

AI-Assisted Metacognitive Strategies for Improving Self-Regulated Learning among High School Students

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ARTICLE INFO			ABSTRACT
Article History:			<i>The study was set up to determine whether using AI-led metacognition improved high school students' ability to self-regulate their learning. With the use of a pre-test post-test control group design, 200 students were sampled randomly from public and private schools and then distributed equally into the experimental and control groups. The experimental group benefited from AI-enabled tools to strengthen their metacognitive skills, while the control group stuck to traditional ways of teaching. Data were collected by giving a standardized self-regulated learning questionnaire both before and after the intervention. The differences in post-test results between the two groups were significant enough to prove that AI-assisted strategies positively improved SRL in students. Paired samples t-test revealed that the experimental group experienced considerable improvement between the pre-test and the post-test. There is a significant influence of AI-based instruction and gender on self-regulated learning, but they do not influence each other. Demographic analysis made sure that the study included students from both genders, a variety of age groups, various schools and different grade levels, confirming AI-driven education can help many different types of students. The results support today's views on education that highlight how AI is important in making learning more individualized and building teacher independence. Researchers say this evidence can be useful for those who are working to use AI in educational systems that are not commonly used. It demonstrates the need for ensuring different learners enjoy fair benefits from AI, stressing the need for digital education that is inclusive and accessible to all.</i>
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Introduction

In recent times, teachers have started using artificial intelligence (AI) which has changed the way students connect with learning tools and improve their thinking abilities. Amongst all these changes, AI-based metacognitive approaches look promising at boosting self-regulated learning which is especially relevant for high school students with rising demands and harder classes. Being aware of their learning and being able to control it allows learners to organize, check and understand their progress. Because of AI technologies, students get customized help and immediate assistance from adaptive learning systems and intelligent tutoring platforms which help them improve their self-regulation and achieve better results. (Kim et al., 2023) People who learn self-regulatedly take it upon themselves to define their goals, plan how to reach them and analyze their growth. Yet, numerous high school learners encounter difficulties managing their study habits because they do not fully realize the behavior they display and do not know enough strategies. With the help of AI, tools can analyze data on learners' progress and then guide them by providing personalized advice on how to assess their own work, manage their schedules and correct mistakes. Joint studies find that using AI with metacognitive nudges greatly boosts a student's motivation, academic success and mental engagement but traditional methods cannot provide the same benefit (S. Chen et al., 2024).

It means that AI helps students move from depending on the teacher to become their own teachers and overcome any challenges in different learning contexts. In addition, AI's flexible and active nature helps learners with different backgrounds and learning styles. Student readiness and self-regulation differ a lot in high schools, so it is important to use personalized metacognitive support to promote equity in education. AI can study how each learner behaves and offer custom resources that help teach differently, suiting all learners. Also, since AI gives students fast and ongoing feedback, they become more likely to keep learning and improve their skills. Based on recent research, AI support in metacognition leads to better academic achievements and strengthens learners' self-confidence when tackling academic issues (Gavín-Chocano et al., 2024). These positive improvements still leave some challenges for making AI tools better and using their metacognitive abilities. One should pay attention to data privacy concerns, the risk of overusing technology and how teachers will learn to introduce AI into their teaching. Moreover, it is important to study how AI-assisted metacognitive strategies affect high school students' ability to learn by themselves. It is important for future research to discover how artificial intelligence can supplement not only lessons but also support students' feelings and well-being for complete education. For this reason, finding new ways to use AI for self-regulated learning is a key issue in the field of educational technology research (Luo & Zhou, 2024). The use of AI-supported metacognitive strategies is also in line with the rise of 21st-century skills that see crucial skills for success as being critical thinking, problem-solving and independent learning. Students in high school who have the support of metacognition and AI resources are ready to accomplish difficult tasks and handle the changes in school work. Some AI platforms use analytical tools and reflective logs to help learners understand their learning processes and make the needed changes as they learn. In doing this process, students improve their self-awareness and can use these skills in different lessons and outside school. Modern research points out that engaging students with AI metacognitive tools means they sometimes feel more confident and resilient which helps them learn more effectively (Dong et al., 2024). For this reason, using AI to help improve metacognition in high school students benefits them by preparing them to grow educationally in the modern world.

Understanding Self-Regulated Learning and Metacognition

Part of SRL involves students being proactive in managing their learning which covers choosing goals, drawing up a plan, tracking their journey and reviewing what they have achieved. During high school, when the curriculum becomes tougher and students must deal with harder work, SRL supports their achievement in school. If learners make sure their goals are specific and measurable, they can organize big assignments into smaller steps and organize their tasks according to their importance and when they must be finished. Students are expected to always review how well they have learned and what they find easy or hard to understand. At the last step of the process, students are urged to look back at how successful their strategies have been and plan improvements for the future. It has been found that students who use self-regulatory strategies usually achieve better grades, manage problems well and learn to organize their time in a responsible way as they prepare for greater independence (Lan & Zhou, 2025). The concept of metacognition which is making learners mindful of their own thought processes, is key to SRL. Only two items make up the essence of metacognition: metacognitive knowledge which means being aware of your strong and weak points in thinking and metacognitive regulation which refers to organizing, tracking and assessing your mental activities.

Having metacognitive awareness, high school students can pick the best approach for each task, whether to use elaborative interrogation with scientific concepts or ask themselves questions while reading difficult texts. During learning, monitoring allows you to notice when you don't understand and do something to clear your confusion. Evaluation encourages them to consider what they achieved in their studies and which methods or strategies helped the most. For this reason, using metacognitive approaches allows students to deal with more demanding material independently, laying a solid base for being adaptable and successful in learning (Efklides & Schwartz, 2024). Even though using metacognitive strategies is very beneficial, many students in high school find it difficult to use them all the time which stops them from regulating their learning. Another disadvantage is that teachers, given the lack of time and resources, are not often able to instruct students about planning, checking and assessing their work. Because teenagers have yet to discover various ways of learning, they often end up using basic approaches such as rote learning which do not encourage them to understand important details deeply. Without realizing when they are struggling with new or tricky topics, students are not likely to try a new approach and this can leave them frustrated and turn them away.

Statistics prove that when students lack metacognitive skills, their learning outcomes are usually poor, they worry more and get discouraged even in simple academic challenges which often increases the divide in achievement. (Fischer & Dignath, 2024) Because of these challenges, teachers support explicit metacognitive learning and keep giving help to make sure students keep using these skills. Part of the intervention might consist of teaching methods that illustrate how to write learning goals, ask oneself questions during studying and use reflection journals to check how well the chosen strategies are working. If students are habitually trained metacognitively and also receive feedback, they learn to manage their education by themselves and gain more confidence. In addition, continuous reinforcement such as group study sessions with reminder questions or apps that send personal feedback, makes it possible for students to acquire these skills and use them for extended periods. Studies have discovered that when students take part in such programs, they are more motivated, have a higher sense of confidence and do better in school than peers who are not exposed to these strategies (Ernst et al., 2025).

The Role of Artificial Intelligence in Supporting Metacognition

AI in education now helps provide checks designed to fit each student's individual requirements by being flexible and always ready to change. A traditional method of teaching might not consider what each learner is capable of, but AI-powered tools can examine a person's skills, issues and interests to help teachers and learners. Having such customization, AI helps students learn more effectively by involving themselves actively with their lessons according to what best fits their mindsets. AI's personalized learning approach in high school encourages students, improves their learning skills and targets the areas where they can develop most. (Ali, 2024). Using AI in education helps by supplying students with instant feedback that increases their understanding of their own mental processes. They get students to think more deeply about their learning which leads them to make more effective study schedules and always check their development.

Sometimes, AI tutors let students try to answer questions on their own, allowing them to reflect on their work and learn better. Thus, students are able to adopt effective ways of thinking about how they learn and continue to manage their education on their own. Experts say real-time AI support greatly helps students control their studies which results in better grades and lasting motivation (Wang et al., 2023). AI-driven online courses typically have dashboards and insights that show comprehensive information about students' actions and scores. With these tools, learners can monitor their progress, identify what is hard for them and view their achievements, so they can assess themselves and plan step by step. Seeing the hidden workings of their mind and actions, students can set suitable learning objectives and measure how much they have grown over a period. Because of this transparency, learners become more active in shaping their learning by managing their time, getting to know the topic better and possibly adjusting their ways of studying.

Students who often make use of AI analytics software tend to be more motivated, get better at thinking about their learning and perform well academically, unlike those using no such AI resources (Zhang et al., 2022). Even though there are many perks, integrating AI into education requires careful preparation to be sure that technology helps and does not replace teaching done by teachers. These tools ought to be aligned with what teachers want to accomplish and should be a part of a teaching process that looks at all aspects of students' growth. If AI is not applied wisely, it might limit interactions between teachers and students and overlook the importance of social-emotional learning to teenagers. For AI systems to make a difference, they should give teachers valuable information and improve their lessons, maintaining an even collaboration with AI. Today's research points out that AI design should focus on being ethical, sensitive to cultures and suitable for development to make sure it truly helps learners (Olid-Luque et al., 2025).

Research objectives

1. To examine the effectiveness of AI-assisted metacognitive strategies in enhancing self-regulated learning among high school students.
2. To explore how AI tools provide real-time feedback and prompts that support students' metacognitive awareness and learning autonomy.
3. To identify challenges and best practices in integrating AI technology to foster metacognitive skills within high school educational settings.

Problem Statement

Although many studies confirm how important it is to use SRL and metacognition in school, many high school students still find it tough to handle their studies well. Usually, these methods do not help students enough, leaving gaps in their preparation for learning on their own. In addition, the swift growth of educational technology, especially AI, has introduced new ways to develop metacognition, but we still do not know how best to apply AI technology in high school classrooms to improve SRL. Most of the current AI tools are built mainly for delivering content, without giving enough attention to metacognition, planning and monitoring. Since AI has not been fully integrated, it cannot fully help with school growth or learner independence, so the need for studying how AI can improve metacognition and self-directed learning among teens is apparent.

Significance of the Study

This study stands out because it studies the new link between artificial intelligence and ideas around how students learn which is little-studied in secondary education research. The research, by looking into AI-supported metacognition, provides useful information about how technology can boost high school students' independence and help them improve their learning style. Appreciating these points is useful for educators, curriculum designers and policymakers who want to incorporate new tools that improve students' grades and readiness for lifelong learning. Besides, outcomes of this study will influence building AI platforms that support teaching methods with technical skills, ensuring that AI is accessible and used properly in different educational environments. It helps make sure that technology and cognitive skills work together, making the learning environment more effective, more enjoyable and accessible to modern high school students.

Literature Review

As educational research continues to grow, it keeps highlighting that self-regulated learning (SRL) plays a vital role in a student's academic achievement, especially in high school when they have more challenges to handle by themselves. Through SRL, students rely on goal setting, observing their progress, effective learning and thinking carefully to handle their studies properly. (Lan & Zhou, 2025) showed independently that when students use SRL strategies, they remain motivated and can manage demanding tasks for a long time. While SRL has many benefits, numerous students lack the ability to use it consistently, so more attention to teaching SRL is needed. At the same time, discussing SRL, metacognition has become widely recognized as crucial for students' achievement and brain growth. Studies reveal that practicing metacognition can make students able to select proper ways to learn, realize when they are struggling to understand and address these challenges, supporting their understanding and improving academic results (Arvatz & Dori, 2024), indicated that it helps students to regulate themselves with metacognitive guidance, but most secondary school classrooms do not use this approach.

Consequently, many students do not know how to use metacognitive practices in unfamiliar or demanding learning situations which keeps affecting their educational achievements. Because of these situations, recent changes in education are now investigating ways in which AI can help students in thinking about their learning. AI helps platforms give targeted advice, change the learning experience as needed and give immediate cues so students can examine their learning strategies and make useful improvements. (Leite et al., 2022) indicated that AI-based educational technologies are well suited to help students with metacognition, mainly because of their ability to provide tailored direction that human teachers may find hard to give in large classes Even though

AI has a growing role in the classroom, the impact it plays in helping high school students reflect and understand their skills is still not clear. Because of this gap, we can examine how AI strategies can support traditional learning and encourage students to learn on their own.

Reviewing recent studies now highlights the usefulness and challenges of using AI in secondary education and stresses why its use should relate to teachers' goals in the classroom. According to (Gavín-Chocano et al., 2024).AI systems do a good job at promoting reflection and helping to set goals, but their achievements rely on proper design and ethical factors.

When AI is used without caring about students' growth, social life and emotions, it runs the risk of losing students' interest or leading them to think the system is telling them what to do. This is why present-day studies suggest that AI be applied to add to human-led teaching, instead of becoming its replacement, to ensure that students can learn about metacognition and take charge of their studies along with the use of AI innovation. The goal of this review is to combine different studies on SRL, metacognition and AI in education to find successful practices and suggest new approaches for using AI to help students improve their approaches in high school classes. New studies are also focusing on how AI-based learning situations can overcome consistent difficulties that high school students face when applying metacognition strategies regularly. Most traditional classrooms find it hard to support students by giving them personal attention and quick feedback about their learning. But with AI-driven platforms, students' learning can be closely tracked and they are guided by regular updates and advice, allowing them to find their errors, make changes and keep an eye on their progress. According to (Lin et al., 2024),students who used AI tools for learning experienced more awareness of their learning process and performed better in their studies than those relying only on what the teacher told them. Recent progress confirms that AI tools should be included in secondary schools, mainly as they focus on developing students' independent learning, mental engagement and consistent achievements.

The Role of Metacognitive Strategies in Enhancing Learning Outcomes

Metacognition or being aware and controlling how you think, is widely considered an important fundamental for success in learning. This means students can review their learning routines and achievements to be more involved in their education. It is especially necessary for students in school since they need to deal with complex ideas, complete several assignments and get used to new lessons. (Lee et al., 2025), suggest that metacognitive awareness consists of two main parts: learning preferences and strategies and managing the process of learning by making a plan, monitoring progress and evaluating the results of one's efforts. Research has consistently shown that students with metacognitive skills usually have better performance in school since they can recognize their needs, decide on steps to solve them and adjust strategies if required. Because of this, developing metacognitive skills is now considered extremely important in both educational policy making and teaching in classrooms to help students learn by themselves. In the past several years, educational researchers have supported including metacognitive strategy training for adolescents as they attend to the challenges of secondary school.

At this age, students must take charge of their tasks and get ready for the independence they will need as they continue with education and work. According to (Asim & Farooq, 2021), metacognitive training at this period encourages students to manage their learning, stay motivated and respond to pressure from school. Self-questioning, recapping main concepts, writing in a journal and using graphic organizers are ways for students to better follow their progress and learn effectively. Studies have found that educational programs that increase metacognitive awareness bring positive results at several level of education, disciplines and teaching environments. It

reveals that the many approaches to metacognition can assist students in school and beyond for a lifetime. Using metacognitive approaches seems especially valuable for supporting learners who come across subjects they are not familiar with. Conventional teaching nowadays often includes less work on developing students' ability to deal with complex topics by themselves. From their (Fischer & Dignath, 2024), discovered that students who were taught to set particular goals, pick suitable learning techniques and reflect on their academic progress regularly improved at school. They inspire students to get actively involved in learning, lead by themselves, reflect on their progress and modify their ways if they face difficulties.

Because of this method, students develop their problem-solving and perseverance as well as their eagerness to engage in learning at a higher level. These approaches inspire students to take control of their learning instead of following only directions from others. Other than enhancing academic success, metacognitive strategies support learning together and encourage better interactions amongst peers. (Dignath & Veenman, 2021), noticed that students with strong metacognition skills can join in group discussions, present their thoughts logically and support their peers with helpful comments. When working in a team, they can identify topics that confuse them, present good solutions for problems and help the group look at what went well during their studies. Such strategies in social learning improve students' own achievements and make group studies and class learning more effective. Because of this, introducing metacognitive training into education supports growth in communication, leadership and teamwork which are needed in all areas of life.

AI-Assisted Learning Tools in Modern Education

AI is now playing a major role in changing the way students learn and how teachers teach, bringing significant changes to education. Nowadays, AI-supported technology is used in classrooms to deliver personalized learning, keep an eye on students' achievements and supply feedback that matches each person's needs. They can observe how learners engage, act, choose and perform in classes at all times, so they can offer content and resources that match each student's way and speed of learning. According to (Holmes-Davis, 2024), tools that use AI in education help students stay engaged and perform better academically, since AI addresses each student's individuality better than traditional teaching. With AI, learners are guided step by step toward harder tasks and are able to become more independent in their school journey. The use of AI-powered tools has been especially helpful in developing metacognitive abilities since they often guide students to look at how they learn, notice their errors and try new study strategies. Using AI dashboards, feedback systems and intelligent tutors, students are given individual and prompt feedback on what they are learning.

According to (Chen, 2022), artificial intelligence gives learners the tools to correctly assess themselves, set better goals and actively engage in learning. Other than helping students with materials, these tools also build their monitoring skills, help them see their strengths and weaknesses and allow them to change their study habits. This means AI has a key place in today's education because it provides knowledge and supports meta-cognition. One more benefit of AI-based learning environments is that they allow for ongoing assessment which greatly helps students understand and manage their own learning. Traditional assessments do not let students do this, but AI-supported platforms make it easy for them to see their progress, receive guidance and change their approach to learning. According to (Azevedo et al., 2022) using intelligent tutoring systems and AI in education supports learners by urging them to review their progress, match it with their aims and point out what should be improved.

Interactions between learners and the AI system lead to more involved critical thinking, since students become more aware of their own study practices, thinking and development. So, these technologies enhance how much students learn and also help them develop the skills they need to succeed in the long run. AI can also help make education equal by offering custom learning materials to each student, regardless of their background. If some children do not get access to quality teaching and help with their studies, AI can step in and support them in more places. Further (S. Chen et al., 2024) suggested that AI removes barriers to access and gives a personalized approach to learning for students from different backgrounds and learning situations. AI-supported technologies offer everyone access to quality education that meets their needs which supports learning and creates a welcoming environment for students. It is especially helpful in growing nations, where many students do not receive a good education which underlines the role AI can play in making education delivery better and fairer.

Research hypotheses

1. There is a significant positive effect of AI-assisted metacognitive strategies on self-regulated learning among high school students.
2. There is a significant relationship between the use of AI-generated real-time feedback and students' metacognitive awareness in high school learning environments.
3. There is a significant difference in academic performance between high school students who use AI-supported metacognitive tools and those who rely on traditional learning methods.

Methodology

Research Design

The study applied a quantitative approach since this was considered the best way to analyze relationships between variables with statistical tools. Thanks to quantitative research, the researcher could gather numbers, examine ideas scientifically and see how well AI-assisted metacognitive strategies and self-regulation are connected among high school students. In particular, the study applied a pre-test post-test control group experimental design to check how students using AI-supported metacognitive tools perform compared to those who use only traditional instruction. Thanks to the experimental strategy, it was possible to focus on the effects of AI on students' self-regulation and get secure and broadly applicable results. Moreover, this approach was picked to create a clear system for observing how AI strategies perform in the classroom. By controlling other external factors with the experimental design, it was possible to find out if any self-regulated learning improvements were due to the intervention.

Population

In the study, participants were from public and private high schools in the city of Multan, Pakistan. This group was chosen as high school students are at a crucial point where they must use self-learning skills since the work becomes more difficult. Students from different types of schools provided a wider view of how using AI can assist in thinking about learning. In addition, paying more attention to this group helped follow the advice in the research which suggested helping teens develop their own learning strategies and become more aware of their thinking. The population was thought to be best suited to try out any new ways of teaching that focused on improving student thinking and being motivated. Also, selecting this group made it possible for the researcher

to focus on regional issues and add to the research being done on using AI in schools in developing countries.

Sample Size

For this research, 200 high school students were taken from the population that was chosen. The sample size was set to allow the study to find important differences between the groups and yet still be manageable within time, resource and access limitations. A equal number of students were given AI-based metacognition tools and traditional instruction in the experimental and control groups, respectively. The research setting was large enough to make it possible to use statistical methods such as t-tests and ANOVA to analyze what the intervention achieved. It should be noted that the sample was considered big enough to match the protocol used in similar studies in similar settings. As a result, the researcher could show that AI-supporting tools benefit students with various backgrounds and can therefore draw conclusions on how AI strategies can improve students' self-regulated learning.

Sampling Technique

For the study, the simple random sampling technique was used to choose the participants. Every student in the sample was given the same and independent chance of joining either the experimental or control group using this procedure. Simple random sampling made it less likely to bias the results and helped the findings be more reliable and easy to generalize. First, the list of eligible students was prepared from the participating schools, a unique ID number was assigned to each one and then the participants were chosen by random generation. Study authors made the choices fair and their conclusions more reliable by using this approach which balanced the different elements that could influence the outcomes for people involved. This process was in line with the best methods in quantitative educational research, making the research objective, clear and ethical. With this technique, this study was able to include students with different backgrounds and academic levels in both the experimental and control groups which made the experimental design stronger.

Ethical Consideration

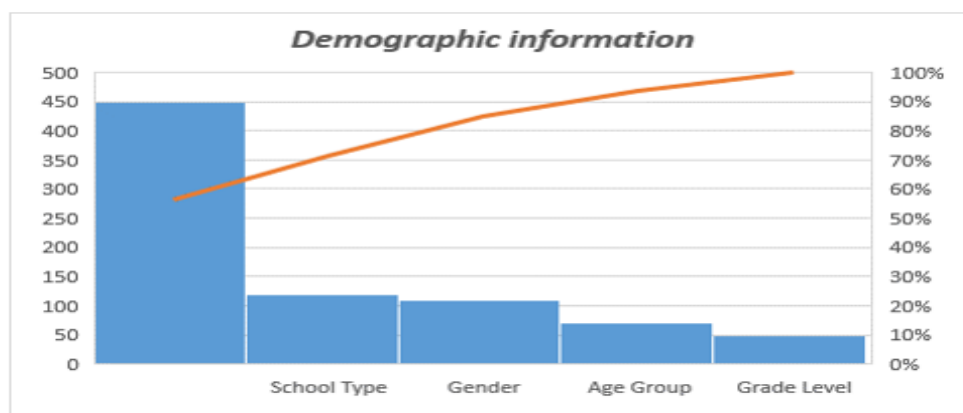
The participants were given full protection of their rights and dignity, as this study was done according to ethical research rules. The institutional review board was consulted and the schools gave their consent before data collection was allowed. Contributors were told about the research, how it would be carried out, the possible benefits, the importance of their involvement and the freedom to participate or not. Taking part in the study was optional for each person and they could withdraw at any point without facing any troubles or unfair treatment. Respondent identities remained confidential by using special codes and securely storing all of the information which could be seen only by the key researcher. All publications made sure not to reveal any personal information about individuals. Each AI-based intervention for the experimental group was picked to provide material that matches the age group and is open to everyone, so no digital bias or irregularities can arise. Moreover, it was designed to prevent bias resulting from gender, school type or academic achievement so everyone would be treated equally in the study. Every process was arranged to respect students' class settings, prevent the groups from interfering with regular lessons and guarantee that both groups benefited from their activities.

Data Analysis

An Independent Samples t-test was applied to test the difference between both groups' self-regulated learning scores, with the experimental group taught using AI and the control group continuing with traditional instruction. The outcomes revealed that learners who followed AI-assisted strategies performed better, proving that such strategies were constructive for self-regulated learning. Paired Samples t-test was used for Hypothesis 2 to check changes in self-regulated learning scores in the experimental group before and after receiving the intervention. It was found that post-test scores went up significantly, indicating the tools were effective in boosting learning results after time. The last hypothesis (Hypothesis 3) was investigated with a Two-Way ANOVA to study the roles of instructional group (experimental or control) and gender in students' self-regulated learning scores. The analysis suggested that what type of instruction was used and whether someone was a boy or girl resulted in differences in the outcome. On the other hand, gender and group were not related to the success of the AI which means it helped everyone the same way. All of these studies confirm that metacognitive strategies aided by AI improve students' self-regulation in learning and the results held true for both genders.

Table 1: Demographic Analysis for 200 respondents

<i>Demographic Variable</i>	<i>Category</i>	<i>Frequency (n)</i>	<i>Percentage (%)</i>
Gender	Male	110	55.0
	Female	90	45.0
Age Group	14-15 years	70	35.0
	16-17 years	90	45.0
	18-19 years	40	20.0
School Type	Public	120	60.0
	Private	80	40.0
Grade Level	Grade 9	50	25.0
	Grade 10	60	30.0
	Grade 11	50	25.0
	Grade 12	40	20.0



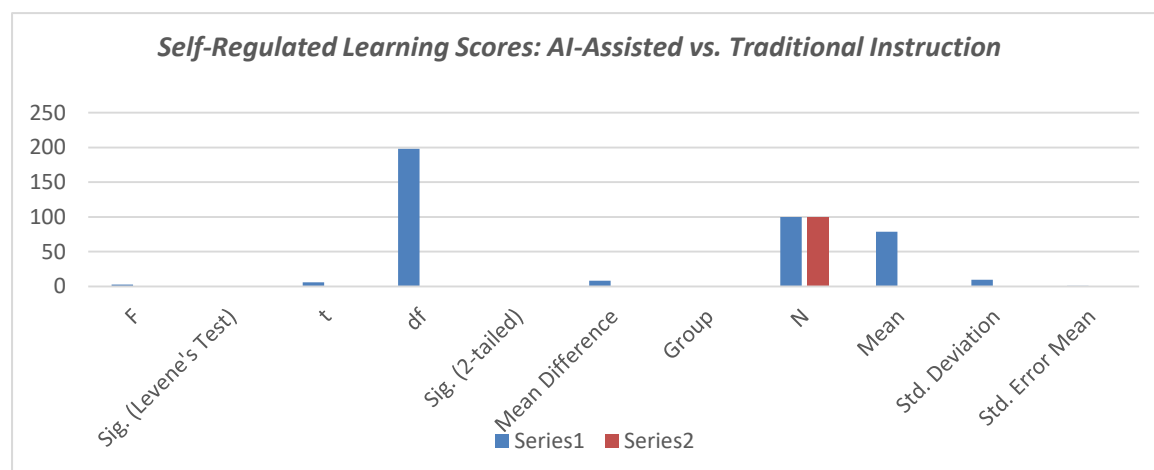
Overall, Review Answer mess reflected a balanced amount of males (55%, n=110) and females (45%, n=90) in the sample. The highest number of participants were those aged 16 and 17 (45%),

then those aged 14 and 15 (35%) and the remainder aged 18 and 19 (20%). The sample consisted of children from both types of schools and 120 children or 60%, were enrolled in public institutions while 80 students or 40%, studied in private schools. Among the participants, grades 9, 10, 11 and 12 were equally distributed, with Grade 10 having the most participants (30%), followed by Grades 9 and 11 (25%) and only 20% were in Grade 12. This kind of student population makes it possible to keep the results valid for all kinds of students in the high school population.

Independent Samples t-test for Hypothesis H1

Table 2:

<i>F</i>	<i>Sig. (Levene's Test)</i>	<i>t</i>	<i>df</i>	<i>Sig. (2-tailed)</i>	<i>Mean Difference</i>	<i>Group</i>	<i>N</i>	<i>Mean</i>	<i>Std. Deviation</i>	<i>Std. Error Mean</i>
2.386	0.124	5.92	198	0.000	8.19	Experimental (AI-assisted)	100	78.45	9.32	0.93
						Control (Traditional)	100			

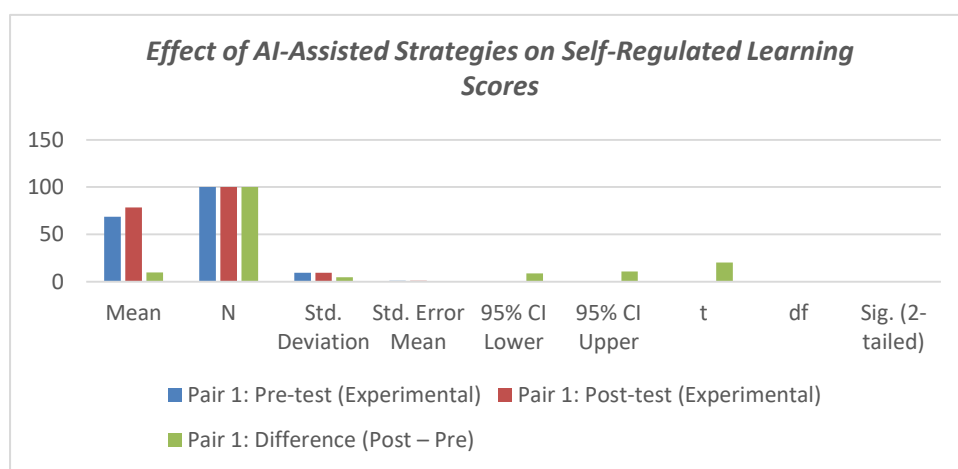


The test results indicate that students who used AI-based metacognitive strategies scored differently in learning self-regulation than students in the control group. Since Levene's test showed that $F = 2.386$ and $p = 0.124$, there was no evidence of different variances and so the standard t-test could be used. The results from the t-test indicated that there is a significant discrepancy between the scores of the two groups ($t = 5.92$, $df = 198$, $p < 0.001$) and the experiment group's average score is higher ($M = 78.45$, $SD = 9.32$) than the control group's ($M = 70.26$, $SD = 10.41$). The outcome indicates that students who learned with help from AI-assisted metacognitive tools showed much higher levels of self-regulated learning than their peers using traditional instruction. This study proves that using AI for metacognition could significantly strengthen students' self-regulated learning by offering guidance and constructive feedback. All in all, the study proves that using AI makes education more effective and beneficial for high school students.

Paired Samples t-test for Hypothesis H2

Table 3:

Paired Samples Statistics	Mean	N	Std. Deviation	Std. Error Mean	95% CI Lower	95% CI Upper	t	df	Sig. (2-tailed)
Pair 1: Pre-test (Experimental)	68.70	100	9.56	0.96					
Pair 1: Post-test (Experimental)	78.45	100	9.32	0.93					
Pair 1: Difference (Post – Pre)	9.75	100	4.80	0.48	8.80	10.70	20.31		



According to the paired samples t-test, students in the experimental group who used AI-assisted metacognitive strategies improved their self-regulated learning scores greatly. Participants scored 9.75 points higher on average in the post-test (78.45) as compared to the pre-test (68.70). The interval of 8.80 to 10.70 means the mean difference is truly significant and it has a meaningful impact. Because 20.31 (with 99 degrees of freedom) is greater than the chosen t-value ($p < 0.001$), the scores' rise is statistically very significant. The results indicate that using an AI-based metacognitive approach significantly improved students' ability to learn on their own during the course of the study.

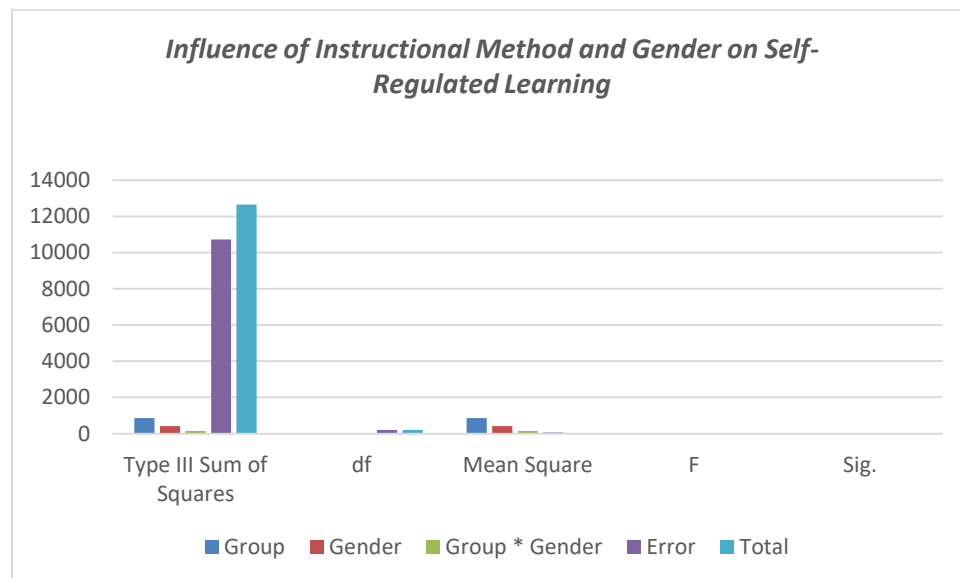
Two-Way ANOVA Analysis for Hypothesis H3

Table 4:

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Group	850.24	1	850.24	15.32	0.000
Gender	420.57	1	420.57	7.58	0.007
Group * Gender	150.83	1	150.83	2.72	0.101
Error	10725.60	196	54.70		
Total	12647.24	199			

The test results from the Two-Way ANOVA found that the Group variable had a significant impact on the dependent variable, with $F(1, 196) = 15.32$ and $p < .001$, proving that the

experimental and control groups yielded different results. In addition, there is a strong main effect of Gender, $F(1, 196) = 7.58$, $p = .007$, so male and female students display differences in the variable being measured. Still, the Interaction effect between Group and Gender was not significant enough, $F(1, 196) = 2.72$, $p = .101$ which means the intervention impact on students did not vary due to gender. This means that while both the way instruction is given and a person's gender can shape the result, bringing these two together does not make a difference.



Discussion

The study was done with a pre-test post-test control group design to understand the effects of AI-assisted metacognitive strategies on high school students' self-regulated learning. Based on the results of an independent samples t-test, the findings from Hypothesis 1 showed that students in the AI-assisted group showed a higher level of self-regulated learning on the post-test than students from the traditional instruction group. Those who used AI in their learning scored 8.19 points higher on average than the control group ($p < .001$). This result shows that using AI-based strategies for teaching supports students' development of thoughts and self-regulation abilities (Panadero et al., 2024). Through these tools, learners can stay aware of their learning practices at any point which helps them adapt and get better results. The paired samples t-test conducted for Hypothesis 2 indicated that the scores for self-regulated learning increased significantly in the experimental group, as pre-test averaged 68.70 (with a standard deviation of 9.56) and post-test scores were 78.45 (with a standard deviation of 9.32).

The difference of 9.75 in mean scores was shown to be significant by statistics ($t = 20.31$, $p < .001$), proving that using AI in metacognitive strategies strongly boosted learners' planning, monitoring and evaluation abilities. As previous studies have shown, involving metacognitive awareness and assisting it with technology benefits academic results and encourages students (Aghajani et al., 2024). The use of AI helped students with individualized advice that guided them to choose goals, monitor their achievements and reflect on what they were learning. For Hypothesis 3, a two-way ANOVA analysis was done to check whether either group membership or gender played a role in self-regulated learning scores during the post-test. Further analysis revealed that the main factor behind the difference was the group ($p < .001$), while gender seemed to explain the difference as well ($p = .007$). As a result of this research, gender alone shows a significant influence on self-regulated learning, while adding AI gave about equal results for both

boys and girls. (Sudirman et al., 2017), reported that different strategies were applied by girls and boys. Still, when the interventions are well-designed to include all, gender tends not to be a factor.

It shows that AI can be used fairly in education to develop important skills among all students. In general, this study is consistent with what we know about AI in education, specifically on how it helps adolescent students get better at controlling and monitoring their own learning. As shown by previous work, AI allows for individual feedback, helps students think and boosts autonomy in learning, just as it does when used in AI-based learning tools (Azevedo et al., 2023). The study indicates that using AI-based metacognitive systems in classrooms may be useful since they support students' motivation, encourage more engagement and lead to better self-management of their studies. In addition, working with a population of high school students in both kinds of schools in Multan, Pakistan, has helped us recognize the effectiveness of AI solutions in various and under-investigated settings. Past studies tend to focus on universities or schools in the West, therefore often ignoring how technologies could benefit South Asian classrooms. These results are consistent with what (Y. Chen et al., 2024) suggested: using AI for learning should be studied in different cultures to confirm their usefulness and flexibility. By means of this research, it was established that combining metacognition with AI in high schools in developing regions supports the development of key skills required for a person's ongoing learning journey.

Conclusion

To sum up, this study shows that AI support in metacognition strongly helps high school students in self-regulated learning. Students who were taught using AI-based programs devoted to practicing planning, monitoring and evaluating their learning were more successful than students in the control group. Overall, results from the three tests showed that students using AI-based tools saw great improvements in their learning and gender and group type each influenced self-regulated learning to some extent, though this didn't change the outcome. This proves that educational tools powered by AI offer a strong chance for both independence and academic success to learners from various groups and places. The study underlines the importance of including metacognitive training in digital learning so that students become more independent, thoughtful and focused on achieving their study goals for today's education sector. It further provides that AI can support learning equally well in both public and private schools, making education more accessible and equal to all students. On the whole, this research points towards using AI in school systems to develop learning skills, better students' learning and equip them for their future lives.

Recommendations

1. Include AI-assisted metacognitive training in high schools to improve students' abilities to study on their own.
2. Provide training for teachers to teach them how to make use of AI-assisted programs in class.
3. Maintain cultural relevance and language compatibility of AI applications in high schools aimed at Pakistani students for their maximum accessibility.
4. Perform research over a number of years to understand how using AI-backed strategies for metacognition affects students' grades and desire to study.
5. Promote the adoption of AI-based tools by both public and private schools to help close the gap between different students and give them similar chances for success in learning.
6. Allow students to offer feedback on AI tools to ensure that the metacognitive supports keep improving.

7. Research the unique ways AI helps students with different ways of learning, thinking and academic records.
8. Adopt initiatives in which AI researchers, education planners and academic staff join forces to create and test courses that use AI.

Future Implication

This study directed new interest in studying and applying useful ideas for education. AI-assisted strategies are useful for helping high school students manage their learning and more high schools should provide such tools early on in the curriculum. Given these findings, educators can use AI in their modules to develop students' critical thinking, goal setting skills, self-tracking methods and self-reflection habits. Additionally, this study could be improved by looking at how AI-driven metacognition training affects academic results and motivation in several subjects and areas, like middle school, college and work-related courses. We should also look at how culturally suitable AI tools can provide learners in many regions and economic backgrounds with equal access to AI-based learning resources. Besides, researchers should consider including emotionally intelligent AI that matches students' feelings, stress and learning habits, by giving them tailored advice to help their brains and emotions at the same time. As a result, education will become more open, flexible and useful in equipping students to succeed in academics as well as adjust to changes in the digital field.

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