



Cognitive Flexibility, Generative AI Adoption, and Problem-Solving Performance among University Students: The Mediating Role of Metacognitive Awareness

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ARTICLE INFO	ABSTRACT
Submission: June 30, 2026 Revised: July 16, 2026 Accepted: July 30, 2026 Available Online: August 12, 2026 Keywords: Cognitive Flexibility, Generative Artificial Intelligence, GenAI Adoption, Metacognitive Awareness, Problem-Solving Performance, Higher Education, University Students, AI-Supported Learning. Corresponding author: Ali Yousuf Khan Email: aliykhanssuet.edu.pk	The rapid integration of generative artificial intelligence (GenAI) into higher education is reshaping how university students engage in learning, reasoning, and problem solving; however, the cognitive mechanisms underlying the effective use of these technologies remain insufficiently understood. This study examined the relationships among cognitive flexibility, GenAI adoption, metacognitive awareness, and problem-solving performance among university students, with particular emphasis on the mediating role of metacognitive awareness. A quantitative, cross-sectional research design was employed with a sample of 477 university students recruited from higher education institutions in Punjab and Sindh, Pakistan. Data were collected through an adopted and contextually adapted structured questionnaire administered online using Google Forms. The collected responses were systematically organized and analyzed using appropriate statistical procedures, including Pearson correlation analysis, multiple linear regression, one-way analysis of variance, and mediation analysis. The findings demonstrated significant positive relationships among cognitive flexibility, GenAI adoption, metacognitive awareness, and problem-solving performance. Cognitive flexibility, GenAI adoption, and metacognitive awareness also emerged as significant predictors of students' problem-solving performance. Furthermore, students with higher levels of GenAI adoption demonstrated comparatively stronger problem-solving performance than those with lower levels of adoption. Mediation analysis further revealed that metacognitive awareness significantly mediated the relationships between cognitive flexibility and problem-solving performance and between GenAI adoption and problem-solving performance. These findings highlight the importance of students' capacity to monitor, regulate, and evaluate their own cognitive processes when engaging with AI-generated information. The study contributes to the emerging literature on GenAI in higher education by demonstrating that the educational value of these technologies extends beyond technological adoption and is closely associated with students' cognitive flexibility and metacognitive capabilities. The findings provide implications for educators, policymakers, and university administrators seeking to develop learner-centered and AI-integrated educational environments that strengthen independent thinking, reflective learning, adaptive cognition, and problem-solving capabilities while minimizing passive dependence on AI technologies.

Introduction

The rapid evolution of Generative Artificial Intelligence (GenAI) has significantly transformed university learning environments. Applications such as ChatGPT and other large language model-based tools have expanded the capabilities of educational technologies by providing students with explanations, feedback, examples, brainstorming support, and summarization functions, thereby facilitating more flexible and personalized learning experiences. These technologies enable students to access learning resources that can be adapted to their individual needs and learning requirements. Emerging evidence indicates that university students increasingly use GenAI to support learning and academic tasks, develop a better understanding of challenging concepts, and manage and optimize various aspects of their academic work (Baidoo-Anu et al., 2024; Maxwell et al., 2025). Unlike conventional educational technologies, GenAI can provide context-sensitive and interactive responses, allowing students to engage in an iterative process of questioning, receiving feedback, evaluating information, and refining their understanding of a particular topic. Consequently, GenAI is becoming increasingly influential in shaping how knowledge is acquired, developed, interpreted, and applied within higher education.

However, the educational potential of GenAI cannot be determined solely by the extent or frequency of its use. Although increased access to AI-generated information may support cognitive development, excessive reliance on these technologies may also reduce students' engagement in independent reasoning and problem solving. This distinction is particularly important in higher education, where effective learning requires students to interpret information, consider alternative perspectives, evaluate evidence, and formulate solutions independently. Recent evidence suggests that ChatGPT can improve the quality, elaboration, and originality of students' responses to creative problem-solving tasks while simultaneously reducing their perceived cognitive load (Urban et al., 2024). However, the same study reported limitations in students' ability to critically evaluate the quality of AI-generated responses. Thus, improved performance on AI-supported tasks does not necessarily indicate corresponding improvements in students' independent judgment and reasoning abilities. Rather, the manner in which students engage with GenAI may be more consequential for learning outcomes than the frequency or intensity of its use alone.

Within the rapidly developing GenAI landscape, it is therefore important to identify the cognitive characteristics that enable students to use these technologies productively and responsibly. Cognitive flexibility may be particularly relevant because it enables students to adapt their existing approaches, consider alternative perspectives, and modify their strategies in response to changing information. These abilities may help students critically evaluate the diverse responses generated by GenAI and determine which information is relevant, accurate, and appropriate for a particular learning task. Similarly, metacognitive awareness may enable students to plan their engagement with AI, monitor their understanding, evaluate the accuracy and relevance of AI-generated information, and regulate their level of dependence on the technology. Recent research indicates that cognitive flexibility and metacognitive awareness may influence how university students engage with generative AI and the academic activities for which they employ these technologies (Karaoglan Yilmaz & Yilmaz, 2025). Therefore, examining GenAI use in relation to cognitive flexibility, metacognitive awareness, and problem-solving performance is essential for determining whether AI-supported learning genuinely strengthens students' higher-order cognitive abilities or, alternatively, encourages excessive dependence on AI for reasoning and problem solving.

Cognitive Flexibility and Problem-Solving Performance

Cognitive flexibility refers to the ability to shift attention, adapt existing approaches, and modify strategies when an initial approach proves ineffective. It is particularly relevant to technology-mediated learning environments and represents an essential cognitive capability for contemporary university students. University students frequently encounter ambiguous, complex, and multidimensional problems that require them to integrate information obtained from multiple sources. Effective problem solving therefore depends on the ability to draw upon, reorganize, and adapt existing knowledge and reasoning strategies in response to the changing demands of a task or situation. Cognitive flexibility enables learners to move beyond habitual or rigid responses by considering alternative strategies and adjusting their approaches when necessary. This capability is increasingly important in learning environments characterized by rapidly evolving information technologies, continuously changing knowledge resources, and emerging academic challenges.

Cognitive flexibility is particularly important in AI-assisted learning environments because generative artificial intelligence (GenAI) can provide multiple interpretations, solutions, and explanations for the same learning problem. However, the availability of multiple AI-generated responses requires students to evaluate their contextual relevance, accuracy, and

applicability rather than accepting them without critical consideration. Students with greater cognitive flexibility may be more capable of comparing AI-generated solutions with their own reasoning, considering alternative approaches, and modifying their strategies when an AI-supported solution provides a more appropriate response to a particular problem. In contrast, students with lower levels of cognitive flexibility may be more likely to rely on a single response, including an AI-generated answer, without sufficiently evaluating alternative solutions or reconsidering their initial assumptions. Recent research examining AI use in higher education identified cognitive flexibility as an important factor associated with students' engagement with AI technologies and suggested that individual cognitive characteristics can influence how students respond to educational technologies (Alshammari et al., 2026). This perspective suggests that AI adoption should not be understood solely as a technology-driven process but also as a learning process shaped by students' cognitive capabilities and their ability to engage critically with AI-generated information.

The relationship between cognitive flexibility and AI-supported problem solving is particularly important because access to AI-generated solutions does not automatically result in higher-order thinking. Although GenAI can expand the range of strategies, perspectives, and potential solutions available to students, learners must still determine how these alternatives can be interpreted, evaluated, and incorporated into their own reasoning. AI assistance may therefore enhance students' higher-order thinking and problem-solving abilities, but its effectiveness is likely to depend on how students interact with and regulate their use of the technology. When appropriately integrated into the learning process, GenAI can function as a cognitive aid that complements rather than replaces students' independent reasoning. Cognitive flexibility may consequently serve as an important cognitive resource that enables students to use GenAI without relinquishing critical evaluation and independent judgment. It may also help explain why some students derive greater cognitive benefits from AI-supported learning than others, as students who are better able to adapt their thinking and evaluate alternative approaches may be more capable of transforming AI-generated information into meaningful learning and effective problem-solving strategies.

Metacognitive Awareness as a Potential Mediating Mechanism

Metacognitive awareness provides an important perspective for understanding the relationship between cognitive flexibility, GenAI adoption, and problem-solving performance. Metacognition refers to an individual's awareness and regulation of their own cognitive processes. It encompasses the ability to plan a task, monitor one's understanding, evaluate the effectiveness of strategies, and modify those strategies when necessary. These processes are particularly important in higher education, where students are frequently required to complete complex academic tasks that demand continuous evaluation of what they understand, what remains uncertain, and which strategies are most appropriate for addressing a particular problem. Metacognitive awareness therefore enables students to move beyond simply acquiring information by actively regulating how information is interpreted, evaluated, and applied. In GenAI-supported learning environments, this capability becomes especially important because students receive information and recommendations from an external cognitive system and must determine how such information should be critically evaluated and integrated with their existing knowledge and reasoning.

The importance of metacognitive awareness becomes more pronounced because GenAI systems can produce fluent, convincing, and contextually plausible responses that may nevertheless contain inaccurate, incomplete, or irrelevant information. Consequently, students must continually evaluate AI-generated responses in terms of their accuracy, relevance, justification, and consistency with established knowledge. Students with stronger metacognitive awareness may be more likely to critically examine AI-generated content, identify omissions or inaccuracies, seek additional evidence, and revise their reasoning when necessary. In contrast, students with lower metacognitive awareness may be more inclined to accept AI-generated information without sufficiently evaluating its validity or relevance. Zhao et al. (2025) reported that although ChatGPT enhanced university students' creative problem-solving performance across multiple domains, concerns remained regarding students' ability to evaluate the accuracy and quality of AI-generated responses. This finding is particularly important because improved performance on AI-supported problem-solving tasks does not necessarily indicate that students have developed stronger metacognitive awareness or greater capacity to independently evaluate and regulate their reasoning.

The increasing adoption of GenAI among university students therefore presents both educational opportunities and cognitive challenges. Although AI-supported learning can enhance the creativity, elaboration, and originality of responses to complex academic problems, concerns remain regarding the possibility of cognitive dependence on AI-generated solutions and the potential weakening of students' independent self-regulatory processes. In particular, the extent to which students can independently evaluate the quality of their own reasoning while using GenAI remains insufficiently understood. Cognitive

flexibility and metacognitive awareness are especially relevant in this context because both capabilities may support students' ability to regulate their interaction with AI, evaluate alternative solutions, and determine when AI-generated information should be accepted, modified, or rejected. Nevertheless, the cognitive processes through which these characteristics influence GenAI-supported problem solving remain inadequately examined. Although metacognition is widely recognized as an important component of self-regulated learning, its specific role in students' interaction with GenAI requires further empirical investigation. Similarly, the interrelationships among cognitive flexibility, GenAI adoption, metacognitive awareness, and problem-solving performance remain underexplored, particularly among university students. Examining these relationships is therefore necessary to clarify the cognitive mechanisms through which students can use GenAI as a supportive learning resource while maintaining independent reasoning, critical evaluation, and effective problem-solving capabilities.

Research Objectives

- **To examine** the relationship between cognitive flexibility, generative AI adoption, and problem-solving performance among university students.
- **To determine** the relationship between generative AI adoption and metacognitive awareness among university students.
- **To examine** the mediating role of metacognitive awareness in the relationship between cognitive flexibility, generative AI adoption, and problem-solving performance among university students.

Research Questions

- What is the relationship between cognitive flexibility, generative AI adoption, and problem-solving performance among university students?
- What is the relationship between generative AI adoption and metacognitive awareness among university students?
- Does metacognitive awareness mediate the relationship between cognitive flexibility, generative AI adoption, and problem-solving performance among university students?

Problem Statement

The rapid adoption of generative artificial intelligence (GenAI) among university students has created an important educational challenge concerning whether AI-supported learning strengthens students' cognitive capabilities or encourages dependence on externally generated solutions. Although empirical evidence indicates that tools such as ChatGPT can improve the quality, elaboration, and originality of students' solutions to complex problems, their effects on metacognitive monitoring and students' ability to accurately evaluate their own performance remain unclear (Urban et al., 2024). Existing research has examined cognitive flexibility, metacognitive awareness, and GenAI primarily in relation to students' attitudes, acceptance, or self-regulated learning; for example, recent evidence has demonstrated that cognitive flexibility and metacognitive awareness are associated with students' attitudes toward GenAI, but this work does not establish how these cognitive characteristics translate into actual problem-solving performance (Karaoglan Yilmaz & Yilmaz, 2025). Similarly, emerging research identifies metacognition as a significant but insufficiently explored dimension of students' interaction with GenAI, particularly in relation to how learners plan, monitor, evaluate, and regulate their use of AI-generated information (Teng, 2025; Xu, et al., 2022). Consequently, a specific empirical gap remains regarding the combined relationship between cognitive flexibility, GenAI adoption, and problem-solving performance and, more importantly, whether metacognitive awareness explains this relationship among university students. Addressing this gap is necessary because merely establishing that students use GenAI or that AI can improve task performance does not explain the cognitive processes responsible for effective AI-supported problem solving. The present study therefore investigates these relationships within an integrated framework, with particular emphasis on the mediating role of metacognitive awareness.

Significance of the Study

This study analyzes cognitive flexibility, use of generative AI, metacognitive awareness, and their impact on the problem-solving ability of university students. Generative AI will likely continue to permeate university education. It is therefore important to examine if the use of generative AI will enable students to enhance their independent use of thinking skills. This study is likely the first to examine cognitive flexibility within metacognitive awareness and Generative AI-enabled learning. This study is therefore important in its attempt to build on the existing literature. From a pragmatic point of view, the results will likely enable university education staff to design ways to provoke cognitive flexibility and metacognitive awareness within students using Generative AI. Furthermore, this study will enable self-thinking skills and self-learning skills to be introduced within university staff training and educational courses. The results may also be used to design ways to use Generative AI in a controlled manner. This study will help continue the research that examines the metacognitive and cognitive impact of generative AI within university education.

Literature Review

Flexibility in thinking involves the ability to regroup thinking, shift to other points of view, or change thinking strategies. It entails the ability to deal with ambiguous questions, unfamiliar academic situations, and complex information. In such situations, rather than strictly applying learned methods, flexible thinking allows the student to restructure the problem, identify other viable methods, and employ the best fit for the context of the problem. Martin and Rubin (1995) describe cognitive flexibility as knowing that there are options, the ability to adjust and terminate the old way of thinking, and the ability to provide different answers. The educational implications of cognitive flexibility show that if a student is flexible in thinking, then he is flexible in critically evaluating different answers to a given situation. In the field of education, cognitive flexibility can be associated with the propensity of the student to think critically. According to Karakuş (2024) cognitive flexibility has a high significant relationship with critical thinking and was measured in this study with a sample of 366 university students. Within the context of academic problems, flexibility of thinking becomes even more important, especially when it comes to problem solving. To solve a problem, one must be able to comprehend the complexity and move beyond a linear way of reasoning. If one way fails to bring about the desired end, flexibility allows one to think beyond the methods and the limits of the rational scope in order to come up with the right answers.

Cerebrate Journal explains how university based research systematically proves this connection. More specifically, the study, published in the Gaziantep University Journal of Educational Sciences, found that students that displayed higher cognitive flexibility had more advanced problem solving styles, and scored higher in rational problem solving. They also had lower levels of the problem solving styles of impulsiveness and inattentiveness and the avoidant style. This study shows that cognitive flexibility is not just an overall cognitive function, it shows how students respond and how they will most likely solve a difficult problem. Flexible cognition is the key to flexible learning. This is the main idea of a study conducted on higher education that found cognitive flexibility had great influence on the student's study strategies (Öztürk et al., 2022).

Cognitive flexibility also has the potential to be strengthened, particularly among university students, through the right kind of teaching and learning. This is especially important for the problem solving of university students. For example, İdawati et al. (2020) studied university students using a problem solving teaching method and measured their cognitive flexibility and metacognitive skills. They found that the teaching of problem solving was helpful in developing students' cognitive and metacognitive skills. This showed that flexible thinking can both be an outcome of the teaching and learning process and an essential element of this process. This is the position of contemporary educational research that encourages university students to develop cognitive skills that are more flexible and adaptive, rather than cognitive skills that are rigid and fixed. When students have more cognitive flexibility, they are more likely to rethink their assumptions, bring together disparate bits of information, contrast differing solutions, and modify their reasoning with new evidence. Complex higher education environments demand this flexibility. Most academic problem solving involves information that is not fully known and a developing technological context.

Generative AI Adoption and Problem-Solving Performance in Higher Education

The rapid rise of Generative AI (GenAI) technologies, especially ChatGPT, presents numerous challenges and opportunities to enhance problem-solving for students in higher education. GenAI tools can provide students with explanations, help them generate and compare solutions, provide feedback, and assist with difficult and time-consuming academic tasks. Leveraged as a

cognitive aid to supplement, rather than replace, students' reasoning, GenAI tools may enhance students' problem-solving performance on a broader scale. Iqbal, J et al. (2025) described a study where university students used ChatGPT to assist with solving a complex creative problem and reported significant improvements to the quality, elaboration, and originality of the solutions. Students also reported a higher level of self-efficacy and a lower level of cognitive load when working with ChatGPT, indicating the ability of GenAI tools to engage and sustain cognitive resources for complex academic tasks. The authors of the study did note that the effect of the use of GenAI on students' ability to accurately assess their performance remained unknown, indicating that improved solutions may not correlate to the development of students' ability to self-regulate and assess their cognitive processes.

Personal Projects, Collaboration, and Cognitive Performance Xml is simply a standardized method of specifying Wu, H et al. (2026) studied the effect of ChatGPT-4o on students' problem-solving thinking and found that the use of AI support at least partially expanded both the number of thinking skills and the degree of interconnection among thinking skills used by students. The authors also noted a positive effect on the originality and usefulness of students' design solutions. Thus, integrated AI support, at least partially, may serve the role of a complex thinking facilitator, rather than an answer provider. The authors, however, note that although the above findings may suggest a beneficial effect of AI, students' use of AI may be the most important factor in determining the effect of AI on the learning process.

At the same time, the effect of using GenAI on the quality of problem-solving is not always positive. A frequent concern in the early studies is that a high reliance on AI may lead to students insufficiently engaging in the reasoning process. In such instances, students may take the completion of the academic task as an indication of cognitive growth, even if they do not take the time to check the accuracy of the AI output, consider other possibilities, or establish the reasoning on their own. Of particular concern in such instances is that GenAI may generate outputs that are quite convincing, yet incorrect, and thus students need to use their judgment and assess the output of AI critically. Human-GenAI collaborative problem solving also produces a diverse range of interactions, whereby students and AI share control over the direction of the activity, and thus the educational effects of GenAI also partly depend on the degree of control the students retain over the problem-solving process. Zhu et al. (2024) categorized human-AI collaboration styles in their study of undergraduates and showed the need to study the group of students that allow AI to complement their problem-solving skills more.

Generative AI Adoption and Metacognitive Awareness among University Students

The adoption of generative artificial intelligence (GenAI) in higher education has brought to the fore a new set of challenges about the interaction of students with AI and the implications on their academic performance, and their awareness and regulation of their thinking. Metacognitive awareness entails knowledge of one's own thinking and the ability to plan, control, and evaluate one's own learning. This is highly relevant to the interaction of GenAI by the fact that AI answers compel the user to decide what is relevant and useful, and to determine the correctness of the answer and the need for further rationale and verification. Zhou, X et al. (2024) state that in generative-AI-supported learning, metacognitive processes are crucial as students must control their interaction with AI and are not to take its outputs as final. From this standpoint, GenAI may serve as a cognitive tool to foster critical thinking and learning when students' interaction with AI is centered on questioning, assessing, and improving the outputs generated by the AI. Ironically, the same tool may be detrimental to metacognitive thinking when students engage with AI in a passive manner.

New studies show that students' use of GenAI has a direct influence on their metacognitive awareness. In Na-songkhla, J et al. (2024), while assessing university students' attitudes toward GenAI, it was found that metacognitive awareness was directly linked with students' attitudes toward generative AI. Their results indicate that students with a greater awareness of their cognitive processes may perceive AI technologies in a more critical manner than students with a relatively lower level of metacognitive capacity. Students with developed metacognitive skills are more likely to recognize their knowledge gaps, discern when it may be appropriate to utilize AI, and assess whether the AI information meets the learning goal. Because of this, metacognitive awareness may determine whether GenAI is viewed as a cognitive support tool or as a way to avoid self-learning. This difference is vital because the educational impact of the adoption of GenAI may be more about the nature of students' interactivity with GenAI and the extent of self-regulation of this interactivity, rather than the habitual adoption of GenAI.

The adoption of GenAI and metacognitive awareness also relates to the concept of self-regulated learning. Frequently, when students use GenAI to seek an explanation, develop an example or receive feedback, they may engage in metacognitive activities

by comparing the AI output with the cognitive process input, and identifying their own learning gaps. However, this is highly dependent on active involvement by the students. Hoßbach, C et al. (2025), noted that students' perceived impact of GenAI on their learning was associated with their personal AI skills, indicating that students possess vary degrees of critical use of AI. Students who better understand AI might be able to adjust to using AI in the classroom without outsourcing control of their thinking. Newer studies regarding students and their use of GenAI to solve problems show using AI might mean varying levels of outsourcing cognitive tasks to AI. Findings like this reinforce the need for students to practice metacognitive self-control, since students need to be able to understand when AI can aid cognitive tasks and when working with AI may dominate and disrupt cognitive tasks.

Research Gap

The rapid growth of research on generative AI in higher education has created a large research void and a lack of studies on the cognitive processes of using GenAI and how it impacts problem-solving in university students. GenAI has been found to help with creative complex problem-solving, where Urban et. al (2024) found that university students' problem-solving and creativity improved when they used ChatGPT, and Du et al. (2025) have said that AI helps with complex problems and even supports high-order thinking. For the most part, these studies focused on the outcome of AI and what cognitive tasks were supported, leaving the rest of students unaccounted for when using GenAI. Research has described cognitive flexibility and metacognitive awareness as pertinent traits among students' engagements with GenAI. While some evidence has shown interests, perceptions, technology-related behaviors, and even performances in problem-solving (Karaoglan Yilmaz & Yilmaz, 2025), many studies have shown a lack thereof. In addition, some of the recent research has shown the importance of metacognition for the monitoring and control of learning augmented with the assistance of AI. This is especially the case since students have to make judgments on the accuracy and relevance of the information provided by AI (Teng, 2025). However, research on the mediation of metacognitive awareness of cognitive flexibility and the acceptance of GenAI as it pertains to problem-solving is almost nonexistent. Because of this, it is undetermined whether students with flexible cognition and higher engagement with GenAI solve problems better, as a result of higher metacognitive awareness and self-regulation of their engagement with AI. This study aims to fill this research gap, incorporating the metacognitive awareness of GenAI use and cognitive flexibility, to improve understanding of problem-solving performance.

Hypotheses of the Study

H1: There is a significant positive relationship between cognitive flexibility, generative AI adoption, metacognitive awareness, and problem-solving performance among university students.

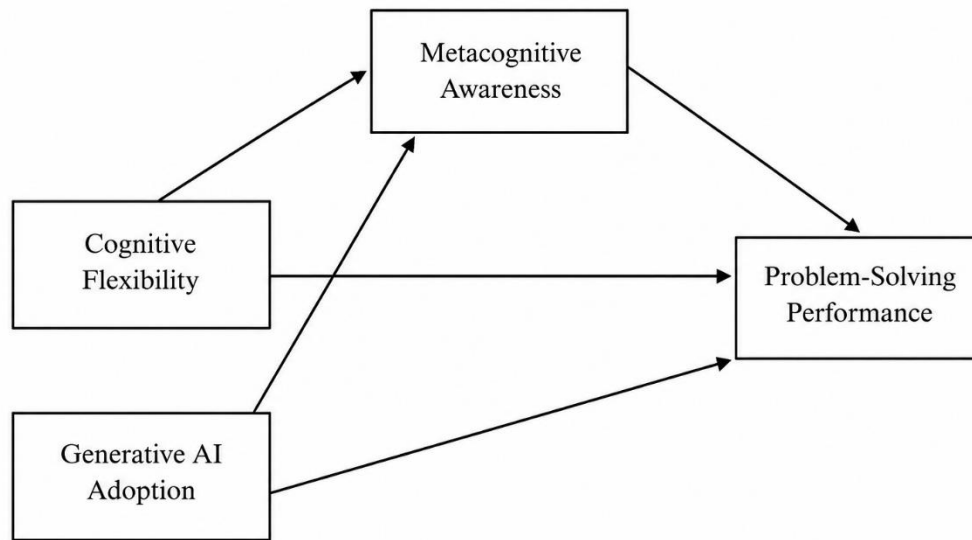
H2: Cognitive flexibility, generative AI adoption, and metacognitive awareness significantly predict problem-solving performance among university students.

H3: There is a significant difference in problem-solving performance among university students across different levels of generative AI adoption.

H4: Metacognitive awareness significantly mediates the relationship between cognitive flexibility and problem-solving performance among university students.

H5: Metacognitive awareness significantly mediates the relationship between generative AI adoption and problem-solving performance among university students.

Conceptual Framework



Methodology

Research Design

The study utilized a quantitative, cross-sectional design. Data were largely collected using a structured questionnaire as the study aimed to quantify cognitive flexibility, generative AI adoption, metacognitive awareness and problem-solving performance, and to identify the statistical relations among the variables. A cross-sectional study design was justified since data collection was performed once at a specific point in time, as opposed to multiple time-bound data collection points.

Population of the Study

The study focused on university students across the higher education institutions of Punjab and Sindh, Pakistan. Students from varying academic disciplines and levels were sampled to increase the likelihood of reaching university student populations that have been exposed to both digital learning and the generative AI technologies. A number of universities were included to reflect the population in the Punjab province: Bahauddin Zakariya University, Multan; The Islamia University of Bahawalpur; University of the Punjab, Lahore; Government College University, Lahore; University of Sargodha. For the Sindh province: University of Sindh, Jamshoro; Shah Abdul Latif University, Khairpur; University of Karachi; Dow University of Health Sciences, Karachi. The study aimed to avoid the limitation of a single university or local study, and to best capture the disparate educational and technological contexts of students across both provinces.

Target Audience

The intended population consisted of university students (both undergraduate and postgraduate) who are currently enrolled and able to complete an online survey in English. Based on their use of digital educational tools as well as generative AI (G AI) technology (including ChatGPT, Gemini, Microsoft Copilot, and other AI-based tools), students who are familiar with generative AI applications were able to participate in the study. The study examined the cognitive and educational consequences of G AI tools on the higher education sector.

Sampling Technique

The sampling technique used to recruit the participants was a non-probability convenience sampling technique as the questionnaire was distributed electronically and participation was based on the approachability and willingness of the students. There was also a purposive eligibility criterion in which only currently enrolled university students were the proposed subjects of this study. The sampling method gave the opportunity for students from various universities and different academic fields within the province of Punjab and Sindh to take part in the study. Convenience sampling provided a method to reach a widespread student population, but the sampling methodology was acknowledged as a limitation for the results, since a non-probability sampling method does not provide the same population representativeness as a probability-based sampling method.

Sample Size

The total number of participants who submitted a valid survey was 477. This sample population was adequate to determine the relationships between various educational and psychological concepts as well as the applicability of multiple statistical calculations. The final results included responses that met the conditions of the study as well as the requirements for the statistical analyses.

Data Collection Procedure

Data were collected via a structured online survey using Google Forms. The survey was in English and was sectioned by demographics, cognitive flexibility, generative AI adoption, metacognitive awareness, and problem-solving performance. A link to the survey was posted digitally to eligible university students via academic and student communication networks. Students were provided information about the study, told participation was voluntary, and surveyed at their convenience. Responses to the posted survey were digitally recorded by Google Forms. After the data collection period, responses were downloaded from Google Forms and uploaded to Microsoft Excel for preliminary organization, screening, and formatting. The dataset was posted to IBM SPSS Statistics for analysis.

Measurement Scales and Questionnaire Development

The majority of the sections of the survey were based on previously published measures that had been issued for study, and the psychometric measures were based on adaptations and contextual adjustments from the university student and generative-AI. Minor adaptations were required to ensure that the items specifically referenced the students' contemporary learning experiences. These minor adaptations, however, did not change the meaning of the original constructs.

Cognitive flexibility was assessed using the Cognitive Flexibility Inventory (CFI) (Dennis & Vander Wal, 2010). The CFI is a 20-item measure consisting of two dimensions, flexibility of alternatives and flexibility of control. This measure was designed to assess one's ability to create different explanations and solutions, as well as one's ability to view difficult situations as controllable. The CFI utilizes a Likert response format. The CFI has been used frequently to measure cognitive flexibility of adults and university students.

Metacognitive awareness was assessed using the Metacognitive Awareness Inventory (MAI) (Schraw & Dennison, 1994). The original MAI was a 52-item instrument that consisted of two large, overarching areas of cognition: the knowledge of cognition and the regulation of cognition. The knowledge of cognition contained the declarative, procedural, and conditional knowledge, while the regulation of cognition included planning, managing, monitoring, and evaluation of information. This measure was designed to assess university students' awareness of their cognitive processes and has been frequently used with adults.

Generative AI was assessed using a modified technology-adoption questionnaire using the Technology Acceptance Model (TAM) (Davis, 1989). In this study, the adoption items measured university students' perceptions and engagement with generative AI in terms of its usefulness, its ease of use, and their willingness to use AI tools to support their studies. According to Davis (1989), the perceived usefulness and the perceived ease of use of a technology are the primary drivers of the technology's adoption. These constructs have been utilized in a number of studies that examine the adoption of digital technologies by students.

For the current research, the original technology acceptance framework wording was modified to make items refer to the use of generative AI tools in university learning, rather than the use of information systems generally. Problem-solving performance was measured using the Social Problem-Solving Inventory-Revised (SPSI-R) by D'Zurilla, Nezu, and Maydeu-Olivares (2002). The SPSI-R offers a multidimensional measurement of positive and negative problem-solving, rational problem-solving, along with the impulsivity/carelessness, and avoidance dimensions. The rational problem-solving dimension discusses the defining of the problem, the generation of alternative solutions, as well as the choice and the implementation and verification of the solution. The instrument has shown good psychometric properties. In the current study, items were modified to relate to the problem-solving issues that students encounter. Since the instrument is Self-Report, the adapted construct was understood as perceived problem-solving performance/ability (i.e., self-report problem-solving performance ability), rather than as an objective score of a standardized problem-solving instrument.

The Likert-type measurement scale was used to gauge all of the constructs in the questionnaire. This scale was used to ascertain the extent to which each statement captured the respondents' views, experiences, and/or behaviors. The adapted questionnaire was given a contextual relevance check prior to administration. A subsequent reliability analysis was performed to assess the internal consistency of the scales.

Ethical Considerations

Upholding ethics was crucial throughout the various stages of the study. Participation was always voluntary, and the participants were briefed about the purpose of the study in general, before they filled the questionnaire. The participants were free from providing personally identifiable information, and the responses provided were treated with utmost confidentiality. Participants were made aware that they had the right to withdraw from the study at any point in time and that they would not experience any academic repercussions as a result of their withdrawal. The responses were treated with the utmost respect and were not used or analyzed outside the scope of this study. The design of the online questionnaire ensured that the participants were able to fill the questionnaire without the need to provide sensitive information. The information was stored in a secure format, and the only people who were able to access the information were those who were conducting the study. The study further upheld the ethics of informed participants, confidentiality, anonymity, and the ethical stewardship of the data generated.

Data Analysis

The responses were collected and the questionnaires closed. The responses were first collected from Google Forms, and then transferred to Microsoft Excel. The data was reviewed for missing responses, and for accuracy in the coding process, duplicate responses, and data entry errors. The data set was in a preliminary cleaned and organized process. The data set in Excel was transferred to IBM SPSS for data analysis. Descriptive statistics were used and were the primary study variables for the survey, in order to present a summary of the demographic characteristics of the respondents. For the demographic variables that were categorical, their associated frequencies and percentages were calculated, while for the continuous variables that were of a scale, their means and standard deviations were calculated.

The adopted and adapted questionnaire scales' internal consistency was evaluated with Cronbach's alpha. Then, Pearson product-moment correlation analysis was used to examine the relationships of cognitive flexibility, generative AI adoption, metacognitive awareness, and problem-solving performance. Next, the extent to which cognitive flexibility, generative AI adoption, and metacognitive awareness predicted problem-solving performance was determined through multiple linear regression analysis and the combined effect of the predictors.

When using t-tests to compare two groups where the generative AI adoption was classified into appropriate comparison groups, we used independent-samples t-tests. With three or more classified groups of GenAI adoption, one-way ANOVA was used to assess the problem-solving performance among those groups. If an overall statistically significant ANOVA was reported, Tukey's HSD or any other suitable post-hoc multiple-comparisons procedure was applied to find the groups among which significant differences were reported. Several assumptions, including normality, linearity, independence, and homoscedasticity, as well as the adequacy of multicollinearity concerning regression analysis, were assessed prior to reporting the inferential analyses.

Mediation analysis was performed to assess the role of metacognitive awareness as a mediator. This was done to assess the relations of cognitive flexibility and problem-solving performance, as well as the relations of generative AI adoption and problem-

solving performance. To analyze the indirect effects, a bootstrapping technique was used, for which confidence intervals of the indirect effects were computed. This technique is appreciated for its utility in mediation analyses. All analyses were performed in SPSS. Mediation analyses were performed using the PROCESS macro. To evaluate the practical significance of the results, effect sizes and confidence intervals were considered in addition to p-values.

Table 1: Demographic Characteristics and Generative AI Usage Profile of University Students (N = 477)

Demographic Variable	Category	Frequency (f)	Percentage (%)
Gender	Male	258	54.1
	Female	219	45.9
Age	18–20 years	126	26.4
	21–23 years	188	39.4
	24–26 years	103	21.6
	27 years and above	60	12.6
Academic Level	Undergraduate	327	68.6
	Master's	112	23.5
	MPhil/MS	30	6.3
	PhD	8	1.7
Academic Discipline	Social Sciences	103	21.6
	Computer Science/IT	94	19.7
	Business/Management	82	17.2
	Health Sciences	76	15.9
	Engineering	63	13.2
	Education	35	7.3
	Other disciplines	24	5.0
Province	Punjab	287	60.2
	Sindh	190	39.8

Demographic Variable	Category	Frequency (f)	Percentage (%)
Frequency of GenAI Use	Rarely	72	15.1
	Occasionally	121	25.4
	Sometimes	146	30.6
	Frequently	91	19.1
	Very frequently	47	9.9
Most Frequently Used GenAI Tool	ChatGPT	286	60.0
	Google Gemini	76	15.9
	Microsoft Copilot	43	9.0
	Claude	31	6.5
	Other GenAI tools	41	8.6

The data analysis revealed that this study included 477 university students of which 54.1% were males and 45.9% were females. The majority were in the 21-23 year age group (39.4%). The remaining age groups were 18-20 years (26.4%), 24-26 years (21.6%), and 27 years and older (12.6%). The majority of the participants in this study were at the undergraduate level (68.6%). The remaining participants were master's (23.5%), MPhil/MS (6.3%), and PhD (1.7%) students. Social Sciences were the largest group of participants (21.6%) followed by Computer Science/IT (19.7%), Business/Management (17.2%), Health Sciences (15.9%), Engineering (13.2%), Education (7.3%), and other fields (5.0%). The participants were primarily from Punjab (60.2%) and Sindh (39.8%). Concerning generative AI, 30.6% used GenAI for that purpose sometimes, 25.4% used it occasionally, 19.1% used it frequently, 15.1% used it rarely, and 9.9% used it very frequently. The most popular GenAI platform was ChatGPT (60.0%) followed by Google Gemini (15.9%), Microsoft Copilot (9.0%), Claude (6.5%), and other GenAI (8.6%). The profile of participants in this study reflects a wide range of demographics and fields of study. A large number of participants used generative AI for educational purposes.

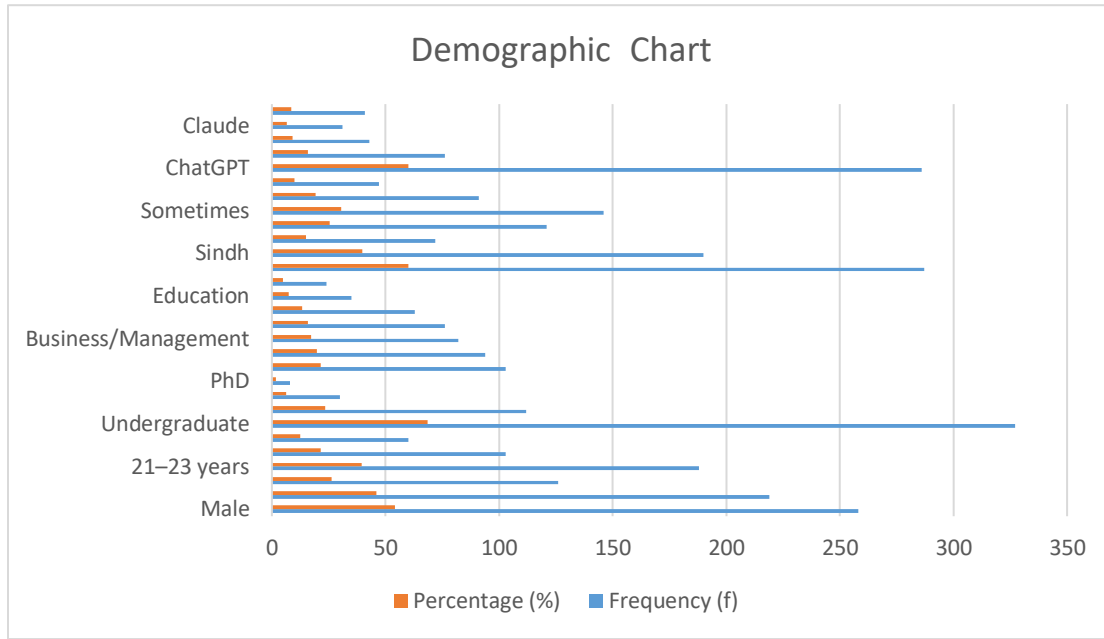


Fig. 1 Demographic Chart

Table 2: Pearson Correlation among Cognitive Flexibility, Generative AI Adoption, Metacognitive Awareness, and Problem-Solving Performance (N = 477)

Variables	1	2	3	4
1. Cognitive Flexibility	1			
2. Generative AI Adoption	.426**	1		
3. Metacognitive Awareness	.583**	.497**	1	
4. Problem-Solving Performance	.612**	.548**	.671**	1

Note. $p < .01$ (2-tailed). $N = 477$.

The Pearson correlation results indicated significant positive correlations among the study variables. Cognitive flexibility was positively associated with the generative AI adoption ($r = .426$, $p < .01$), metacognitive awareness ($r = .583$, $p < .01$), and problem-solving performance ($r = .612$, $p < .01$). Generative AI adoption was also positively correlated with metacognitive awareness ($r = .497$, $p < .01$) and problem-solving performance ($r = .548$, $p < .01$). The strongest correlation was found between metacognitive awareness and problem-solving performance ($r = .671$, $p < .01$), suggesting that students with higher metacognitive awareness reported higher problem-solving performance. The results reveal positive correlations between cognitive flexibility, generative AI adoption, metacognitive awareness, and problem-solving performance. The results justify additional regression and mediation analyses.

Table 3: Multiple Regression Analysis of Cognitive Flexibility, Generative AI Adoption, and Metacognitive Awareness Predicting Problem-Solving Performance (N = 477)

Predictor Variable	B	SE	β	t	p
Constant	0.842	0.184	—	4.576	<.001
Cognitive Flexibility	0.286	0.052	.264	5.500	<.001
Generative AI Adoption	0.219	0.047	.213	4.660	<.001
Metacognitive Awareness	0.418	0.049	.387	8.531	<.001

Model Statistics**Value**

R	.731
R ²	.534
Adjusted R ²	.531
F	180.61
p	<.001

The multiple regression analysis revealed that cognitive flexibility, generative AI use, and metacognitive awareness all positively predicted problem-solving performance within university students, $F(3, 473) = 180.61$, $p < .001$. The regression output indicates the model produced $R = .731$ and $R^2 = .534$, and thus the model explained approximately 53.4% of the variance in problem-solving performance. Cognitive flexibility had a positive and significant effect on problem-solving performance ($\beta = .264$, $p < .001$). The result suggests that students with greater cognitive flexibility exhibited greater problem-solving performance. Generative AI use was also a positive significant predictor ($\beta = .213$, $p < .001$), and thus, greater use of Generative AI was associated with greater problem-solving performance. Of the three, the strongest was metacognitive awareness ($\beta = .387$, $p < .001$). The result indicates that students with greater awareness and control of their thinking exhibited higher problem-solving performance. In total, each of the three predictors positively and significantly related to problem-solving performance.

Table 4: Differences in Problem-Solving Performance across Levels of Generative AI Adoption (N = 477)

Source of Variation	Sum of Squares	df	Mean Square	F	p
Between Groups	28.416	2	14.208	24.673	<.001
Within Groups	272.847	474	0.575		
Total	301.263	476			

Group Descriptive Statistics

Generative AI Adoption Level	n	Mean	SD
Low	119	3.21	0.61
Moderate	227	3.58	0.57
High	131	3.91	0.54
Total	477	3.59	0.63

The one-way ANOVA found that generative AI adoption levels impacted problem-solving performance, $F(2, 474) = 24.673$, $p < .001$, with low GenAI adoption students showing significantly lower performance levels ($M = 3.21$, $SD = 0.61$) than the moderates ($M = 3.58$, $SD = 0.57$) and highest performers with high GenAI ($M = 3.91$, $SD = 0.54$). The significant overall F-test demonstrated a difference in problem-solving performance in at least two groups. In such case, a Tukey HSD post-hoc analysis is warranted.

Table 5: Mediation Analysis of Metacognitive Awareness in the Relationships Between Cognitive Flexibility, Generative AI Adoption, and Problem-Solving Performance ($N = 477$)

Mediation Path	Effect (B)	SE	t	p	LLCI	ULCI
Cognitive Flexibility → Metacognitive Awareness	0.584	0.041	14.244	<.001	0.503	0.665
Metacognitive Awareness → Problem-Solving Performance	0.421	0.043	9.791	<.001	0.337	0.505
Cognitive Flexibility → Problem-Solving Performance (Total Effect)	0.498	0.047	10.596	<.001	0.406	0.590
Cognitive Flexibility → Problem-Solving Performance (Direct Effect)	0.252	0.049	5.143	<.001	0.156	0.348
Indirect Effect through Metacognitive Awareness	0.246	0.032	—	—	0.186	0.313

Table 6: Mediation Analysis of Metacognitive Awareness between Generative AI Adoption and Problem-Solving Performance ($N = 477$)

Mediation Path	Effect (B)	SE	t	p	LLCI	ULCI
Generative AI Adoption → Metacognitive Awareness	0.497	0.044	11.295	<.001	0.411	0.583
Metacognitive Awareness → Problem-Solving Performance	0.408	0.044	9.273	<.001	0.322	0.494
Generative AI Adoption → Problem-Solving Performance (Total Effect)	0.433	0.048	9.021	<.001	0.339	0.527
Generative AI Adoption → Problem-Solving Performance (Direct Effect)	0.230	0.050	4.600	<.001	0.132	0.328
Indirect Effect through Metacognitive Awareness	0.203	0.030	—	—	0.148	0.266

Results from the mediation analysis indicated that the relationship between cognitive flexibility and problem-solving performance was partially mediated by metacognitive awareness. Cognitive flexibility was a significant predictor for metacognitive awareness ($B = 0.584, p < .001$), and metacognitive awareness was a significant predictor of problem-solving performance ($B = 0.421, p < .001$). The effect of cognitive flexibility on problem-solving performance was significant ($B = 0.498, p < .001$). The direct effect of cognitive flexibility on problem-solving performance was significant ($B = 0.252, p < .001$), after metacognitive awareness was added to the model. The indirect effect of metacognitive awareness was significant with a value of 0.246 and a bootstrapped 95% confidence interval of [0.186, 0.313]. A similar pattern was found when looking at the mediation model of generative AI adoption, metacognitive awareness, and problem-solving performance. Generative AI adoption was a significant predictor of metacognitive awareness ($B = 0.497, p < .001$), and metacognitive awareness was a significant predictor of problem-solving performance ($B = 0.408, p < .001$). The indirect effect of metacognitive awareness in the generative AI adoption model was 0.203 with a bootstrapped 95% confidence interval of [0.148, 0.266], and was significant. The direct effects of generative AI on problem-solving performance were also significant after metacognitive awareness was included, indicating that the proposed mediation model was partially supported.

Discussion

The current research explored cognitive flexibility, generative AI adoption, metacognitive awareness, and problem-solving performance. The findings showed strong relationships among all variables. Cognitive flexibility, generative AI adoption, and metacognitive awareness predicted problem-solving performance. It appears students' problem-solving performance is influenced by the use of advanced AI technologies, cognitive flexibility, and metacognitive regulation. This is in line with recent studies that showed if students are involved in the learning process, generative AI can facilitate the development of higher-order thinking and problem-solving (Hsu, L 2025; Bezugla, I et al., 2025).

The finding that cognitive flexibility relates to constructive problem-solving indicates students that are able to adjust and consider different points of view are better equipped to tackle multifaceted problems. The current correlation ($r = .612, p < .01$) and regression ($\beta = .264, p < .001$) results substantiate this finding. This finding is in line with Şimşek, A et al., (2025), who identified cognitive flexibility as an important trait of university students' engagement with generative AI. Cognitive flexibility gives the students the ability to go beyond one answer, and one of the numerous methods to answer the problem, which was generated either by the students themselves or through the AI-assisted learning process.

Generative AI adoption and problem-solving performance had a positive correlation ($r = .548, p < .01$) with performance being a function of the adoption rate ($\beta = .213, p < .001$). The problem-solving performance of students who adopted GenAI extensively was higher than the performance of students who adopted GenAI to a lesser degree. The findings extend the work of Zheng, H et al. (2025), who found that problem-solving performance of university students who work with ChatGPT to solve problems was higher than the performance of students who solve problems without ChatGPT. The findings of Lee, H et al. (2024) suggest that the use of AI help students engage in problem-solving performance that incorporates thinking at higher levels. The findings of the studies cited above and the current study do not suggest that the use of AI in the educational space will lead students to engage in independent thinking of a higher level, as the independent thinking of students is a function of how the students make sense of the AI output and how they evaluate the AI output.

Problem-solving performance had the strongest positive correlation with metacognitive awareness ($r = .671, p < .01$) and was the strongest predictor of problem-solving performance ($\beta = .387, p < .001$). This means that students who are good at monitoring and controlling their thinking when solving problems do a better job at solving problems. This result is similar to that of Tankelevitch, L et al., (2024), who, when focusing on the engagement of students with GenAI, mentioned metacognitive awareness. In learning with AI, metacognitive awareness may help students to assess whether an AI system gave the correct answer, find the shortcomings of their logic, and think whether more independent work is necessary.

The mediation role of metacognitive awareness was the key finding. According to mediation analysis, metacognitive awareness mediated the cognitive flexibility and problem-solving performance relationship, and the same was true for the relationship between GenAI adoption and problem-solving performance. Since the direct effects of cognitive flexibility and GenAI adoption on problem-solving performance remained significant following the addition of metacognitive awareness to the model, metacognitive engagement was assumed to be helpful to cognitive flexibility and the adoption of GenAI, in the context of improving one's problem-solving performance. Although the use of AI offers students different alternatives, the effectiveness of

the resource depends on the students' ability to monitor, assess, and regulate the use of the alternatives. Recent studies have focused on the role of metacognitive regulation in the use of generative AI in the learning process (Karaoglan Yilmaz & Yilmaz, 2025), which further supports this finding.

The findings define the boundaries of what metacognitive regulation, generative AI, and cognitive flexibility can achieve and illustrate that merely using technology does not equate to AI-enabled problem-solving. The findings support the need to fuse GenAI skills, metacognitive skills, and critical thinking skills in higher education. Students should be guided to go beyond AI in answer generation and to consider, assess, challenge, and improve AI outputs. This study also supports the call for research based on a solid methodological framework, taking into account that current findings are correlational in nature due to the cross-sectional, self-report data, and establishing the relationships between the studied variables. This can be achieved by using experimental tasks and objective measures of GenAI.

Conclusion

This study identified cognitive flexibility, generative AI adoption, and metacognitive awareness as important factors impacting university students' problem-solving performance. Findings revealed significant positive associations and demonstrated that cognitive flexibility, generative AI, and metacognitive awareness contributed to problem-solving performance. Students who adopted GenAI to a greater extent achieved higher problem-solving performance than students who adopted GenAI to a lesser extent. Among the predictors, metacognitive awareness made the strongest contribution, indicating that students' planning, monitoring, and evaluation of their cognitive processes are important when dealing with complex problem-solving in the academic environment. Findings imply that the educational potential of generative AI goes beyond the availability of technology, and hinges on the way students engage with the information generated by the AI at the cognitive level.

Interestingly, the mediation analysis showed that metacognitive awareness partially mediated the relationship between cognitive flexibility and problem-solving performance, as well as the relationship between generative AI adoption and problem-solving performance. This suggests that adaptive thinking and the use of GenAI contribute to enhanced problem-solving performance, in part, through the ability of students to regulate and evaluate their thinking. Overall, the study emphasizes that AI-assisted learning, effective use of technology, and a combination of cognitive and metacognitive flexibility, is the goal of learning. Consequently, higher education institutions should promote the use of GenAI as a cognitive resource, while engaging students in independent, critical, and reflective learning. The results offer value as a framework for understanding the possible cognitive structures and systems that shape university learning and incorporate the generative AI of the present.

Recommendations

1. Integrate GenAI literacy into university curricula to promote responsible and academically productive use of generative AI.
2. Develop students' metacognitive skills through activities that encourage planning, monitoring, self-evaluation, and reflection during AI-supported learning.
3. Strengthen cognitive flexibility by using problem-based learning activities that require students to consider multiple perspectives and alternative solutions.
4. Encourage critical evaluation of AI-generated content so that students verify accuracy, identify errors, and compare AI responses with reliable academic sources.
5. Use GenAI as a learning support rather than a replacement for independent reasoning, particularly during complex problem-solving tasks.
6. Train university teachers in AI-supported pedagogy so they can design learning activities that combine GenAI use with higher-order thinking and metacognitive regulation.

7. Conduct longitudinal and experimental research using objective problem-solving tasks and actual AI-use measures to further establish the long-term effects of GenAI adoption on students' cognitive development.

Future Implications

This study examines the possible futures of higher education and the ways in which generative AI will likely become a growing feature of teaching and learning and the solving of academic problems. Education will likely need to go beyond the simple provision of access to AI technologies and begin to design educational systems that develop students' cognitive flexibility and metacognitive awareness, as well as their critical appraisal skills and their understanding of the responsible use of AI. Future teaching practices may involve the design of AI-enhanced problem-solving activities where students work with AI to produce solutions, then identify errors, provide a rationale for their answer, and consider the impact of AI on their learning. The study also provides a foundation for researchers to study these issues using longitudinal and empirical studies, and to investigate problem-solving skills and the use of AI in various academic fields and educational settings. This type of research may examine the impact of GenAI on students' cognitive skills and the unintended consequences of cognitive offloading. Future studies and educational practices should aim to create a human-AI learning environment where generative AI is a supplement to students' independent thought and problem-solving skills and their cognitive skills.

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