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AI-Powered Personalized Learning and Students' Metacognitive Awareness: The Role of Learning Engagement

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ABSTRACT

Artificial intelligence (AI) is increasingly being integrated into higher education to provide personalized learning experiences that respond to students' individual needs, learning pace, progress, and preferences. In this context, the present study examined the association between AI-powered personalized learning and students' metacognitive awareness, with learning engagement examined as a mediating variable. The study addressed limited evidence regarding how personalized AI-supported learning environments are associated with students' awareness and regulation of their own learning and the role of engagement in this relationship. A quantitative, cross-sectional survey design was used, and participants were recruited through convenience sampling. Data were collected from 411 university students enrolled in selected higher education institutions in Multan, Punjab, Pakistan, using a structured questionnaire. The questionnaire included adopted and adapted measures of AI-powered personalized learning and learning engagement, while metacognitive awareness was assessed using the Metacognitive Awareness Inventory (MAI). The findings showed significant positive relationships between AI-powered personalized learning and metacognitive awareness, AI-powered personalized learning and learning engagement, and learning engagement and metacognitive awareness. AI-powered personalized learning was a significant statistical predictor of metacognitive awareness, while learning engagement significantly mediated the relationship between AI-powered personalized learning and metacognitive awareness. The findings indicate that personalized AI-supported learning is associated with students' active involvement in learning and their awareness of their own learning processes. Learning engagement represents an important pathway through which AI-supported personalized learning is connected with metacognitive development. The study contributes to higher education research by integrating AI-powered personalization, learning engagement, and metacognitive awareness within a single framework.

Introduction

Personalized learning tailors instructional content, pace, and learning activities to students' individual needs, prior knowledge, abilities, and preferences. Artificial intelligence extends this approach by enabling adaptive learning pathways, individualized feedback, and data-informed instructional support based on students' performance and learning needs. Compared with traditional approaches that often provide uniform instructional content, AI-supported personalized learning can offer more flexible and differentiated learning experiences and help address individual learning gaps (Holmes et al., 2022; Rajan & Khan, 2025). Recent evidence further suggests that AI-enabled personalized learning may support student engagement by adapting learning experiences to learners' individual needs and preferences (Ellikkal & Rajamohan, 2025).

AI-supported learning environments can provide opportunities for learners to monitor their progress, reflect on their learning, and regulate their learning strategies (Romdhoni et al., 2025). The most important contribution of learning systems is that they help students regulate their learning process. These systems integrate various learning, cognitive, and metacognitive activities and offer learners greater control over their learning processes. AI-driven learning analytics can support self-regulated and metacognitive learning by helping learners monitor, evaluate, and adjust their learning processes (Romdhoni et al., 2025).

AI-Powered Personalized Learning

AI in personalized learning refers to customizing learning in accordance with students' characteristics and performance using AI. There are several AI technologies that can help facilitate learning. Some of them include intelligent tutoring systems, learning analytics and more recently, Generative AI. Each of these can analyze student data and create individualized learning materials. Unlike traditional learning, classes using AI in personalized learning can customize the learning materials to be given to students and provide individualized feedback to students, based on their progress (Dandachi, 2024).

Adaptive learning pathways have become an important feature of personalized learning in recent years. These systems use students' learning data, progress, and feedback to adjust instructional content and learning activities according to individual needs. As a result, students may follow different learning paths based on their strengths, weaknesses, and learning pace, allowing for a more personalized and effective educational experience. As AI in personalized learning can give individualized feedback to students and facilitate different learning pathways, it can foster students' understanding and direct their attention to what they lack and need to learn, therefore encouraging students to take an active role in learning. Previous research has shown that AI-enabled personalized learning can improve students' engagement and academic performance by adapting instructional content and feedback to individual learning needs (Ellikkal & Rajamohan, 2025).

The emphasis of several recent reviews and integrated frameworks has been on the role of human agency, not the technology itself, in determining the impact of AI in education. It is generally understood that the effect of AI in education will critically depend on integration within learning and the design and the quality of the pedagogy (Tapalova & Zhiyenbayeva, 2022). Because of the advantages of AI in various domains, tailored learning options provided by AI may allow students to track their academic progress, and identify and Address learning gaps, and choose the best way to approach their learning, hence expanding students learning opportunities. The use of AI in education enables students to focus on what they know and what they don't know, and to reflect on how they should act to perform a particular learning activity. These processes require students to raise their metacognitive knowledge, and consequently are associated with metacognitive skills (Kaswan et al., 2024). Students using AI to aid learning should be equipped to analyze the data and information processed by the AI, to be able to determine when and how to rely on the AI for learning, to evaluate the outcome, and to analyze the limitations of the AI (Al Balushi, 2026).

Students' Metacognitive Awareness

Metacognitive awareness is the knowledge and understanding of the cognitive processes associated with learning. This type of awareness enables students to determine how they learn, select the most suitable strategies for a given task, assess their level of understanding, and decide if the strategies used lead to learning. Jaleel (2016) viewed metacognition as the knowledge and awareness of the factors related to the learning process, including the learning task and the strategies used to accomplish the learning goal. In education, the development of students' metacognitive awareness helps students identify the learning skills they use and the gaps they have. This awareness gives students the ability to make appropriate choices when addressing academic challenges.

From a learning outcome perspective, the focus on metacognitive awareness is justified because learning and teaching should not be about acquiring and transmitting information, respectively. Students should be helped to plan how they will achieve the learning

goal, and teachers should be facilitators to guide students in achieving this. Students need to evaluate their performance. Students should be aware of how they learn so that they can choose strategies and decide on the course of action they will take based on the outcome. Awareness is linked to learning strategies and behavior. This includes cognitive and metacognitive approaches to learning (McCabe, 2011).

Using AI in learning can help students identify their strengths and weaknesses and can support metacognitive processes such as monitoring, reflection, and evaluation of their own learning. Since metacognitive skills are fairly individualized, the use of AI can help students identify what is really happening in their own learning. Feedback can be instantaneous and inform the student what they are doing well, where they may be having trouble, and help stimulate critical thinking about their own answers. Pacheco et al. (2025) discuss the potential use cases of AI to foster metacognitive skills of students. AI may help students construct and evaluate learning goals. Further research shows AI metacognitive assistants help students reflect on the efficacy of the AI and its output. Overall, research supports that AI can help foster the critical consideration of metacognitive skills.

Relationship with AI-powered personalized learning

Personalized AI in learning might help students with their metacognition, especially with feedback and path customization based on student performance. Students get cues to help evaluate their learning and understanding. This sort of environment fosters the practice of metacognition, but exactly how much depends on how deeply students interact with the AI, and how much students reflect on the guidance given (Rekha et al., 2024).

Learning Engagement

Learning engagement refers to the extent of effort and interest students put in learning activities. It has the three components of engagement namely: behavioral, emotional and cognitive. Behavioral engagement is evidenced by students' participation in classroom activities, while emotional engagement is evidenced by students' happiness, satisfaction or enjoyment during the learning process. Cognitive engagement is evident when students use deep learning strategies (Fredricks et al., 2004).

Learning engagement is crucial in capturing students' behavior and actions in relation to learning. Understanding learning engagement allows educators to take into account various learning situations when implementing planned learning activities. Engaging learners in different situations calls for an understanding of situational engagement. From a critical analysis of situational context, more recent studies support that technology, to include Artificial Intelligence (AI), has the potential to positively influence students' behavioral, emotional and cognitive engagement in learning (Carroll et al., 2021).

AI-powered personalized learning has the potential to increase engagement by adapting to the needs and levels of each student. It can adjust difficulty of content, and provide feedback and learn activities to assist students in deepening their understanding. When these elements of learning are individualized to students, they can better understand ways in which they can participate in learning activities. Positive effects of educational technologies powered by artificial intelligence (AI) on learning environments and student engagement are starting to emerge. Effect size is dependent on the designed and implemented instructional strategies (Noe et al., 2010). Other studies focus on the use of AI in digital learning environments and highlight impact on engagement, self-directed learning, and other interrelated behaviors (Niyazova et al., 2026).

Problem Statement

Personalized learning approaches have become increasingly common in educational settings because they help address the diverse learning needs of students. Previous studies have mainly focused on their effects on academic performance, learning behavior, and student interest. However, limited attention has been given to how personalized learning influences students' metacognitive awareness, which refers to their ability to understand, monitor, and regulate their own learning processes. In addition, the relationship between personalized learning and students' learning engagement remains underexplored, particularly among university students. AI-supported personalized learning has been explored in previous studies with respect to academic achievement, engagement, self-regulation, and other learning outcomes, but each of these constructs has been studied in isolation. Another review also found that less attention was paid to AI supported learning systems that explicitly focus on students' metacognitive behavior and self-regulation (Gyekye, 2025). Existing studies have shown that the use of AI to support personalization is related to engagement and metacognitive processes, but research on the relationship of learning engagement with the metacognitive awareness of AI-powered personalized learning is relatively scarce. This mediating role is theoretically relevant because personalized learning can stimulate students' active participation, attention, and involvement in learning, which can be linked with the degree of students' monitoring and regulation of their own learning. The present study aims to bridge this

gap and to explore the correlations between AI powered personalized learning, learning engagement, and metacognition within a single framework among the students of the University of Multan, Punjab, Pakistan and specifically test the mediating role of learning engagement.

Research Objectives

1. To examine the relationship between AI-powered personalized learning and students' metacognitive awareness.
2. To examine the relationship between AI-powered personalized learning and students' learning engagement.
3. To examine the mediating role of learning engagement in the relationship between AI-powered personalized learning and students' metacognitive awareness.

Significance of the Study

This study is significant because it provides a clearer understanding of how AI-powered personalized learning may influence students' metacognitive awareness and whether learning engagement plays an important role in this relationship. The findings may help teachers and educators understand how AI-based personalized learning can be used to encourage students' active participation, reflection, and awareness of their own learning processes. For educational institutions**, t**he study may provide useful insight for designing AI-supported learning environments that address students' individual learning needs while promoting meaningful engagement. The study may also benefit students by highlighting the importance of active involvement in personalized learning and developing greater awareness of their learning strategies. Furthermore, the findings may provide a useful foundation for researchers interested in AI in education, personalized learning, metacognition, and learning engagement, particularly by addressing the limited attention given to the mediating role of engagement in this relationship.

Literature Review

AI-Powered Personalized Learning in Contemporary Education

Personalized learning using Artificial Intelligence (AI) has expanded upon individualized learning to include customizing the learning content, pace, and learning activities. Farhood et al. (2025) conducted a systematic review of the literature on the use of AI in personalized learning between 2015 and 2025. They reported its use in learning and teaching across K–12, higher education, and online learning settings. The review also reported the use of different techniques and approaches of machine learning to develop intelligent learning pathways and systems, tutoring and recommendation systems and generative AI. Other reviews have reported similar findings in the use of AI in other levels and situations of learning and teaching. The review by Merino-Campos (2025) reported that AI has the potential to customize and adapt learning content and offer individualized instructional feedback to learners.

Research has reported that personalization of learning using AI depends on the way the technology is integrated and the purpose it is intended to achieve. The integrative review by Hariyanto et al. (2025) reported that from an instructional design perspective, AI can model the teaching of a subject and offer learning activities to achieve and assess learning. The review cited data privacy, equity and access to technology as the major limitations of using AI in learning and teaching. Other reviews have reported the dominance of quantitative research on the use of AI in personalized learning. The reviews call for complementary studies focusing on cognitive and behavioral effects of using AI in learning and teaching.

Students' Metacognitive Awareness and AI-Supported Learning

Metacognitive awareness is the ability of a student to be aware of, and manage, their own learning. This includes recognizing what they know and do not know, recognizing learning problems, choosing strategies to overcome learning problems, and evaluating their learning. Through the use of AI in learning, personalized feedback and learning analytics have changed the way learners view their learning and provide opportunities for learners to reflect on their learning.

The use of AI in learning has also been shown to support students' thinking. Developing metacognitive awareness is one way to enhance learners' control over their own thinking, learning and achievement. It has, however, been noted that to effectively achieve this goal, learners need to actively participate in the use of technology. In learning analytics, Tezer (2025) showed that integrating AI in learning has enhanced the use of personalized learning, adaptive learning and individualized feedback. Personalizing learning in this manner offers learners opportunities to overcome challenges posed by inadequate control of their learning. AI in educational

settings, therefore, has the potential to shift the role of learners from that of passive learners to strategic learners and give them the ability to manage their own thinking and learning (Romdhoni et al., 2025).

Learning Engagement in AI-Powered Learning Environments

Learning engagement includes the behavioral, cognitive, and emotional aspects of students' participation in educational processes. The effects of the application of AI in education on engagement have been attributed to individualized learning, immediate and continuous feedback, and interactive content. Heung and Chiu (2025) conducted a systematic review and meta-analysis on the effects of ChatGPT on learning. They reviewed 17 studies and 1,735 participants and found a medium effect size on engagement. The studies reviewed reported positive impacts of ChatGPT on all three dimensions of engagement. While ChatGPT increased engagement, Heung and Chiu (2025) also noted potential concerns related to students' dependency on and over-reliance on AI.

Mehmood et al. (2025) view personalized learning analytics as facilities for learners' reflection and metacognitive development. Rasheed (2025) describe an adaptive AI system that identifies and adjusts to learners' behavior in real time. Therefore, personalized learning, at least in principle, permits learners to be in charge of and responsible for the assessment of their own learning. Publications have, however, focused on the implementation of technology for the improvement of learning, as well as the consequences for learning and personalization, rather than the development of learners' metacognitive awareness. Najam et al. (2025) reported numerous educational impacts as the predominant research findings in recent studies on AI-personalized learning. Bachtiar (2026) identified similar research gaps. Hence, it is legitimate to expect that studies in the field will address the influence of AI-based personalized learning on learners' metacognitive awareness.

Abrar et al. (2025) noted that learning aided by ChatGPT created a medium level of engagement, and one of the ways AI is led to engage students is through the provision of personalized tutoring. On the other hand, Saleem et al. (2025) indicated that engagement is enhanced when AI is personalized to learn the individual preferences and needs of students and provide them with tailored educational content and feedback. According to Ellikkal and Rajamohan (2025), one of the ways adaptive AI influences student engagements are by adapting and individualizing instruction, and (Shete et al., 2024), mentioned that one of the influences of generative AI on student engagement is by shaping students' thinking and learning activities. In summary, the more personalized ways that students interact with AI in learning, the greater the opportunities that are available to influence learning engagement and the ways in which students are cognitively and emotionally influenced to learn.

Learning engagement focuses on how students are actively involved and participate in self-directed learning. This assists students in assessing and reflecting on their own learning. This in turn, improves students' metacognitive skills. A study involving 2,989 university students found a positive relationship between metacognition and learning engagement, with learning strategies and learning behaviors playing mediating roles in this relationship (An et al., 2024). The findings indicated that students with stronger metacognitive abilities tended to demonstrate greater learning engagement and more effective use of learning strategies.

Participants who engaged more cognitively in learning were able to strategize and assess their learning more effectively. The results of the study by Amoako et al. (2024) substantiate this, and in a related study, integrated the use of artificial intelligence (AI) in learning to facilitate students in developing their learning engagement and metacognitive processes. Hence, integrating and interpreting both learning engagement and metacognitive processes of students in conjunction with each other is pivotal when using AI in learning.

Hypotheses

Table 1. Study Hypotheses and Proposed Relationships

Hypothesis	Proposed Relationship
H1	There is a significant positive relationship between AI-powered personalized learning and students' metacognitive awareness.
H2	There is a significant positive relationship between AI-powered personalized learning and students' learning engagement.

Hypothesis	Proposed Relationship
H3	There is a significant positive relationship between students' learning engagement and students' metacognitive awareness.
H4	AI-powered personalized learning is a significant statistical predictor of students' metacognitive awareness.
H5	Learning engagement significantly mediates the relationship between AI-powered personalized learning and students' metacognitive awareness.

Conceptual Framework

The conceptual framework presents the proposed relationships among AI-powered personalized learning, learning engagement, and students' metacognitive awareness. AI-powered personalized learning is considered the independent variable, metacognitive awareness is the dependent variable, and learning engagement is the mediating variable. The framework proposes that AI-powered personalized learning is directly associated with metacognitive awareness and is also indirectly associated with metacognitive awareness through learning engagement.

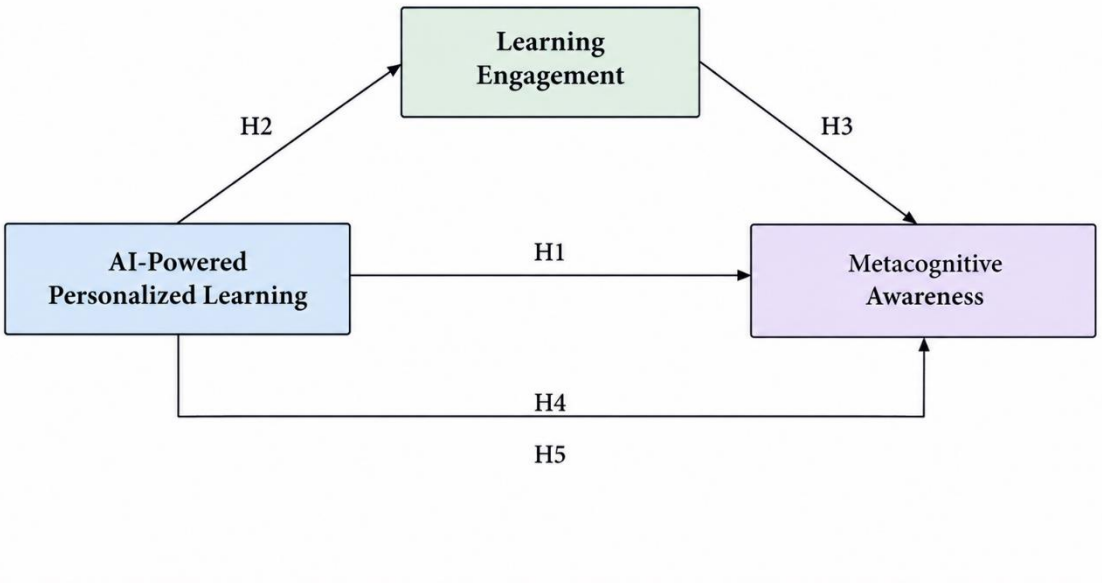


Fig. 1: Conceptual Framework of the Study

Source: Developed by the authors based on the reviewed literature and study hypotheses.

Methodology

Research Design

This study used a cross-sectional survey research design to evaluate university students' perceptions regarding AI-based personalized learning and to assess levels of learning engagement and metacognitive awareness. A self-report questionnaire was employed to collect data for this research.

Population

The research population consisted of university students enrolled in selected higher education institutions in Multan, Punjab, Pakistan. The study collected data from students enrolled in selected higher education institutions in Multan, Punjab, Pakistan. The participants were university students who met the predefined inclusion criteria and voluntarily participated in the study.

Sampling Technique

This study employed a convenience sampling technique to recruit university students who were accessible and willing to participate. The questionnaire was created using Google Forms, and the survey link was distributed to selected university students through WhatsApp. Participation was voluntary, and respondents completed the questionnaire at their convenience. Convenience sampling was considered appropriate because it provided practical access to eligible participants within the available study period.

Ethical Considerations

Participation in the study was voluntary. The questionnaire was administered electronically through Google Forms, and participants completed the survey at their own discretion. Participation was based on willingness to take part in the study, and responses were collected solely for research purposes.

Sample Size

A total of 411 participants completed the questionnaire and were included in the final analysis. Because participants were recruited through convenience sampling from selected higher education institutions in Multan, Punjab, Pakistan, the sample was not intended to be nationally representative of all university students across Pakistan. Therefore, the findings are interpreted in relation to the study sample and should be generalized beyond this context with caution.

Data Collection

The study used an adopted and adapted structured questionnaire to collect data from participants. The questionnaire consisted of items that assessed each of the study variables. All scale items were measured using a five-point Likert scale, ranging from

1 = Strongly Disagree to 5 = Strongly Agree**.**

AI-Powered Personalized Learning:

The 12 items measuring AI-powered personalized learning were adapted from a previously published study and assessed personalization according to students' academic needs, learning preferences, learning pace, and learning level (Nhan, 2025). The scale assesses learning contents and pathways powered by adaptive technology, individual learning needs and preferences, difference and variation in learning tasks, supporting and reinforcing learning with AI, control of learning speed and pace, and learning support. The items were adapted to reflect the context of AI-supported personalized learning among university students while retaining the original focus on individualized learning needs, preferences, pace, learning pathways, and instructional support. The adapted instrument comprised 12 items measured on a five-point Likert scale ranging from 1 = Strongly Disagree to 5 = Strongly Agree.

Learning Engagement

Learning engagement was measured using a 15-item instrument informed by the student engagement framework of Fredricks et al. (2004) and adapted to the context of AI-supported learning with reference to (Nhan, 2025). The instrument addressed the behavioral, emotional, and cognitive dimensions of engagement, including students' participation, motivation, attention, and involvement in learning activities. Items were contextualized to reflect students' engagement within AI-supported personalized learning environments. All 15 items were measured on a five-point Likert scale ranging from 1 = Strongly Disagree to 5 = Strongly Agree, with higher scores indicating greater levels of learning engagement.

Metacognitive Awareness

Metacognitive awareness was assessed using the 52-item Metacognitive Awareness Inventory (MAI) (Schraw & Dennison, 1994). The MAI measures two broad dimensions of metacognition: knowledge of cognition and regulation of cognition. Knowledge of cognition includes declarative, procedural, and conditional knowledge, while regulation of cognition includes planning, information-management strategies, monitoring, debugging strategies, and evaluation. All 52 items were measured on a five-point

Likert scale ranging from 1 = Strongly Disagree to 5 = Strongly Agree, with higher scores indicating greater metacognitive awareness.

Data Collection Procedure

The questionnaire was created on Google Forms. A link to the Form was sent via online channels to selected university students to complete the questionnaire electronically. The nature of participation was voluntary. The data in Google Forms is automatically compiled. The compiled data were downloaded and imported to Microsoft Excel for preliminary organization, checking, and coding. The data were screened for completeness and clarity before analysis, and only eligible complete responses were retained for the final dataset of 411 participants. Data Organization also facilitates analysis. After data screening and organization, the data were exported to SPSS for analysis.

Data Analysis

Data were initially entered and structured in Microsoft Excel and imported to SPSS for analysis. Percentages and frequencies were computed to determine respondent's demographic characteristics. Means and standard deviations were calculated for the core study variables. Cronbach's alpha was determined to assess the scales' reliability and consistency. There were three core variables, namely AI-powered personalized learning, learning engagement and metacognitive awareness. Correlation was determined for AI-powered personalized learning and the other two variables using Pearson product-moment correlation. Prediction was determined for AI-powered personalized learning using linear regression. Mediation analysis was conducted using PROCESS Model 4 to examine the indirect effect of AI-powered personalized learning on metacognitive awareness through learning engagement. Linear regression coefficients and bootstrapped confidence intervals were used to assess the direct and indirect effects.

Table 2: Demographic Characteristics of the Respondents by Gender, Age, and Educational Level

Demographic Variables	Categories	Frequency (f)	Percentage (%)
Gender	Male	196	47.7
	Female	215	52.3
Age	18–22 years	231	56.2
	23–27 years	132	32.1
	28–32 years	32	7.8
	33 years and above	16	3.9
Educational Level	Undergraduate	239	58.1
	Master's	112	27.3
	MPhil	42	10.2
	PhD	18	4.4
Total Respondents	—	411	100.0

Demographic data of 411 participants is provided in Table 2. Most (52.3%) of the participants were female. The sample was relatively well balanced between female and male participants. The mean age of the participants was 23.2 years. The majority (56.2%) of the participants was between 18 and 22 years of age; the second largest group (32.1%) of the sample was between 23 and 27 years. The smallest groups were between 28 and 32 (7.8%) years of age and 33 years and above (3.9%). Most of the sample (58.1%) was enrolled in an undergraduate program. A smaller group (27.3%) were master's students, an even smaller group (10.2%) was enrolled in an M.Phil. program, and the remaining sample (4.4%) was enrolled in a Ph.D. program. From the demographic data, the research included participants from different age groups, genders and university levels.

Table 3: Reliability Statistics, Means, and Standard Deviations of Study Variables

Variables	No. of Items	Cronbach's Alpha (α)	Mean (M)	Std. Deviation (SD)
AI-Powered Personalized Learning	12	0.918	3.84	0.68
Learning Engagement	15	0.904	3.79	0.65
Metacognitive Awareness	52	0.936	3.87	0.61
Overall Scale	79	0.945	3.83	0.65

Table 3 shows the major study variable means, standard deviations and reliability levels of the study sample consisting of 411 participants. Cronbach's alpha ranged from 0.904 to 0.936. The items comprising the constructs of AI-powered personalized learning and learning engagement showed Cronbach's alpha at 0.918 and 0.904, respectively. The items comprising the metacognitive awareness scale demonstrated Cronbach's alpha at 0.936. Thus, the overall scale of the study also reflected Cronbach's alpha at 0. 945. The study variables reflected a positive perception by participants. Of the three variables, metacognitive awareness was the most endorsed (M = 3.87, SD = 0.61), followed by AI-personalized learning (M = 3.84, SD = 0.68), and learning engagement (M = 3.79, SD = 0.65). Standard deviation scores reflected a moderate level of variability in the study sample.

Table 4: Pearson Correlation Between AI-Powered Personalized Learning and Students' Metacognitive Awareness

Variables	Mean	Std. Deviation	1	2
AI-Powered Personalized Learning	3.84	0.68	1	
Metacognitive Awareness	3.87	0.61	0.62	1

The correlation between AI-personalized learning and students' meta-cognitive awareness is presented in Table 4. A positive, statistically significant relationship was found between the two variables ($r = .62$, $p < .001$). This finding indicates that higher levels of AI-powered personalized learning were associated with higher levels of students' metacognitive awareness. The correlation was positive, moderately strong, and statistically significant. These findings suggest that AI-powered personalized learning may be relevant to supporting metacognitive awareness among university students in higher education.

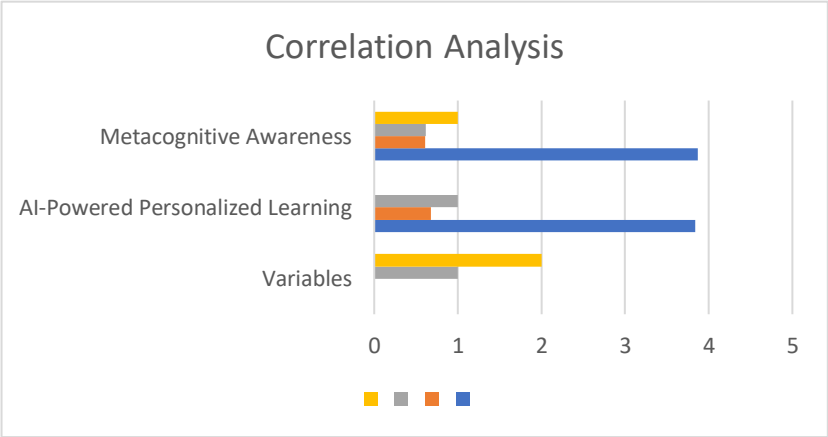


Fig. 2: Correlation Analysis

Table 5: Pearson Correlation Between AI-Powered Personalized Learning and Students' Learning Engagement

Variables	Mean	Std. Deviation	1	2
AI-Powered Personalized Learning	3.84	0.68	1	
Learning Engagement	3.79	0.65	0.58	1

The correlation of AI-powered personalized learning and learning engagement of 411 participants is shown in Table 5. A positive and significant correlation ($r = .58$, $p < .001$) means participants who reported higher AI-powered personalized learning also reported higher learning engagement. The correlation of $r = .58$ indicates a moderately strong positive correlation. Therefore, in the context of the sample, AI-powered personalized learning was positively associated with students' learning engagement.

Table 6: Pearson Correlation Between Students' Learning Engagement and Metacognitive Awareness

Variables	Mean	Std. Deviation	1	2
Learning Engagement	3.79	0.65	1	
Metacognitive Awareness	3.87	0.61	0.64	1

Correlation between Learning Engagement and Metacognitive Awareness ($N = 411$) is shown in Table 6. A positive and statistically significant correlation was found between learning engagement and metacognitive awareness ($r = .64$, $p < .001$). Hence, learning engagement of students was related to their level of metacognitive awareness. Positive correlation between the two variables shows there is a moderately strong association. Hence, learning engagement and metacognitive awareness of students in the sample were related.

Table 7: Simple Linear Regression Analysis of AI-Powered Personalized Learning Predicting Students' Metacognitive Awareness

Predictor	R	R^2	Adjusted R^2	F	B	β	t	p
AI-Powered Personalized Learning	.62	.384	.382	255.19	.56	.62	15.97	< .001
Constant	—	—	—	—	—	—	—	—

AI-powered personalized learning was significantly associated with students' metacognitive awareness in the regression model ($\beta = .62$, $t = 15.97$, $p < .001$). The model explained 38.4% of the variance in metacognitive awareness ($R^2 = .384$), and the overall regression model was statistically significant ($F = 255.19$, $p < .001$). Therefore, AI-powered personalized learning was identified as a significant statistical predictor of students' metacognitive awareness within the study sample.

Table 8: Mediation Analysis of Learning Engagement in the Relationship Between AI-Powered Personalized Learning and Students' Metacognitive Awareness

Effect	B	SE	β	t	p	95% Bootstrapped CI
AI-Powered Personalized Learning → Learning Engagement	0.55	0.05	0.58	11.75	< .001	[0.46, 0.64]
Learning Engagement → Metacognitive Awareness	0.43	0.06	0.46	7.18	< .001	[0.31, 0.55]
AI-Powered Personalized Learning → Metacognitive Awareness (Direct Effect)	0.32	0.05	0.36	6.42	< .001	[0.22, 0.42]
Indirect Effect through Learning Engagement	0.24	0.04	—	—	—	[0.17, 0.32]
Total Effect	0.56	0.05	0.62	11.20	< .001	[0.46, 0.66]

Mediation analysis of learning engagement is shown in Table 8. The analysis showed that AI-powered personalized learning predicted learning engagement ($\beta = .58$, $p < .001$). Additionally, learning engagement predicted students' level of metacognitive

awareness (β = .46, p < .001). The effect of AI-personalized learning on metacognitive awareness through learning engagement was 0.24. The 95% bias-corrected confidence interval of this effect was 0.17 and 0.32. As the lower and upper limits of the confidence interval did not include 0, the effect was considered to be significant. In addition, the direct effect was also significant (β = .36, p < .001). Therefore, learning engagement was considered to partially mediate the relationship between AI-powered personalized learning and students' metacognitive awareness.

Discussion

This study investigated the relationship between individualized learning with AI, learning engagement, and metacognitive awareness of students. A positive relationship was observed among the three variables. individualized learning with AI was positively associated with students' metacognitive awareness (r = .62, p < .001) and their engagement in learning (r = .58, p < .001). learning engagement was also positively associated with students' metacognitive awareness (r = .64, p < .001). The results of the regression analysis indicated that individualized learning with AI was a significant statistical predictor of students' metacognitive awareness. Furthermore, the mediation analysis showed that learning engagement significantly mediated the relationship between AI-powered personalized learning and students' metacognitive awareness. Thus, AI-powered personalized learning environments were positively associated with students' metacognitive awareness and learning engagement and may support students' regulation of their learning processes (Kaur et al., 2026).

The first major finding indicated that AI-powered personalized learning was positively associated with students' metacognitive awareness. The regression model explained 38.4% of the variance in metacognitive awareness, suggesting a meaningful statistical relationship within the study sample. One possible explanation is that personalized feedback, adaptive recommendations, and individualized learning pathways may encourage students to monitor their understanding, reflect on their progress, and adjust their learning strategies. This interpretation is consistent with the view that AI-supported learning environments can provide opportunities for learners to engage more actively in planning, monitoring, and evaluating their own learning.

This finding is consistent with previous research indicating that AI-supported personalized learning can provide flexible and adaptive learning experiences that respond to students' individual needs (Zaki et al., 2026). Farooqi et al. (2025) similarly reported that the use of AI in higher education was associated with students' engagement with learning content, instructional methods, and learning pace. In addition Sufyan Ghaleb and Alshiha (2023) found that AI-supported learning analytics may facilitate students' reflection and clarification of learning goals. Taken together, these findings suggest that personalized AI-supported learning environments may create opportunities for students to reflect more deliberately on their learning processes and to develop greater awareness of how they approach academic tasks.

The second major finding showed a positive and statistically significant association between AI-powered personalized learning and students' learning engagement (r = .58, p < .001). Students who reported higher levels of personalized AI-supported learning also tended to report greater involvement in learning activities. One possible explanation is that adaptive learning pathways, individualized instructional content, and personalized feedback may help students remain more attentive and involved in learning tasks. This interpretation is consistent with evidence showing that AI-enabled adaptive learning technologies can provide individualized learning routes and tailored instructional support (Usman et al., 2025). Similarly, recent systematic evidence indicates that ChatGPT-supported learning may be associated with behavioral, cognitive, and emotional dimensions of student engagement (Heung & Chiu, 2025).

These findings also have practical implications for the design of AI-supported learning environments. Personalized tutoring, adaptive feedback, and differentiated instructional support may help create conditions that encourage students' active engagement; however, such technologies should be integrated with appropriate pedagogical guidance rather than treated as substitutes for effective teaching. Educators should therefore consider how AI tools are aligned with instructional goals, students' learning needs, and ethical principles when incorporating them into higher education.

The final finding showed a positive and statistically significant correlation between learning engagement and metacognitive awareness (r = .64, p < .001). This association suggests that students who are more actively engaged in learning also tend to report stronger metacognitive awareness, particularly in relation to planning, monitoring, and evaluating their learning. This finding is consistent with previous research showing a positive relationship between metacognition and learning engagement among university students (An et al., 2024). That study further indicated that learning strategies and learning behaviors contributed to the relationship between these constructs. Taken together, the findings suggest that learning engagement and metacognitive processes are closely related within university learning contexts.

Learning engagement partially mediated the relationship between AI-powered personalized learning and metacognitive awareness. The indirect effect was 0.24, with a 95% confidence interval ranging from 0.17 to 0.32, indicating a statistically significant indirect pathway. At the same time, the direct effect of AI-powered personalized learning on metacognitive awareness remained significant. These findings indicate that learning engagement explains part, but not all, of the association between AI-powered personalized learning and students' metacognitive awareness.

This result combines the three major components of the study. Elsewhere, other scholars have investigated and confirmed the roles of AI in both personalization and engagement. For instance, Yaseen et al. (2025) examined the role of adaptive learning technologies, personalized feedback, and interactive AI tools in student engagement. The current study adds to this body of knowledge and confirms that the use of AI in personalizing learning may help enhance students' level of metacognitive awareness.

Conclusion

The study revealed positive relationships between AI-based personalized learning and students' metacognitive awareness as well as between learning engagement and metacognitive awareness, with learning engagement also being positively related to metacognitive awareness. The results of this study suggest that students who experience personalized learning with AI are more likely to experience learning involvement and perceive their learning processes. The mediation analysis additionally revealed that there was a partial mediation effect of learning engagement between AI-powered personalized learning and metacognitive awareness, highlighting the role of engagement as one pathway between personalized AI-supported learning and metacognitive development.

The study extends the existing literature in the realm of higher education in Multan, Punjab, Pakistan by analyzing personalized learning using AI, Metacognitive Awareness, and learning engagement under one umbrella. The results indicate the imperative to create learning spaces that are designed with the support of artificial intelligence, and that promote students' active involvement, reflection and self-monitoring. The findings imply that AI-driven personalization benefits might not just be about the technology, but also about fostering meaningful student engagement effectively.

Limitations

This study has several limitations. First, the cross-sectional design limits conclusions to associations among the study variables and does not establish causal relationships. Second, the use of convenience sampling and the inclusion of students from selected higher education institutions in Multan, Punjab, limit the generalizability of the findings to the broader university student population in Pakistan. Third, the study relied on self-reported questionnaire data, which may be influenced by participants' perceptions and response patterns. Future studies may address these limitations by using longitudinal designs, probability sampling, and samples drawn from a wider range of institutions and regions.

Future Implications

Future research should examine metacognitive awareness and learning engagement among students from different educational levels and regions of Pakistan, as existing evidence in this area remains limited. Exploring these factors across diverse academic disciplines may provide a deeper understanding of how students develop effective learning strategies and remain actively involved in their studies. In addition, longitudinal studies are recommended to investigate how metacognitive awareness and learning engagement change over time. Such research could offer valuable insights into the long-term development of students' learning skills and help educators design more effective educational practices to support academic success... Furthermore, studies focused on differentiating learning processes and how AI educational assistants influence and facilitate learning may also help clarify engagement and metacognitive skills of students. Additional factors such as students' self-regulated learning and motivation, as well as teachers' interaction and AI educational assistants may help clarify the whole picture. Finally, comparing different AI educational assistants may help identify the reasons for students' different levels of engagement and metacognitive skills.

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