concern there however, which not being met with an equal emphasis is one element of how come AI may be or even can be used or utilized in terms of developing or building metacognitive skills or ability which involves thinking about thinking. These abilities help the students to plot, monitor and appraise the learning. Academic performance usually attracts the attention of most studies without considering the issue as to whether the students can learn how to learn. However, metacognition will impact on long-term success because, because of it, the learners will be able to manipulate the strategies and resolve the problems in a self-sufficient manner. Such development can be facilitated by AI learning aids that can motivate the students to reflect upon the learning. These minor but important details will cause the learners to reflect. According to (Luong et al., 2025), the student's prevalence to reflect with the assistance of AI tools tends to show the increased rates of self-awareness about their thinking and the capacity to enhance the process of decision-making at the current level of learning.

Within AI-assisted learning, metacognitive cues can frequently be incorporated into the system to instruct the students to become more involved in the learning process. Such prompts may require any learners to justify their thinking, make guesses, or check their performance prior to the next step. This can be used continuously to make the students more self-aware and take control of their learning. They start questioning the fact that a solution does (or does not) work or at least does not seem to work out anymore there is no more clicking through questions and copying answers. This forms habits such as doubting oneself, setting goals and correcting yourself in the long run and all of these form part of metacognitive thinking. Indeed, studies reveal that this kind of methods elevates the motivation and the confidence levels of the students. (Efklides, 2011), describes, the metacognitive experience when encouraged in the right way, assists in better controlling efforts and becoming more strategic thinkers. In this intention, the AI tools will enable the establishment of a loop of learning and reflection. Nonetheless, it is worth mentioning that the adoption of AI does not imply the betterment itself.

At the same time, there will be more settings where AI has an effect in how the students learn, not merely what they learn as AI finds increasing purchase in classrooms and online learning. The only problem is how to make sure that the AI tools can be developed in ways that would facilitate cognitive development and metacognitive development. Most of the systems in place today still focus on results of performances, such as correct answers in the shortest time. However, this is forgetting the value of the reason that the learner came up with that answer. It would be more effective to apply AI to develop experiences in learning where students think prior to completing a task as well as during and after the task is done. This would assist in instilling lifelong learning skills on them. (Umutlu & Gursay, 2022), explain that intelligent learning environments have a

chance to improve the planning, monitoring, and evaluating of the own learning process in case they are organized appropriately. That kind of environment changes the thinking process towards the long-term growth instead of immediate success and teaches students to become independent, strategic learners.

Research Hypotheses

1. **H1:** There is a significant relationship between AI-based scaffolding and learners' metacognitive awareness.
2. **H2:** There is a significant effect of AI-based scaffolding on learners' problem-solving abilities.
3. **H3:** There is a significant difference in metacognitive awareness among students receiving varying levels of AI-based instructional support.

Methodology

Research Design

The research design used in this study was quantitative. The goal of employing statistical analysis to determine the relationship between AI-based scaffolding and students' problem-solving abilities and metacognitive awareness led to the selection of a quantitative approach. The researcher was able to measure results, look for trends, and make comparisons using numerical data thanks to this methodology.

Two student groups participated in a quasi-experimental design, with one group receiving education aided by AI-based scaffolding and the other group receiving instruction using conventional techniques. Deeper understanding of how AI tools affect students' learning processes was made possible by this design, which made it possible to compare the results of AI-assisted learning with traditional classroom education. Both groups were given structured survey questionnaires and standardized exams to complete in order to gather data. These tools made it easier to get quantitative data that could be compared and statistically examined. The study was able to examine the efficacy of AI-based scaffolding in a systematic and dependable way by administering pre-tests and post-tests to evaluate changes in students' performance and metacognitive awareness before and after the intervention.

Population

Secondary and undergraduate students from particular schools and institutions in Lahore, Pakistan, where AI-based learning resources were already part of the curriculum, made up the study's population. These universities were picked because they have access to AI tools like intelligent tutoring programs and adaptive learning platforms. The students' target age range was 15 to 22 years old, which is a critical developmental stage for the development of metacognitive and problem-solving abilities. Participants were chosen from both public and private colleges, representing a variety of academic fields, and comprising both male and female students in order to guarantee diversity. Using a quasi-experimental design, two groups were created from this population: one group received instruction aided by AI-based scaffolding, while the other group received conventional education devoid of AI support. In order to support AI-integrated learning and make data collecting easier, the chosen universities also have the required infrastructure, such as internet connection and smart classrooms.

Sample Size

Three hundred students from secondary schools and college institutions that have adopted AI-based teaching methods made up the study's sample size. In order to guarantee statistically sound and broadly applicable findings that would be representative of the entire student body, this sample size was selected. The comparatively large sample reduced random mistakes and increased the findings' accuracy. Two equal groups of 150 pupils each were formed from the students. While one group was taught using AI-based scaffolding tools, the other group was taught using a conventional method. The two teaching approaches might be meaningfully compared thanks to this controlled division. The sample was evenly divided between male and female students, enabling possible gender-based analysis if necessary. Because kids were specifically chosen from a variety of educational settings to guarantee a thorough representation, the sample also represented diversity in terms of learning contexts, academic performance, and exposure to technology.

Sampling Technique

This study employed a two-step sampling approach: purposive sampling followed by simple random sampling. Schools and institutions that have already incorporated AI-based tools into their teaching practices were chosen in the first step using purposive sampling. By ensuring that the research was carried out in settings where AI-based scaffolding was already in use, this approach made the setting pertinent to the goals of the study. These educational institutions were chosen on the basis of their active use of AI in the classroom and their availability of suitable equipment. The second step was choosing individual student participants from among the selected institutions using basic random selection. Because every kid had an equal chance of being chosen, selection bias was lessened and participant selection was made fair. This approach facilitated the development of a representative and diverse sample. The researcher was able to retain objectivity in student selection while concentrating on the proper educational atmosphere by combining purposive and random sampling. Additionally, it was useful because data collecting was simpler in organizations that were already accustomed to using AI-based solutions. All things considered, this method improved the sample's validity and relevance without adding bias.

Ethical Considerations

This study's ethical considerations were carefully considered to guarantee each participant's safety, privacy, and wellbeing. All student participants gave their informed consent prior to the start of data collection. Consent was also acquired from the parents or legal guardians of youngsters. The participants received a detailed explanation of the study's objectives and methodology. They were made aware that they could leave the study at any time without suffering any repercussions. Every piece of information gathered from students was kept private and utilized only for study. No personally identifiable information was gathered, including names, contact information, or roll numbers. Information was safely stored and shielded from unwanted access. The study was planned to prevent volunteers from experiencing any stress, discomfort, or bodily or psychological injury. The participants were not at danger from the educational treatments, which included both conventional teaching techniques and AI-based scaffolding technologies. Furthermore, equity and justice were upheld during the entire research process. Discrimination of any kind was prohibited, and every student received respectful treatment.

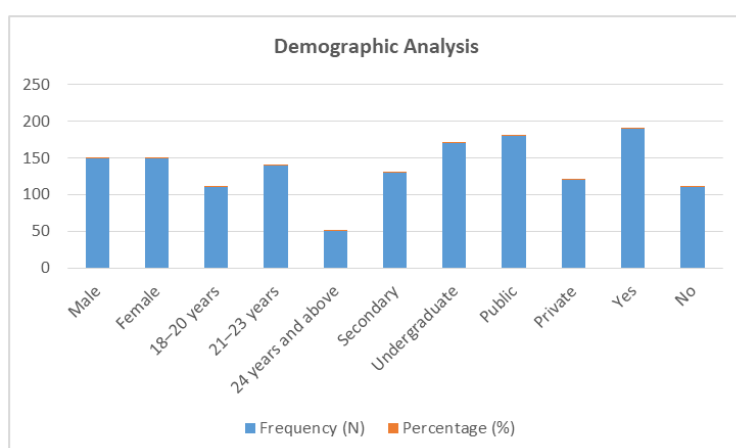
Data Analysis

The information gathered in the study was recorded in quantitative statistical methods to strive to find out the effect of AI inspired scaffolding on the problem solving proficiency and metacognitive

awareness amongst the students. To begin with, the results of pre-test and post-tests that were given out to both experimental and control groups were listed and entered into statistical analysis tools like SPSS. Means, standard deviations, and frequencies were also computed to give a clear description of the responses of the participants and their background data. In assessing the performance of the two groups, inferential statistics like the independent sample t-tests were applied in this regard, which facilitated the conclusion of whether there was significant learning relating to the use of the AI-based scaffolding. The intra-group t-tests were also done to examine possible changes brought about by the interaction of pre-test and post-test scores in each group. In addition, correlation was used to learn more about the correlation between metacognitive awareness growth and the use of AI tools. The outcomes were deduced with the help of a standard significance level (typically, $p < 0.05$) and the presentation of the results was given in terms of a table and graph to facilitate their interpretation. Such an organized analysis helped the researcher to make conclusions regarding the effectiveness of AI-based teaching and gave evidence-based answers towards ways the introduced technologies affect students learning process.

Table 1: Demographic Characteristics of the Participants

<i>Variable</i>	<i>Category</i>	<i>Frequency (N)</i>	<i>Percentage (%)</i>
Gender	Male	150	50.0%
	Female	150	50.0%
Age Group	18–20 years	110	36.7%
	21–23 years	140	46.7%
	24 years and above	50	16.6%
Educational Level	Secondary	130	43.3%
	Undergraduate	170	56.7%
Institution Type	Public	180	60.0%
	Private	120	40.0%
Prior AI Tool Exposure	Yes	190	63.3%
	No	110	36.7%

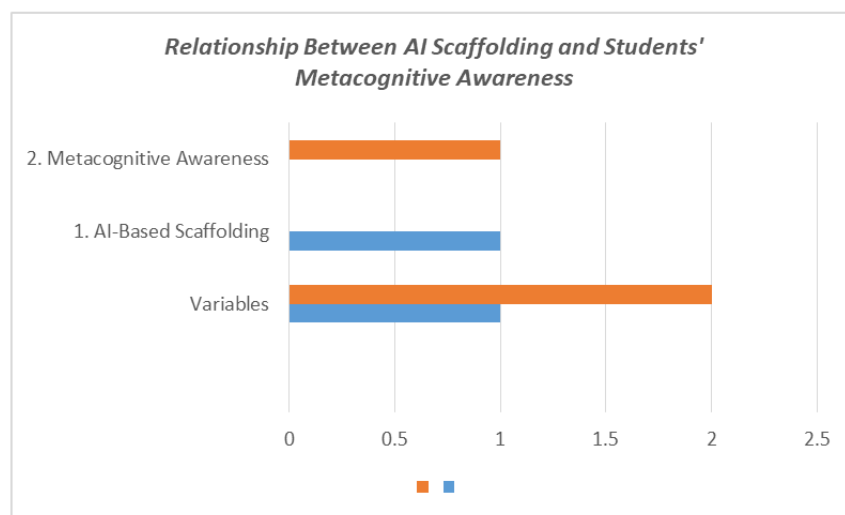


Demographic background of the three hundred students that were involved in the study indicated an equal representation in interview of males and females with 150 (50%), males and 150 (50%) females. Age wise, most of the students belonged to 21-23 age group (46.7%), then came the number of students between 18-20 years (36.7%), and a smaller figure of 16.6 percent was the 24-

year-old student and above. In terms of level of education, most of the respondents (56.7 percent) were undergraduates, whereas other 43.3 percent were of secondary level education. Institutionally, many of the students were in the public institutions (60%) than that of the private institutions (40%). It is noteworthy that the percentage of students declaring previous interaction with AI-based learning tools was detected to be considerable (63.3); meanwhile, 36.7 were in the position of having not interacted with them previously. The following demographics offer a heterogeneous sample pool, which ensures that all of the aspects of students understanding of AI-based scaffolding and metacognitive awareness can be studied in it.

Table 2: Correlation Between AI-Based Scaffolding and Metacognitive Awareness

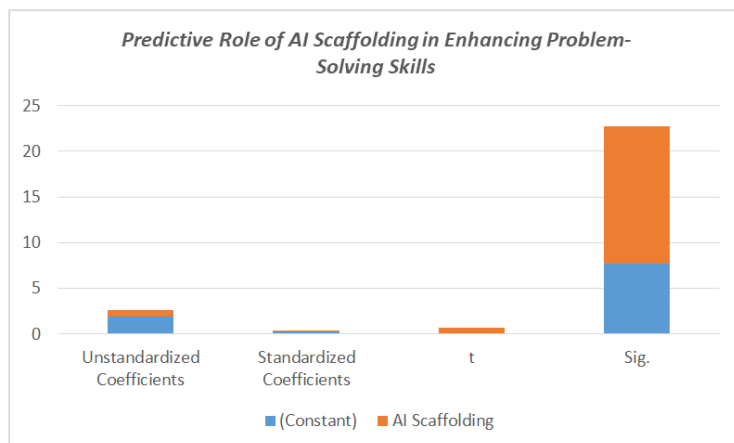
Variables	1	2
1. AI-Based Scaffolding	1.000	
2. Metacognitive Awareness	0.612 ^{<sup>*</sup>}	1.000



The result of the Correlation Analysis of AI-Based Scaffolding against Metacognitive Awareness indicates that there is a positive and significant correlation between the two variables at a 0.01 significance level in which the correlation coefficient is $r = 0.612$. This confirms that the higher the scaffold that involves AI is, the more chance the metacognitive awareness of the students can be enhanced. Simply put, the learners who are more likely to reflect upon their thinking, monitor their learning progress, and make alterations to their approaches are the learners who have more personalized guidance and adaptive feedback delivered by the AI systems. The magnitude of correlation gives an indication to the moderately strong correlation in favor of the supposition that AI-based instructional supports are significant elements in developing self-regulated learning activities. This conclusion is in alignment with other studies which focus on the ability of intelligent tutoring systems to power up the cognitive and reflective involvement of students.

Table 3: Regression Analysis

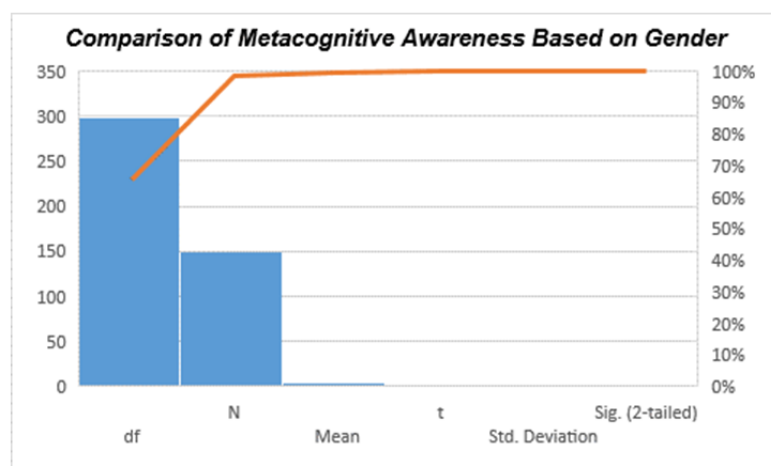
Model	Unstandardized Coefficients	Standardized Coefficients	t	Sig.
	B	Std. Error	Beta (β)	
(Constant)	1.912	0.247	—	7.742
AI Scaffolding	0.679	0.045	0.658	15.038



According to the regression analysis, the effect of AI-based scaffolding in students is statistically significant and positive in terms of developing their problem-solving skills. The unstandardized coefficient ($B = 0.679$) refers to the fact that there will be 0.679 additional units of this problem-solving skills as the score of A I scaffolding score is added. This is given by the standardized coefficient (beta) 0.658 which shows that the correlation between the two variables is very strong and positive. The t value (15.038) is very big and the significance level ($p < .001$) affirms that the relationship is very significant. This implies that AI scaffolding is significant in boosting the problem solving skills of the students probably through structured assistance which fosters self-thoughts, sequential thinking as well as judgmental decision making throughout learning engagements.

Table 4: Comparison of Metacognitive Awareness Based on Gender

Group	N	Mean	Std. Deviation	T	df	Sig. (2-tailed)
Male	150	3.72	0.52	2.641	298	0.009
Female	150	3.88	0.47			



Independent samples t-test checked the statistics mean scores of the male and female students concerning the degree of their metacognitive awareness. The findings describe the fact that the difference between the two groups was found to be statistically in which the degree of metacognitive awareness was high in girls ($M = 3.88$, $SD = 0.47$) students as compared to the boys ($M = 3.72$, $SD = 0.52$) students. With proportion of 2.641 t -value and p -value (which is less than

0.05) of 0.009, the importance of such a difference will be obvious and it could not be due to chance. This result implies that gender has the capability of interfering with the metacognitive capacities of students and women can be generally more mindful or conscious in learning processes in an AI-enhanced learning environment.

Discussion

AI-based scaffolding and metacognitive awareness were found to be significantly and strongly positively correlated in the study. According to this research, students that participate in AI-supported step-by-step learning show enhanced abilities in planning, tracking their progress, and reflecting on their learning procedures. These findings are consistent with earlier studies that highlight the advantages of AI in developing pupils' cognitive and self-control skills. Dever et al. (2023), for example, discovered that intelligent tutoring systems with integrated scaffolding elements helped students better control their learning. These technologies provide reminders and suggestions in real time, which promote deeper cognitive involvement. This evidence is supported by the current study, which shows that structured AI support can foster better learning habits. As a result, teachers can think about incorporating AI tools into their teaching methods to help students become more self-aware and learn on their own, especially in online or remote settings where teacher presence is restricted.

The study's regression analysis offers more proof of the important contribution AI-based scaffolding makes to raising students' metacognitive awareness. To put it simply, students who use AI-assisted help more regularly are more likely to form habits like establishing learning objectives, keeping track of their comprehension, and modifying their approach accordingly. These results are in line with past studies showing that AI systems support the formation of lifelong learning habits in addition to knowledge acquisition. For example, Rizvi (2023) discovered that AI systems that provided adaptive assessment tasks and tailored feedback helped students better control their learning processes. These kinds of systems usually work by means of ongoing feedback loops that encourage students to consider their mistakes and improve. The current study confirms that AI has a good impact on students' cognitive and metacognitive processes in addition to enhancing academic achievement. Thus, including AI scaffolding into teaching methods seems to be a viable way to support both short-term academic improvement and long-term self-regulated learning.

Gender variations in metacognitive awareness are another important conclusion from this study. Metacognitive awareness was higher among female students than among male students, according to independent samples t-tests. This implies that female students might be more introspective, well-organized, and open to receiving help from teachers. In a similar vein, Hmelo and Ferrari (1997) noted that female students typically use more sophisticated self-monitoring and planning techniques in academic settings. Our results support this finding by indicating that these gender-based disparities continue to exist even in learning settings with increased technology. Different learning styles, varying degrees of confidence, or varying amounts of experience with AI tools are some possible answers. For instance, whereas male students could be less receptive to AI-provided instructions and feedback, female students might be more likely to follow them. These findings suggest that developers and educators should take gender preferences into account when creating AI-based learning resources and modify support systems to meet the demands of a variety of learners monitoring techniques in educational environments.

The study's demographic results showed that participation was evenly distributed across public and private universities, and most students had previously used AI tools. It's possible that early exposure helped students feel more at ease using AI to enhance their learning and introspection. This is in line with the results of Wang et al. (2025), who found that students who use AI tools

over time typically become more adept at self-control. Students who repeatedly engage with AI-driven feedback and learning recommendations can identify trends in their learning behavior and make the required corrections. Students who had previously used AI-based metacognitive help in the current study seemed to be more skilled at using these resources. This implies that expanding early access to AI technologies in classrooms could improve the learning results and experiences of children. In addition to embracing AI technologies, educational institutions are urged to guarantee fair access and instruction for every student from the outset.

Conclusion

The results of this study demonstrate the great potential of AI-based scaffolding to raise students' metacognitive awareness, or their capacity to evaluate, control, and enhance their own learning processes. Students showed enhanced abilities in planning, tracking progress, and assessing their learning outcomes through the use of AI technologies that offer immediate feedback, tailored support, and adaptive learning pathways. The findings unequivocally showed that students' metacognitive awareness scores were greater for those who got AI-supported education. Furthermore, the study found that female students demonstrated somewhat higher levels of metacognitive ability than their male counterparts. This could be explained by variations in learning styles, a better receptiveness to structured support, or a response to technology. Additionally, these systems were more likely to be beneficial to children who had previously used AI tools, indicating that early and regular access to educational technology can be crucial for the development of self-regulated learning abilities.

Overall, the study supports previous findings that AI technologies are useful for developing more self-aware, autonomous, and self-assured learners in addition to enhancing academic achievement. These results emphasize how crucial it is to incorporate AI technologies into teaching methods early on in order to support students' long-term development of cognitive and metacognitive abilities.

Recommendations

1. Apply scaffold AI-based to the classroom situation to foster more building of students' metacognitive awareness and awareness of self-regulated learning.
2. Train the educators in order to understand how to use and incorporate the AI tools to facilitate the learning experience.
3. Have students experience AI learning technologies earlier in life so that they can develop metacognition at a much younger age.
4. Develop equivalent artificial intelligence systems that accommodate the levels of learning different people refer to as having different learning preferences, which requires creating gender-inclusive systems of learning, encouraging people to learn in the same magnitude.
5. Encourage the use of the AI tools daily so that the consistency in student learning and reflectivity leads to its result.
6. In order to make the training of metacognitive skills institutionalized, the curriculum must include AI scaffolding.
7. Enhance accessibility to the AI tools by institution types (public and private) to diminish the digital gap in their usage.

8. Present more research on the persistent impact of AI scaffolding; think about multiple student groups and educational outcomes.

Future Implications

Study results are meaningful in terms of their implications for the future of education, especially toward the utilization of artificial intelligence as educational assistance in guiding learners. As long as there is a future where AI tools will be more advanced and thus more accessible, they will be able to make students more aware of the way in which they think and study. In other words, to optimize learning, schools and universities have to focus on the implementation of AI-based scaffolding tools in the teaching process. The resources may be utilized to assist students in planning, monitoring their knowledge, and reflecting on what they have learned. It may also happen in the near future that, with the assistance of AI, teachers will have an opportunity to design unique learning experiences that take into account all the needs of the students and lead to a more efficient and even exciting process of studying. In addition, the training of teachers in the utilization of AI tools will also be a key issue because they could teach the students how to utilize them properly. Policymakers will also be recommended to invest in the provision of AI technology to both government and privately run institutions to bring equality among students. It is possible to carry out future studies, and this can be done by looking at the effects of AI on different types of students over time—gender-wise, age-wise, or by learning style.

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