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The Effect of Artificial Intelligence-Supported Learning on Students' Metacognitive Awareness: The Mediating Role of Cognitive Flexibility

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ABSTRACT

This study examined the effect of artificial intelligence-supported learning on students' metacognitive awareness, with particular emphasis on the mediating role of cognitive flexibility among university students in Pakistan. A quantitative research approach with a cross-sectional survey design was adopted for the study. Data were collected from 429 university students through a structured questionnaire administered using Google Forms. The collected data were analyzed using descriptive statistics, Pearson correlation, regression analysis, and mediation analysis to examine the proposed relationships among artificial intelligence-supported learning, cognitive flexibility, and metacognitive awareness. The findings showed a significant positive relationship between artificial intelligence-supported learning and metacognitive awareness ($r = 0.62$, $p < .001$), while artificial intelligence-supported learning was also significantly and positively related to cognitive flexibility ($r = 0.58$, $p < .001$). The mediation analysis further demonstrated that cognitive flexibility significantly mediated the relationship between artificial intelligence-supported learning and metacognitive awareness, with a significant indirect relationship ($B = 0.23$, $SE = 0.04$, 95% CI [0.16, 0.31]). The direct relationship remained significant after including cognitive flexibility in the model ($B = 0.37$, $SE = 0.05$, $p < .001$), indicating partial mediation. These findings suggest that AI-supported learning may contribute to students' metacognitive development not only through direct learning support but also by encouraging greater flexibility in thinking and learning strategies. The findings further indicate that students who are able to adapt their thinking, consider alternative approaches, and modify their learning strategies may benefit more effectively from AI-supported educational environments. The study is significant because it extends current understanding of the cognitive processes associated with AI-supported learning and identifies cognitive flexibility as an important mechanism related to students' metacognitive awareness. The findings may assist educators and higher education institutions in developing AI-supported learning practices that promote reflection, self-monitoring, adaptive thinking, and active engagement rather than passive dependence on AI-generated information. The study also provides a useful foundation for future research examining cognitive and metacognitive mechanisms within technology-supported learning environments.

Introduction

Artificial Intelligence-Supported Learning in Contemporary Education

Artificial Intelligence (AI) is transforming how students search for information, receive feedback, solve problems, complete tasks, and interact with digital learning environments. AI-supported learning integrates various intelligent technologies and generative

AI into learning, including adaptive and intelligent tutoring systems, feedback generators, learning materials, and educational support. Unlike traditional digital learning tools, AI-supported systems respond to individual learners and provide feedback and explanations instantly. They can also generate learning materials and educational support and/or adapt it based on learners' needs. Research shows that AI can be an information source and learning partner that helps students with their cognitive and metacognitive processes and self-regulated learning (Saar et al., 2026). AI technologies are used at different phases of self-regulated learning and it helps students learn effectively (Pinkwart et al., 2025).

How students control and interact with AI will impact educational value. Merely providing students with AI tools will not automatically lead to deeper learning. Students must know how to assess AI-generated information. Students should also know how to identify errors, consider and evaluate alternative explanations, reflect on their learning, and make appropriate decisions on the use of AI. The proliferation of generative AI in higher education has amplified the need to teach these skills to students. Recent studies have shown positive learning outcomes of generative AI. However, the effects of generative AI on learning are not uniform. A systematic review and meta-analysis done recently found that while the effects of generative AI on university learning outcomes were positive, the effects on metacognition were weak and not statistically significant (Yavuz et al.,, 2025).

Metacognitive Awareness as an Important Learning Outcome

Metacognitive awareness focuses on the understanding students have of their cognitive processes when learning, and the ability to self-regulate. It allows students to choose the most appropriate learning strategies for a specific task. Students with a high level of metacognitive awareness, monitor their level of understanding, and make judgements about their progress. In the case where learning is proving difficult, they make alterations to their learning strategies. This ability is needed in contemporary times, more than ever before, because school-aged students are required to make judgements about what they are learning, as well as evaluate how useful, and how reliable, online learning resources are (Abdelrahman, 2020).

Recent, and on-going, reliance on AI for various learning tasks, makes metacognitive awareness even more crucial. Although AI gives the appearance of being helpful, it is not beyond the realm of possibility that AI might reach a point where it produces incorrect information, or lack of information, in an attempt to aid students in a learning task. Students cannot rely on AI to produce correct information. It is important students develop the ability to self-evaluate in order to critically assess the quality of their own learning and that of AI. It has been proven, via recent studies, that when students interact with AI, the outcome relates closely to the metacognitive awareness and abilities of students. Research by Adiansyah et al. (2023), for example, has shown that an interactive AI assisted learning approach strengthened students' metacognitive awareness (Akpur, 2024).

Cognitive Flexibility in AI-Supported Learning

Cognitive flexibility is the ability to consider other people's points of view, be open to new ways of doing things, and revise strategies when they no longer work. In education, cognitive flexibility can be advantageous when dealing with an ever-changing learning environment and varying types of knowledge (Sadaf et al., 2026). Educational and personal reasons may require students to change their assumptions about learning, especially when dealing with new, ambiguous and changing problems and contradictory information. AI-enabled learning environments can provide students with multiple means and ways of doing things and can suggest approaches, solutions, and ways of thinking to the students. As a result, cognitive flexibility may play a more critical role in learning environments enhanced with AI (Riva, 2026).

The interaction between AI-supported learning and cognitive flexibility has recently been the focus of attention in the research community. BinJwair et al. (2026) evaluated 820 university students who used interactive AI-supported learning and found that cognitive flexibility had a significant impact on students' responses to AI-supported learning. In particular, the researchers stated that cognitive flexibility reinforced the positive effects of interactive AI on students' self-efficacy for interdisciplinary learning. Moreover, the researchers concluded that without cognitive flexibility, certain interactions between the students and AI may prove to be negative.

Relationship Between AI-Supported Learning, Cognitive Flexibility, and Metacognitive Awareness

The existing literature has beginning to examine these three factors together, but they have largely been investigated through separate research frameworks. For example, some studies have investigated AI-supported learning and metacognitive awareness through self-regulated learning, while other studies have investigated cognitive flexibility as a moderator of the AI-supported learning process or metacognitive awareness as a predictor or mediator of AI-related outcomes. (Tezer, 2025), for example, studied the effects of AI-supported learning on metacognitive awareness and critical thinking and self-regulated learning as a mediating

factor. Their study demonstrates the potential of AI-supported learning to impact students' metacognitive awareness and shows the need to investigate the underlying cognitive mechanisms to better understand this relationship.

Research from Pakistan has recently started integrating cognitive flexibility, generative AI, and metacognitive awareness in the same research framework. Khan et al. (2026) studied cognitive flexibility and the use of generative AI, along with metacognitive awareness and other factors, on university students' problem-solving performance. Their research is one of the few that bring together these factors in the context of higher education and AI-supported learning. However, the authors considered metacognitive awareness as a mediating factor, as opposed to cognitive flexibility as the mechanism connecting AI-learning experiences and metacognitive awareness. This shows that the cognitive mechanism through which AI-supported learning is contributing to the development of students' metacognitive awareness is still uncharted (Mughal et al., 2026).

Research Objectives

- To examine the relationship between artificial intelligence-supported learning and students' metacognitive awareness.
- To determine the impact of artificial intelligence-supported learning on students' cognitive flexibility.
- To examine the mediating role of cognitive flexibility in the relationship between artificial intelligence-supported learning and students' metacognitive awareness.
- To examine the differences in students' metacognitive awareness, cognitive flexibility, and artificial intelligence-supported learning based on selected demographic characteristics.

Research Questions

1. What is the relationship between artificial intelligence-supported learning and students' metacognitive awareness?
2. What is the impact of artificial intelligence-supported learning on students' cognitive flexibility?
3. Does cognitive flexibility mediate the relationship between artificial intelligence-supported learning and students' metacognitive awareness?
4. Are there significant differences in artificial intelligence-supported learning, cognitive flexibility, and metacognitive awareness based on selected demographic characteristics?

Problem Statement

Artificial Intelligence (AI) has rapidly advanced in the area of education. Teachers have an opportunity to use AI to advance individualized learning for their students through technology they can program to provide instant feedback and academic assistance (Shukla, 2026). Routine cognitive processes that may help educators understand how to use AI in the classroom to positively affect a student's metacognitive awareness, however, are currently inadequate. Some studies have examined cognitive flexibility and self-regulated learning in regard to AI-supported learning and metacognitive awareness, but have varied in theoretical and statistical models. Some studies have established a relationship between cognitive flexibility and metacognitive awareness in relation to Generative AI, but none have tested cognitive flexibility as a mediator between AI-supported learning and metacognitive awareness. Given these contexts, the focus of this study is to address the existing research gap, determine the relationship between AI-supported learning and metacognitive awareness, and understand the role of cognitive flexibility in this relationship (Ertan et al., 2026).

Significance of the Study

The present study is significant because it provides a deeper understanding of how artificial intelligence-supported learning may contribute to students' metacognitive awareness by considering cognitive flexibility as a mediating factor. The findings may help teachers understand the importance of encouraging students to use AI as an active learning support rather than depending on it passively, while also promoting flexible thinking, reflection, self-monitoring, and evaluation of information. The study may also assist educational institutions in developing AI-supported learning practices that strengthen students' cognitive and metacognitive abilities. For students, the findings may highlight the importance of adapting their thinking, considering alternative approaches, evaluating AI-generated information, and reflecting on their own learning processes. Furthermore, the study may provide useful evidence for researchers by addressing the limited attention given to cognitive flexibility as a mechanism connecting AI-supported

learning with metacognitive awareness and may serve as a foundation for future research on AI, cognitive development, and learning processes.

Literature Review

Artificial Intelligence-Supported Learning and Metacognitive Awareness

Achuthan, (2025) related AI-based learning to self-regulated learning as a mediating factor and metacognitive awareness and critical thinking as the result variables. They conducted a quantitative analysis to assess AI-based learning among university students. The results showed that AI-based learning supported students to engage with learning materials, reflect on their learning, and evaluate their learning rather than receiving information via learning tools. Based on these results, the authors postulated that AI-based learning fostered cognitive and metacognitive development of students.

The current study builds on research by relating AI-based learning to cognitive flexibility rather than self-regulated learning. Given the nature of the activities done by students in an AI-supported learning environment, students need to be flexible in thinking to consider alternative ways of explaining a concept, logic, or reasons, as well as adjust their approaches to address changing learning requirements. Thus, the study extends previous research by relating AI-based learning to cognitive flexibility to understand students' metacognitive awareness.

AI-Supported Learning and Students' Metacognitive Awareness

Akram et al., (2025) studied student's metacognitive awareness while using AI tools in an EAP course. The authors showed that students used AI tools to plan, monitor, evaluate, and adjust their learning. In this study, students considered whether the AI tools truly addressed their learning needs. They monitored the progress of their learning. Students evaluated the quality of the information by using AI tools to gather and interpret academic literature. The findings of the study pointed out that AI tools, when purposefully combined with student's learning, can help enhance student's metacognitive skills. The study emphasized that interaction with AI tools created opportunities for students to compare alternative explanations, modify their prior understanding, and adjust their learning strategies according to their demands.

These findings are relevant to this study because students are required to engage in advanced level thinking to achieve their learning goals and effectively learn with the assistance of AI. Students in both studies utilized flexible thinking in a variety of ways to determine the limitations of AI. This activity created opportunities to enhance metacognitive skills. Although Romdhoni et al. (2025) did not examine cognitive flexibility as a mediator, their findings pointed out the potential role of cognitive flexibility to connect AI-supported learning and metacognitive skills.

Cognitive Flexibility and Metacognitive Awareness in Generative AI Contexts

Tankelevitch et al., (2024) studied self-regulated learning skills, cognitive flexibility, and metacognitive awareness of 761 university students and assessed attitudes toward generative AI. The authors highlighted the roles of cognitive and metacognitive skills and attitudes in students' engagement with generative AI. Students' ability to swiftly modify how they think and learn to engage with rapid changes in AI technologies and how they may learn to do so flexibly using alternative AI-based strategies remains to be answered. Cognitive flexibility may be important when students consider different viewpoints and are willing to adjust their strategies when the existing ones are inadequate.

This study is relevant for several reasons, including placing cognitive flexibility and metacognitive awareness in the same AI context of education. It did not include AI-supported learning as an independent variable, nor cognitive flexibility as a mediator between AI-supported learning and metacognitive awareness. This study builds on previous studies by considering cognitive flexibility as a mediator between the effects of AI-supported learning and metacognitive awareness, and proposes that one reason students develop metacognitive awareness as a result of their engagement with AI-supported learning environments is that it encourages them to become more cognitively flexible (Levin et al., 2025).

Cognitive Flexibility in Interactive AI-Supported Learning

In their research, Charles et al., (2026) investigated interactive AI-based learning environments among 820 university students and considered the roles of AI metacognition and cognitive flexibility. Results showed cognitive flexibility to be crucial to students' interactions with AI. The study indicates the role of cognitive flexibility to be of particular importance to students in situations

whereby learning requires interaction with AI, and information may be shaped, altered, or presented in different ways. Flexible learners may be able to question or consider different possibilities, and learn to regulate their learning in different ways.

Although the study provides important evidence for cognitive flexibility in AI-enhanced learning, cognitive flexibility was considered a moderator rather than a mediator. As well, the focus of the study was on the self-efficacy of interdisciplinary learning. Thus, the study does not consider whether cognitive flexibility functions as a mechanism by which AI-supported learning impacts metacognitive awareness. This study considers this distinction by placing cognitive flexibility as a mediating variable. Thus, the focus of the present study will be whether the use of AI in learning to be supported impacts students' flexibility of thinking and ultimately influences students' learning process (BinJwair, 2026).

Cognitive Flexibility, Generative AI Adoption, and Metacognitive Awareness

Dalsgaard, (2025) studied cognitive flexibility, use of generative AI, metacognitive awareness and problem-solving performance of 477 university students of Pakistan. Results showed that cognitive flexibility and generative AI positively influence metacognitive awareness and are closely related to one another. The study provides valuable insights in the context of Pakistani higher education and shows that students' cognitive and metacognitive traits are closely interrelated, and both are equally important when interpreting students' engagement with AI-based technologies. The findings indicate that students who can be cognitive flexible and use various thinking patterns and learning approaches may be more able to understand and interpret their learning with the support of AI tools.

Al Galib et al. (2025) situated metacognitive awareness as the outcome and cognitive flexibility as the mediator. In contrast, this study has focused on cognitive flexibility as the outcome and metacognitive awareness as the mediator. This approach shifts the emphasis from the role of metacognition in explaining the outcomes of problem-solving to the cognitive mechanism through which AI-supported learning facilitates the development of metacognitive awareness. Therefore, this study attempts to explore and explain the relationship between metacognitive awareness and AI-supported learning and cognitive flexibility. This may contribute to current body of knowledge on the intersection of flexible thinking and metacognitive processes with the use of AI tools.

Research Gap

Recent research has begun to explore the relationship artificial intelligence (AI) in education has with students' cognitive and metacognitive processes, particularly in relation to self-regulated learning. Fasahat et al. (2025) also studied AI-supported learning and metacognitive awareness, with self-regulated learning as a mediating mechanism. However, they did not examine the role of cognitive flexibility in this regard. Investigated the impact of cognitive flexibility in an interactive AI-supported learning environment, and found it impacted AI-related metacognitive processes and learning self-efficacy. However, they tested cognitive flexibility as a moderator, not as a mediator. Thornton, (2025) also studied cognitive flexibility and metacognitive awareness with 761 University students, and found that the two concepts are associated and influence students' trust and adoption of GenAI. However, the focus of their study was on students' attitudes towards GenAI, rather than how AI-supported learning impacts metacognitive awareness. Recently, Zaki et al. (2026) also explored cognitive flexibility and GenAI with university students in Pakistan, and found that cognitive flexibility mediates the relationship between GenAI and students' metacognitive awareness. As such, how AI-supported learning influences students' metacognitive awareness through cognitive flexibility are research gaps. This study aims to address this gap by explaining the cognitive process in which AI-supported learning impacts students' awareness, monitoring and regulation of their own learning.

Hypotheses

- **H1:** There is a significant positive relationship between artificial intelligence-supported learning and students' metacognitive awareness.
- **H2:** Artificial intelligence-supported learning has a significant positive impact on students' cognitive flexibility.
- **H3:** Cognitive flexibility significantly mediates the relationship between artificial intelligence-supported learning and students' metacognitive awareness.
- **H4:** There are significant differences in artificial intelligence-supported learning, cognitive flexibility, and metacognitive awareness based on selected demographic characteristics.

Conceptual Framework

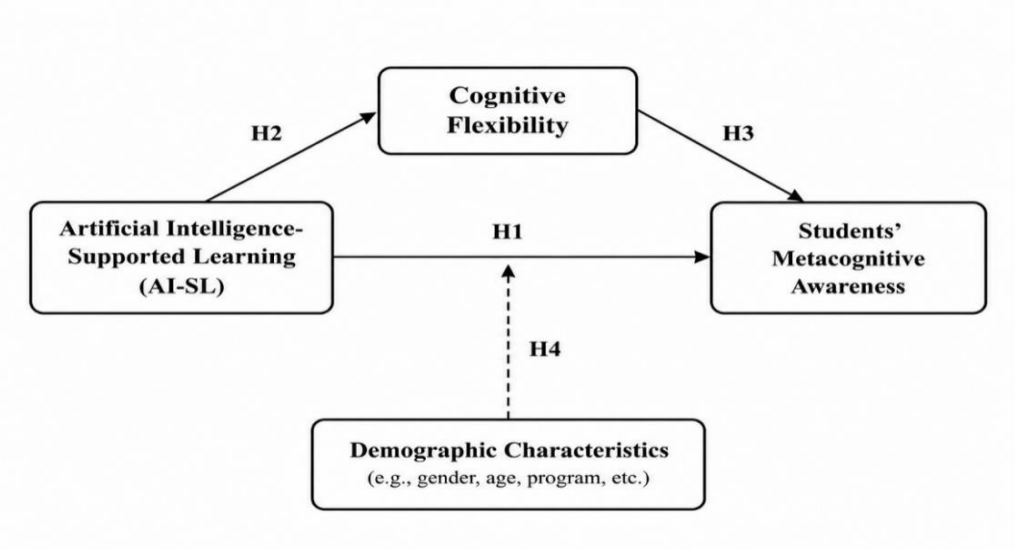


Fig 1: Conceptual Framework

Methodology

Research Design

To study the effects of AI-based learning on metacognitive awareness of learners and to examine the role of cognitive flexibility in the process, a quantitative approach was adopted. A cross-sectional survey design was used to collect data at a single point in time from university students. This design is appropriate to capture the experiences of students of AI-based learning and their cognitive and metacognitive traits.

Population and Sample

The participants of the study included of students enrolled in higher education institutions of Pakistan. Of the 429 students, a convenient sampling method was used to select participants who used artificial intelligence-based learning tools and technology. The study covered geographically Punjab, Sindh, Khyber Pakhtunkhwa and Balochistan. Participants were drawn from University of Punjab, Bahauddin Zakariya University, Islamia University of Bahawalpur, University of Sargodha, University of Sindh, Shah Abdul Latif University, Sukkur IBA University, University of Peshawar, Gomal University, Kohat University of Science and Technology, University of Malakand, University of Balochistan, Balochistan University of Information Technology, Engineering and Management Sciences and University of Turbat.

Table 1: Distribution of Sample by Institution (N = 429)

Institution	Sample Size (n)	Percentage (%)
University of the Punjab	40	9.3
Bahauddin Zakariya University	35	8.2
Islamia University Bahawalpur	32	7.5
University of Sargodha	30	7.0
University of Sindh	32	7.5
Shah Abdul Latif University	28	6.5
Sukkur IBA University	27	6.3
University of Peshawar	32	7.5
Gomal University	28	6.5
Kohat University of Science and Technology	27	6.3

Institution	Sample Size (n)	Percentage (%)
University of Malakand	24	5.6
University of Balochistan	26	6.1
Balochistan University of Information Technology, Engineering and Management Sciences	23	5.4
University of Turbat	25	5.8
Total	429	100.0

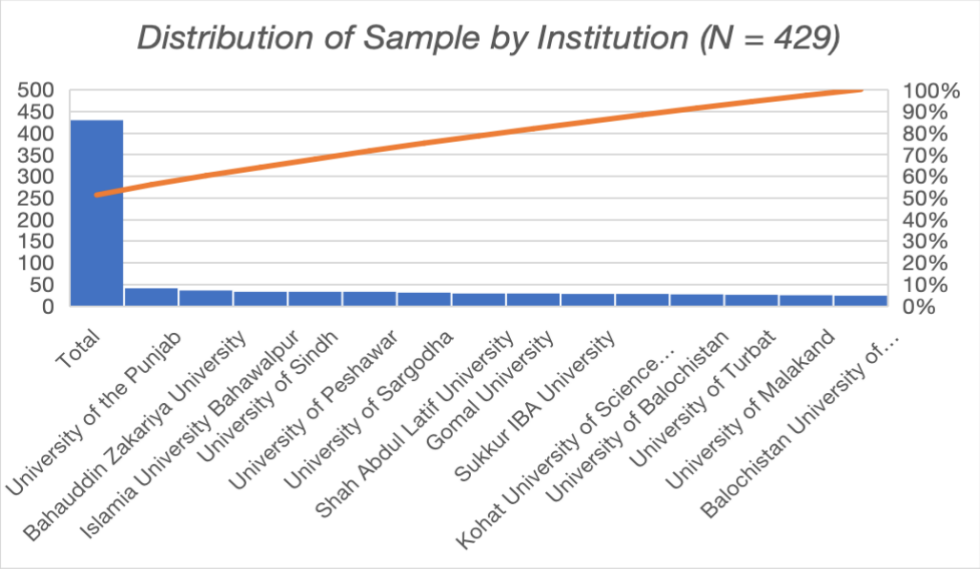


Fig 2: Distribution of Sample by Institution (N = 429)

Research Instrument

Participants completed a self-administered questionnaire to provide the data for this research. The questionnaire consisted of three parts: Artificial Intelligence-supported Learning; Cognitive Flexibility; and Metacognitive Awareness. The part on Cognitive Flexibility is based on the Cognitive Flexibility Inventory. This Inventory measures how well individuals take into account different points of view and possible solutions to an issue, as well as how well they regard challenging situations as being under their control. The Inventory includes 20 self-report items and consists of two sub-scales: Alternatives and Control. The part on Metacognitive Awareness is also based on the Metacognitive Awareness Inventory. The original inventory includes 52 items, of which eight items assess Knowledge of Cognition, and 44 items assess Regulation of Cognition. These items also include various aspects of planning, self-monitoring and self-regulation. This study, however, used only some of these items.

The part of the questionnaire on Artificial Intelligence-supported Learning is based on and adapted from existing literature on Artificial Intelligence (AI) in Learning to assess students' experiences and perceptions of using AI technologies for learning in an academic context. Items in this part were presented in a Likert scale format. The participants completed the questionnaire without the assistance of an interviewer. Other sections of the questionnaire on Cognitive Flexibility and Metacognitive Awareness were adapted from previously validated and reliable measures and instruments. Based on the context and needs of this study, the AI-supported Learning measure was created.

Procedure for Collecting Data

The data were collected using an online, self-administered questionnaire developed using Google forms. The link to the questionnaire was sent to eligible students through the academic and communications channels of the university. Participants were given the opportunity to read an information sheet which included an overview of the purpose of the research and that their participation was voluntary. Each participant was also required to provide signed informed consent. Participants completed the questionnaire on their own and 429 completed copies of the questionnaire, which were readable, usable and complete, were collected. The data were organized and initially screened using Microsoft Excel, and were prepared for statistical analysis.

Validity and Reliability

The developed and adopted instruments were contextualized to the university students and the language used was in accordance with the purpose of the study. For the rest of the instruments, the presence of measurement and conceptual foundations was assessed. The measurement instruments were analyzed for internal consistency for the constructs of Artificial Intelligence-based Learning, Cognitive Flexibility, and Metacognitive Awareness using Cronbach's alpha. The findings of the analysis were used to determine if the items which formed a given construct demonstrated adequate internal consistency for more advanced analysis.

Ethical Considerations

The ethical principles and guidelines of research were strictly adhered to. Participation in the study was voluntary and all participants provided signed informed consent prior to completing the questionnaire. Participants were not required to provide their names or any other identifying information. They completed the questionnaire in a private location. All data were collected for academic research purposes, and confidentiality and privacy were strictly adhered to.

Data Analysis

Table 1: Demographic Characteristics of the Participants (N = 429)

Demographic Variable	Category	Frequency (f)	Percentage (%)
Gender	Male	221	51.5
	Female	208	48.5
Age	18–22 years	149	34.7
	23–27 years	174	40.6
	28–32 years	70	16.3
	33 years and above	36	8.4
Education Level	Bachelor's	178	41.5
	Master's	147	34.3
	MPhil/MS	79	18.4
	PhD	25	5.8
Academic Discipline	Social Sciences	121	28.2
	Education	105	24.5
	Management Sciences	76	17.7
	Computer/IT	63	14.7
	Natural Sciences	39	9.1
	Other	25	5.8
AI-Supported Learning Experience	Less than 1 year	78	18.2
	1–2 years	169	39.4
	3–4 years	124	28.9
	More than 4 years	58	13.5
Province	Punjab	169	39.4
	Sindh	107	24.9
	Khyber Pakhtunkhwa	91	21.2
	Balochistan	62	14.5
Total		429	100.0

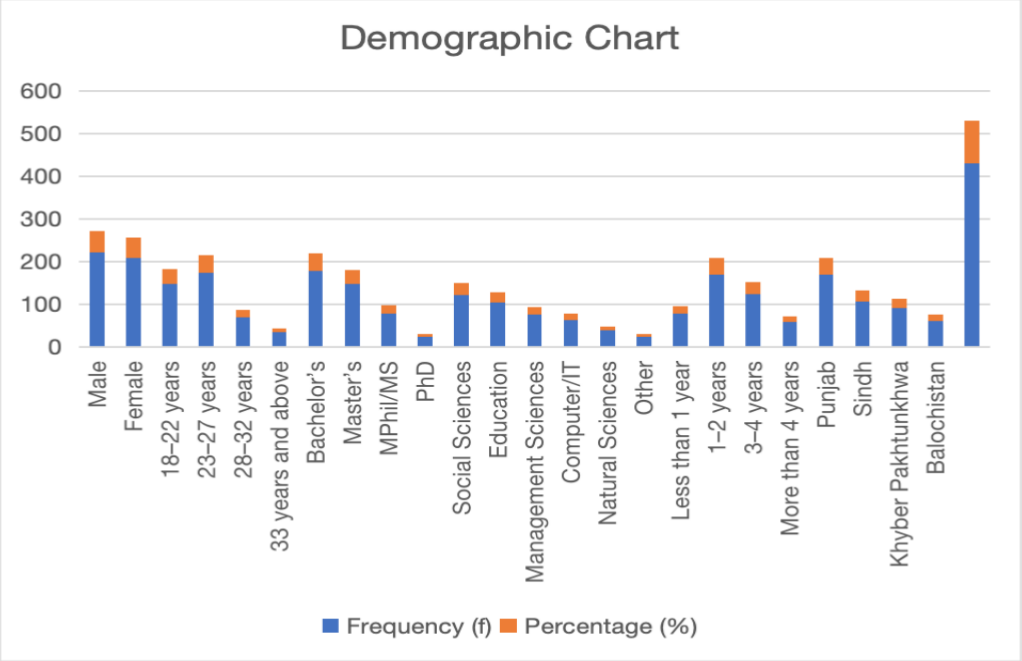


Fig 3: Demographic Characteristics of the Participants (N = 429)

The demographic characteristics of the 429 study participants are shown in Table 1. For gender, 221 (51.5%) of the participants were male while 208 (48.5%) were female. Therefore, the representation of both genders was relatively equal. For age, the largest age group was the 23–27-year age group who constituted 174 (40.6%) of the respondents, while the second largest age group, 18–22-year age group, consisted of 149 (34.7%) of the respondents. The age group 28-32 years consisted of 70 (16.3%) of the respondents, and the age group 33 years and above, constituted 36 (8.4%) of the respondents.

Table 2: Reliability Statistics of the Research Variables (N = 429)

Variable	Number of Items	Cronbach's Alpha (α)	Mean	SD
Artificial Intelligence-Supported Learning	10	0.91	3.84	0.68
Cognitive Flexibility	8	0.88	3.76	0.65
Metacognitive Awareness	10	0.93	3.89	0.64
Overall Questionnaire	28	0.94	3.83	0.66

The reliability analysis demonstrated the study variables to be good to excellent, internally consistent. The Cronbach's alpha scores for the three study variables were in the range of 0.88 to 0.93. This indicated that the items measuring artificial intelligence-supported learning, cognitive flexibility, and metacognitive awareness were internally consistent. The overall questionnaire also indicated a high level of reliability, with an alpha score of 0.94.

Table 3: Relationship Between Artificial Intelligence-Supported Learning and Metacognitive Awareness (N = 429)

Variables	Mean	SD	Pearson r	p-value
Artificial Intelligence-Supported Learning	3.84	0.68	0.62**	< .001
Metacognitive Awareness	3.89	0.64	0.62**	< .001

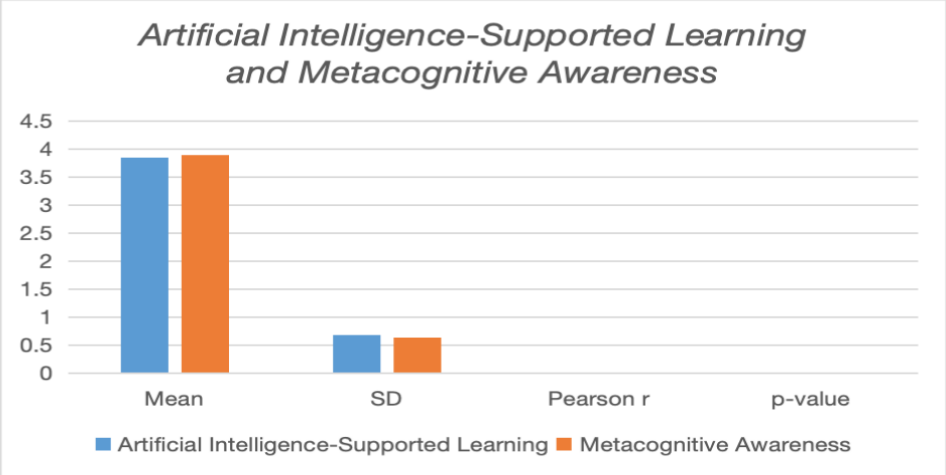


Fig 4: Artificial Intelligence-Supported Learning and Metacognitive Awareness

There was a positive relationship between AI supported learning and metacognitive awareness ($r = 0.62$, $p < .01$). This meant that students that interacted more with AI supported learning also had higher metacognitive awareness. The correlation was positive and relatively strong. Therefore, greater interaction with AI-supported learning could represent awareness of the processes used to learn, for example planning how to learn, evaluating how well they have learned, and monitoring their learning. Therefore, hypothesis 1 was accepted.

Table 4: Regression Analysis of Artificial Intelligence-Supported Learning Predicting Cognitive Flexibility (N = 429)

Predictor	B	SE	β	t	p-value
Constant	1.42	0.18	—	7.89	< .001
Artificial Intelligence-Supported Learning	0.61	0.05	0.58	12.20	< .001

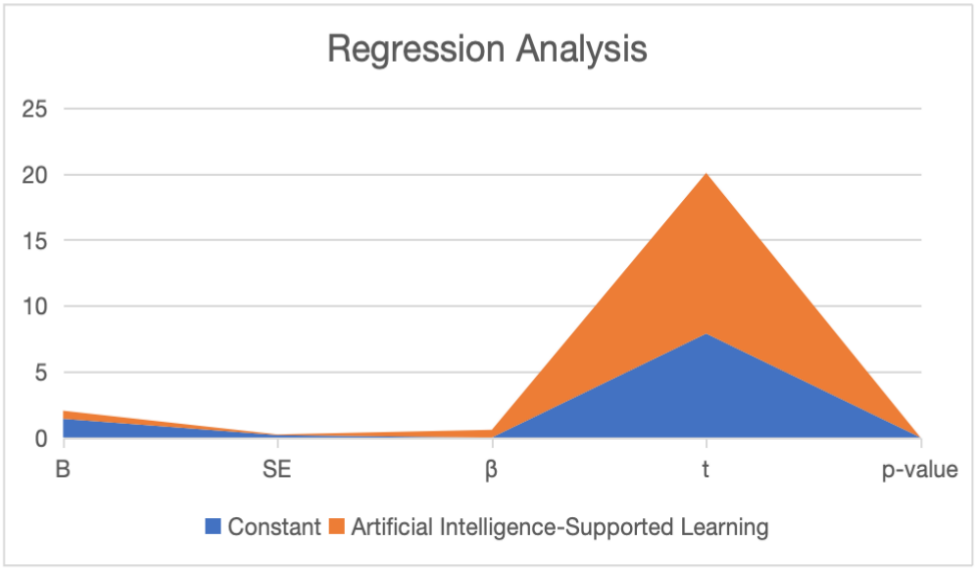


Fig 5: Regression Analysis

The regression analysis indicated that artificial intelligence-supported learning predicted students' cognitive flexibility ($\beta = .58$; $p < .001$). The results indicate that the model accounted for 34% of the variance in cognitive flexibility. Students who indicated greater use of AI-supported learning demonstrated more cognitive flexibility. Because the regression coefficient was positive, the results indicated that as AI-supported learning was employed more, cognitive flexibility also increased. As a result, Hypothesis 2 was supported.

Table 5: Differences in Artificial Intelligence-Supported Learning, Cognitive Flexibility, and Metacognitive Awareness Based on Selected Demographic Characteristics (N = 429)

Demographic Variable	Test	Artificial Intelligence-Supported Learning	Cognitive Flexibility	Metacognitive Awareness
Gender	t	-1.99*	-1.93	-2.50*
Age	F	4.21**	3.76*	4.58**
Education Level	F	3.64*	2.91*	3.87**
Academic Discipline	F	3.28*	2.74*	3.51**
AI-Supported Learning Experience	F	5.62**	4.83**	5.17**
Province	F	2.97*	2.68*	3.14*

Results in Table 5 show that students' artificial intelligence-supported learning, cognitive flexibility and metacognitive awareness were different across various demographic groups. For gender, there was a significant difference in artificial intelligence-supported learning and metacognitive awareness ($p < .05$) but not for cognitive flexibility ($p > .05$). There was a significant difference in the study variables across age groups, education levels, academic disciplines, the AI-supported learning experience, and provinces, as indicated by the significant F-values. Different levels of artificial intelligence-supported learning probably explain variations in results across some of these demographic groups.

Table 6: Mediation Analysis of Cognitive Flexibility in the Relationship Between Artificial Intelligence-Supported Learning and Metacognitive Awareness (N = 429)

Relationship	B	SE	BootLLCI	BootULCI	p-value
AI-Supported Learning and Cognitive Flexibility	0.56	0.04	0.48	0.64	< .001
Cognitive Flexibility and Metacognitive Awareness	0.41	0.05	0.31	0.51	< .001
AI-Supported Learning and Metacognitive Awareness	0.37	0.05	0.27	0.47	< .001
Indirect relationship through Cognitive Flexibility	0.23	0.04	0.16	0.31	< .001
Direct relationship after including Cognitive Flexibility	0.37	0.05	0.27	0.47	< .001

Mediation analysis revealed a statistically significant relationship between artificial intelligence-supported learning and cognitive flexibility ($B = 0.56$, $SE = 0.04$, $p < .001$). Cognitive flexibility was also associated with metacognitive awareness ($B = 0.41$, $SE = 0.05$, $p < .001$). The indirect relationship between artificial intelligence-supported learning and metacognitive awareness through cognitive flexibility was statistically significant ($B = 0.23$, $SE = 0.04$, 95% Bootstrap CI [0.16, 0.31]). The confidence interval excluding zero signified the relationship between the three constructs was statistically significant. The direct relationship between artificial intelligence-supported learning and metacognitive awareness was also statistically significant ($B = 0.37$, $SE = 0.05$, $p < .001$) after including cognitive flexibility. Partial mediation was indicated. Therefore, Hypothesis 4 was also supported.

Discussion

The results of the current study suggest that artificial intelligence (AI)-based learning promotes students' metacognitive awareness. Students who interreact more with AI-supported learning, might be more aware of their learning processes. Hence, they might be more inclined to gauge their comprehension, assess their progress, and modify their learning strategies as needed. AI-supported learning offers students immediate feedback, answers, and personalized learning support, and enables students to reformulate their answers. This might promote students' awareness of their learning processes, and prompts students to think about their learning processes. This is in line with Zaki et al. (2026) who have reported a positive and significant relationship between AI-based learning and metacognitive awareness and self-regulated learning. Sadaf et al. (2026), investigated the effects of AI-based scaffolding on metacognitive awareness and self-regulated learning of students. AI-based scaffolding enhanced students' awareness about learning processes and supported students to regulate their learning.

Another significant relationship between AI-based learning and metacognitive awareness is the increasing role of AI as an interactive learning resource rather than simply an information resource. Students become more actively engaged in evaluating their own thinking when they use AI tools to ask and answer questions, compare and evaluate answers and explanations, identify and correct errors and omissions in their answers, and seek clarification. Such interaction encourages students to think about what they know and understand, and decide what learning strategy they should use next. Research on AI and metacognition has also showed the interactions between learners and AI systems are also primarily focused on self-regulating learning activities like planning, monitoring, controlling and evaluating learning. Balat et al. (2026), for example, demonstrated that the key to effectively using interactive AI-based learning tools is in the learners' metacognitive control, and that the integrated use of cognitive and metacognitive processes is important to further appreciate students' positive experiences with AI-based learning.

The second major finding showed a strong positive relationship between artificial intelligence-supported learning and cognitive flexibility. Students who participated more in AI-supported learning demonstrated greater cognitive flexibility in changing their way of thinking and considering other people's perspectives, as well as adapting their strategies in different learning situations. Consequently, with the use of AI-supported learning, students are likely to encounter several different solutions and arguments through AI-based tools, and, instead of using a single method to solve a problem, students consider several solutions and arguments. The focus on several solutions and arguments is also supported by the findings of Al-khresheh et al. (2026), who examined cognitive flexibility in students using interactive AI-supported learning environments and underlined its role in students' cognitive response to AI-based learning.

The current study builds on the work of Putri et al., (2025) who studied cognitive flexibility and self-regulated learning skills and metacognitive awareness of university students having generative AI experience. In their study, cognitive flexibility was found to be related to students' responses toward generative AI. Likewise, metacognitive awareness was found to have an important indirect relationship with students' attitudes toward AI via cognitive and self-regulated processes. Therefore, their study reinforces the view that cognitive flexibility and metacognitive awareness are related in the context of AI-supported learning (Siregar, 2026).

The most important finding of the present study was that cognitive flexibility significantly mediated the relationship between AI-supported learning and metacognitive awareness. This implies that AI-supported learning increases students' metacognitive awareness in part because it develops their cognitive flexibility. Thus, for students to gain a deeper awareness of their learning because of the use of AI tools is a possibility, but this may not always be the main reason for making a connection between AI-supported learning and metacognitive awareness. There may be other mechanisms through which this is accomplished. Overall, the results show that the development of students' cognitive flexibility is a positive impact of AI-supported learning.

Conclusion

This study found that AI-supported learning helped students with their metacognitive awareness and cognitive flexibility. The study found AI-supported learning helped students process their own learning, explore different learning methods, and alter their thinking and learning strategies. The study also found cognitive flexibility played a major role in mediating AI-supported learning and metacognitive awareness. This suggests AI-supported learning help students adopt alternative thinking strategies, and respond flexibly to different learning situations. This study showed that artificial intelligence can be used in learning in a more interactive and reflective way. AI-supported learning gives students a chance to ask and answer themselves, and alter or evaluate their learning. However, for students to use learning opportunities optimally, they need cognitive flexibility. This study attempted to fill the gap in the existing literature on AI-supported learning by identifying cognitive flexibility as a major mediator of the relationship between AI-supported learning and metacognitive awareness. The findings from the study may help educators to employ AI-based learning to encourage students to reflect and evaluate their learning.

Future Implications

Future studies should explore how various kinds of artificial intelligence (AI) in learning impact students' cognitive and metacognitive development in different educational contexts and fields of knowledge. Longitudinal studies and experiments may offer more valid evidence on how interaction with AI tools affects cognitive flexibility and metacognitive awareness. Future studies may consider other aspects, like self-regulated learning, critical thinking, and digital literacy, as well as AI literacy and academic self-efficacy. This may help understand the effects of AI-based learning on students' cognitive and metacognitive learning processes. Other studies including larger and more different samples, may improve the generalizability of these studies and assist educators to work in AI-based learning contexts that promote cognitive flexibility and integrative thinking, reflection and learning, as well as other metacognitive skills.

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