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CONVENIENCE AT THE COST OF COGNITION? THE MEDIATING ROLE OF COGNITIVE ENGAGEMENT BETWEEN GENERATIVE AI USE AND CRITICAL THINKING

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Abstract
As Generative Artificial Intelligence (GenAI) becomes an increasingly common tool in higher education, it has sparked several significant concerns regarding its impact on students' critical thinking skills. While GenAI tools can help students access information, explanations, and academic help quickly, over-reliance on these tools can reduce the amount of independent intellectual work. This study investigates the association between the use of GenAI and critical thinking among university students, focusing on the mediating effect of cognitive engagement. A cross-sectional survey was undertaken using a quantitative approach with 400 undergraduate and postgraduate students in Pakistan. Partial Least Squares Structural Equation Modelling (PLS-SEM) was used to analyse the data. The results indicate strong positive correlations among the use of GenAI, critical thinking, and cognitive engagement, as well as between cognitive engagement and critical thinking. Additionally, cognitive engagement fully mediates the relationship between GenAI use and critical thinking. The results underscore the need for students to be cognitively engaged when applying GenAI in their learning. The study adds to the body of knowledge on AI-supported learning by highlighting the need for cognitive engagement in comprehending the link between using GenAI and critical thinking. In practice, it suggests that universities encourage responsible use of GenAI by conducting critical analysis, independent thinking, and reflective learning. In general, the study indicates that the educational value of GenAI is not just about its applications, but also about how engaged students are with the information that is produced.
Keywords: *Generative Artificial Intelligence, GenAI Use, Cognitive Engagement, Critical Thinking, University Students, Higher Education, PLS-SEM.*

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Introduction

In the field of higher education, generative artificial intelligence (GenAI) has become a powerful technological advancement, revolutionizing the way university students access information, perform academic tasks, and interact with learning resources. These tools, like ChatGPT, Google Gemini, and Microsoft Copilot, give explanations, summarise academic content, give feedback, and help with problem-solving. As they become more accessible, they are also providing opportunities for personalised learning and academic support, and have raised concerns about students' independent reasoning, intellectual work, and critical thinking skills (Kasneci et al., 2023; UNESCO, 2023; Tlili et al., 2023). Generative AI systems can generate responses that are context-specific and can be used in a conversational format, enabling students to get immediate help and learn about academic subjects in various ways. As a result, GenAI is gaining significance in today's university learning environments.

The use of GenAI in higher education has sparked discussion on how it affects student learning and thinking. On the other hand, AI-powered learning makes complex concepts comprehensible, allows students to delve deeper into other interpretations, and provides timely academic support. However, over-reliance on AI-generated answers diminishes the need for independent information processing, problem-solving, and analytical thinking (Kasneci et al., 2023; UNESCO, 2023). An important question is whether the convenience of generative AI increases students' critical thinking skills or whether it is an invitation to give up on their own thinking and rely on external information provided by the AI system. This is especially important since critical thinking is still regarded as one of the key graduate outcomes that help people to understand information, assess evidence, recognize assumptions, and reach logical conclusions (Facione, 1990; Halpern, 2013).

It is generally accepted that critical thinking is a key skill that students should develop during their university education, as they should not only be able to receive information but also evaluate its validity and implications. It includes a series of related cognitive abilities such as interpretation, analysis, evaluation, inference, explanation and self-regulation (Facione, 1990). Today, students are facing vast amounts of digital information, including AI-generated content, in their academic settings. Hence, it is important to be able to identify information that is accurate from that which is incorrect or misleading. While it allows for access to knowledge, GenAI answers are incorrect, references may be made to nonexistent or fabricated sources, or explanations may be missing. Students are thus required to think for themselves and not take information on faith (Bender et al., 2021; Kasneci et al., 2023). This is a critical area of educational research, as it relates to the relationship between the use of GenAI and critical thinking.

A potential risk of generative AI is that it could lead to cognitive offloading, or the use of external tools that offload the cognitive processes that would otherwise take place in the human mind. People often use external aids and environmental supports to help them remember, process information, and make decisions (Risko & Gilbert, 2016). While using external resources is efficient, overreliance on external resources can decrease the opportunity to practice some cognitive processes. In higher education, students relying on GenAI to create explanations, solve problems, or compose assignments are less engaged in the mental processes that foster independent thinking. Cognitive offloading, however, does not always have negative learning effects, as the effects are dependent on the type of task and on how external help is used. Hence, educational implications of GenAI should be analyzed with consideration of not only usage frequency but also the cognitive processes involved in the usage.

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Cognitive engagement is an important factor that helps to understand the correlation between the use of GenAI and critical thinking. Cognitive engagement is the mental investment, concentration, strategic learning, and effort that students put into academic activities (Fredricks et al., 2004). It shows how well students engage with information, relate new information to what they already know, think about what they are learning, and use strategies to solve problems. In an AI-enabled learning environment, the key is whether students are using generative AI to enhance their learning, or are just getting answers done for them. Students who use AI-generated explanations as a point of departure for further research, compare alternatives, and critically analyze the information given are engaged in learning. In contrast, students who provide a "yes" or "no" answer without thinking critically exhibit low-level thinking.

The concept of cognitive engagement is explained using the Interactive, Constructive, Active and Passive (ICAP) framework proposed by Chi and Wylie (2014). The framework proposes that various types of student engagement are linked to varying levels of cognitive engagement and learning. Passive engagement is receiving information, while active engagement is simple manipulation of learning materials. Constructive engagement involves the learner(s) generating new ideas, explanations, or inferences, and interactive engagement involves collaborative knowledge construction. In the context of GenAI in education, this approach implies that students gain more educational value by actively building their knowledge by interacting with AI tools than by receiving generated content. Therefore, cognitive engagement is an important pathway between the use of GenAI and students' critical thinking skills.

Recent studies have explored the potential of generative AI in higher education and the obstacles that must be overcome. Kasneci et al. (2023) explored the use of LLMs to assist personalised learning, explain concepts, and offer academic support, and raised issues around accuracy, reliability, and students relying on AI-generated content. Likewise, Tlili et al. (2023) pointed out the educational potential of ChatGPT and the ethical and pedagogical issues that arise from using it. UNESCO (2023) also highlighted the importance of human-centred approaches, institutional guidance, and responsible integration of generative AI in education. The discussions suggest that the educational implications of GenAI are complex and are not limited to using or not using these tools.

While previous research has investigated students' uptake, usefulness, academic applications, and educational challenges of GenAI, there is a need for further research to explore the cognitive mechanisms that link the use of GenAI with critical thinking. Specifically, there is a need to focus on the role of cognitive engagement, as AI-generated information does not necessarily lead to meaningful learning or independent thinking. It is crucial to differentiate between the use of GenAI for intellectual support and for replacing personal efforts in order to understand its impact on students' cognitive development. Considering cognitive engagement as a mediator gives a more holistic understanding of the link between GenAI use and critical thinking.

It is especially pertinent in the context of higher education, where universities are facing the challenges and opportunities of new technologies in education, such as in Pakistan. Students use generative AI to learn academic concepts, complete assignments, summarise information, and seek help with academic-related tasks. But the use of these tools is shaped by variations in digital literacy, academic support, and responsible technology use. The findings indicate that the use of GenAI is related to students' cognitive involvement and critical thinking skills, which offers valuable insights for educators and higher education institutions interested in adopting GenAI in educational practices.

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Given these considerations, the present study aims to explore the relationship between the use of GenAI and critical thinking among university students, focusing on the mediating role of cognitive engagement. In particular, it examines the relationship between GenAI use and students' critical thinking skills, the relationship between GenAI use and students' cognitive engagement, and whether there is an indirect relationship between GenAI use and critical thinking through students' cognitive engagement. The study is guided by the cognitive offloading perspective (Risko & Gilbert, 2016), the student engagement perspective (Fredricks et al., 2004), and the ICAP framework (Chi & Wylie, 2014). The study aims to link students' usage of generative AI with their cognitive engagement and critical thinking skills by combining these viewpoints.

The study contributes by focusing on the cognitive processes involved in the educational use of GenAI, rather than on the adoption and frequency of use. The results it provides guide educators at universities to create learning activities that prompt students to critically analyze AI-generated content, provide evidence and draw their own conclusions. The study concludes that it is vital to keep meaningful cognitive engagement in the context of the use of generative AI in higher education.

Literature Review

Generative AI Use in Higher Education

Generative artificial intelligence (GenAI) has grown in significance for higher education, providing students with access to information, explanations, summarisation of academic content, and support for learning activities. In contrast to conventional digital learning technologies, GenAI systems generate context-specific answers in response to conversations, enabling students to learn flexibly about academic material. ChatGPT and like technologies can help brainstorm ideas, provide writing support, clarify concepts, and assist with problem-solving, which may enhance the accessibility of educational resources (Kasneci et al., 2023; Tlili et al., 2023). These features have sparked students' curiosity about the use of generative AI in their learning.

The potential of GenAI for education goes beyond its technological utility, however. The impact of its usage is influenced by students' purposes, frequency of use, and their degree of engagement in processing AI-generated information (Abbas et al., 2024). Some students use GenAI to explain complex concepts and to look at things from different angles, while others rely on GenAI to generate pre-prepared academic answers. UNESCO (2023) emphasizes the need for human-centred approaches to generative AI in education, including issues of academic integrity, information accuracy, and the maintenance of human agency. Likewise, Kasneci et al. (2023) highlight opportunities and obstacles to integrating large language models in the educational context. This implies that the study of GenAI should not be restricted to an academic context but should also include an understanding of the cognitive processes involved in using it.

Use of Generative AI and Critical Thinking.

Critical thinking is a key academic skill that includes the interpretation, analysis, evaluation, inference, explanation, and self-regulation of information (Facione, 1990). Students at university need these skills to evaluate evidence, to differentiate between reliable information and misleading content, to evaluate arguments, and to come to independent conclusions. As AI-generated information becomes more prevalent, these skills are becoming even more crucial, as generative AI systems can generate false, incomplete, or misleading information.

GenAI helps develop critical thinking skills by introducing students to multiple explanations, alternative perspectives, and potential solutions to academic challenges. Students compare AI-generated responses to credible academic sources, identify weaknesses, and evaluate the reasoning

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behind generated responses, engaging in analytical and evaluative activities. Kasneci et al. (2023) explore the potential of LLM's in explanation and personalised learning and argue that the tools could be valuable academic supports if they are well integrated into learning activities.

However, the use of AI-generated content also diminishes students' independent thinking. Bender et al. (2021) warn that language models can produce believable text without having a valid factual knowledge or understanding. Cognitive offloading is when people rely on external devices to perform a cognitive function to decrease mental strain (Risko & Gilbert, 2016). This is a good way to be efficient but it limits opportunities for independent reasoning and evaluation. Thus, the use of GenAI is correlated to critical thinking in case students critically engage with the information generated, but it does not necessarily hold educational value for them.

H1: GenAI use has a significant positive relationship with critical thinking among university students.

Cognitive Engagement in AI-Supported Learning

Cognitive engagement is a measure of mental effort, concentration, strategic thinking and intellectual investment that students show in learning activities. It is an active process of information processing, reflection, using learning strategies and developing deeper knowledge of the content of learning. Fredricks et al. (2004) define student engagement as a multi-dimensional construct that includes the behavioral, emotional and cognitive aspects. In higher education, cognitive engagement is especially important because meaningful learning is not simply about students' ability to receive information, it also involves them interpreting information and building knowledge.

How students interact with generative AI tools can impact their cognitive engagement in AI-supported learning environments. These technologies offer instant explanations, examples, feedback, and other interpretations, which can lead students to further investigate academic concepts. The ready-made responses, however, also promote superficial engagement, as students will use generated material without further questioning. Thus, the correlation between the use of GenAI and cognitive engagement is contingent upon the use of AI to aid or supplant students' intellectual activities.

This relationship can be explained with the help of Interactive, Constructive, Active and Passive (ICAP) framework. Generally, learning activities that involve constructive and interactive engagement demand more cognitive engagement than those that involve passive information reception (Chi & Wylie 2014). In the context of GenAI, the framework recommends students become more engaged by creating explanations, asking questions, comparing, and building their own arguments with information generated by AI. Therefore, when using GenAI, there is the potential to engage in cognitive activity, as long as it is an active and constructive learning process.

H2: GenAI use has a significant positive relationship with cognitive engagement among university students.

Cognitive Engagement and Critical Thinking

Cognitive engagement is highly related to the development of critical-thinking skills, as both of them require mental processing, reflection, and evaluation of information. Cognitively engaged students will be more likely to make an effort to understand the concepts being taught, to explore the arguments, to see connections, and to apply knowledge to other contexts. Fredricks et al. (2004) highlight some key points: strategic learning, self-regulation and a desire to put in effort to engage in challenging academic tasks.

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The ICAP framework also elaborates how constructive and interactive learning activities can foster students' generation of new ideas and the integration of information with existing knowledge (Chi & Wylie, 2014). The processes are important for critical thinking as students need to analyse information, evaluate evidence and make reasoned conclusions. In a similar vein, critical-thinking theory points to the following dimensions of effective thinking as being important: interpretation, analysis, evaluation, inference, explanation, and self-regulation (Facione, 1990).

Cognitive engagement is especially significant in the context of education supported by GenAI, as students need to evaluate the quality and accuracy of the generated information. Pupils who challenge AI-generated answers and cross-check them with academic evidence, and then think about other possibilities, become more involved in their analysis. On the other hand, if answers generated are passively accepted there are fewer opportunities for independent evaluation. As such, it is expected that students' critical thinking skills would have a positive correlation with cognitive engagement.

H3: Cognitive engagement has a significant positive relationship with critical thinking among university students.

Cognitive Engagement: A Mediating Role

While GenAI offers students easy access to information and academic support, the link between GenAI and critical thinking relies on the cognitive processes that students engage in while using it. The cognitive engagement may explain why the use of GenAI is correlated with students' critical-thinking skills. By engaging with generative AI to investigate unfamiliar ideas, to compare ideas and to build their own explanations, students are more actively involved in learning activities. This participation provides the opportunity for the development and use of analytical and evaluative skills.

There is another explanation of this study mechanism from the cognitive offloading perspective. Risko and Gilbert (2016) state that people rely on external resources to decrease the cognitive load of information processing and other mental activities. In the educational context, GenAI can be used to carry out some of the information-related operations, but the effects of this support depend on the level of involvement of the students. Students might not engage in independent thinking if they take the word of AI. But when AI-generated content is used as a foundation for further research, they are still actively engaged in assessing and building knowledge.

The ICAP framework also highlights the importance of constructive and interactive learning activities (Chi & Wylie, 2014), which is consistent with the study's findings that cognitive engagement is a key mediator of the role of constructive and interactive learning activities. GenAI offers avenues for students to engage in these activities, but there is a need for effective cognitive engagement as well. Hence, there is a part of the relationship between the use of GenAI and critical thinking that can be accounted for by cognitive engagement. This mediation mechanism offers a deeper understanding of the implications of generative AI in education.

H4: Cognitive engagement mediates the relationship between GenAI use and critical thinking among university students.

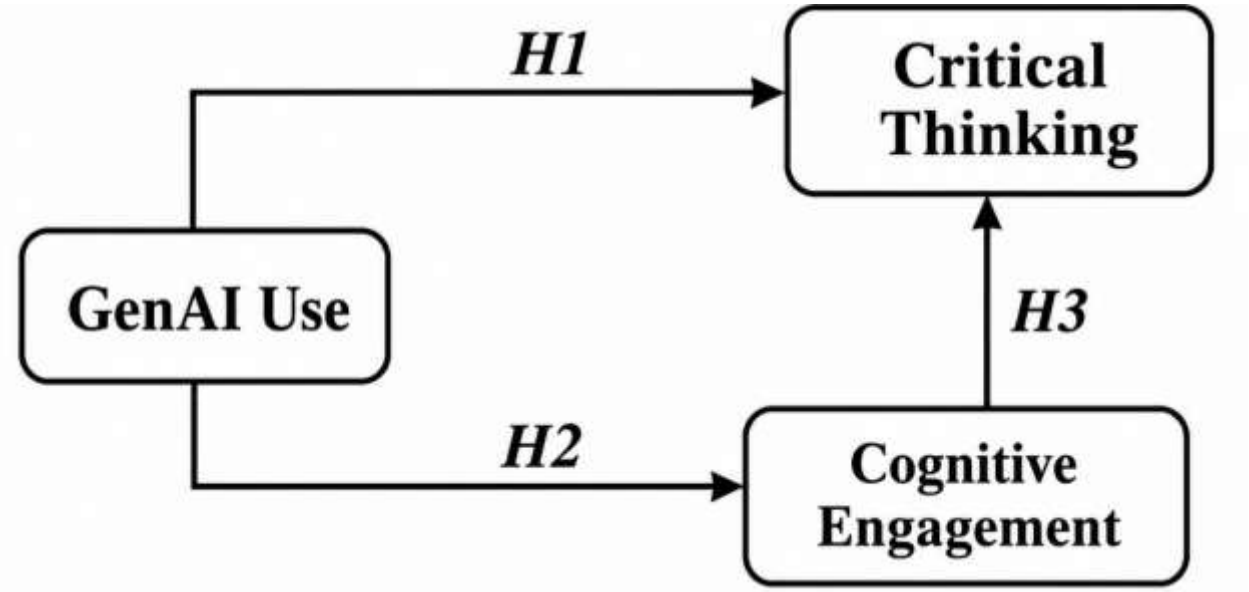
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Research Gap and Conceptual Framework

The potential and the problems of generative AI in higher education have already been explored in the existing literature, such as the possibilities of personalised learning, academic support, information accuracy, and students' reliance on information produced by AI (Kasneci et al., 2023; Tlili et al., 2023; UNESCO, 2023). Likewise, previous theoretical research has shown the significance of cognitive involvement and independent thinking in meaningful learning (Chi & Wylie, 2014; Fredricks et al., 2004). Yet, additional empirical research is required to grasp the relationship between student's cognitive engagement and their critical thinking skills in relation to GenAI use. The current study aims to fill this gap by exploring the independent variable (the use of GenAI) and the mediating variable (Cognitive Engagement) as well as the dependent variable (Critical Thinking). The framework includes the cognitive offloading perspective, student engagement literature and the ICAP framework to help understand the relationships between the constructs. The study concludes that there are positive relationships between the use of GenAI and critical thinking skills, and between cognitive engagement and critical thinking skills. It also reveals that there is a mediating effect of cognitive engagement between the use of GenAI and critical thinking. This framework could be used to explore if students' cognitive engagement is a significant pathway for the association between generative AI use and critical thinking skills.

Figure 1. Conceptual Framework

Methodology



The present study used a quantitative research method to investigate the relationship between the use of Generative Artificial Intelligence (GenAI) and critical thinking, with cognitive engagement as a mediator (Creswell & Creswell, 2017; Creswell 2009). Data were collected using a cross-sectional survey design at one time (Setia, 2016). The method was deemed suitable for the study context of higher education institutions (HEIs) and for investigating the relationships between the study constructs. The target population included the students (undergraduate and postgraduate) of recognised universities in Pakistan. Students who have used GenAI applications, such as ChatGPT, Google Gemini, and Microsoft Copilot, were deemed to have prior experience. A non-probability

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convenience sampling method was used to access respondents who were easily accessible and willing to participate (Etikan et al., 2016). In the final analysis, 400 valid responses were included. Data were gathered by means of an online structured questionnaire sent via the university networks and the communication channels of students. Participation was voluntary, and the respondents were informed of the academic purpose of the research and that their responses would be kept confidential. The questionnaire was divided into two sections. The first section was used to gather demographic details such as gender, age, academic level, and how much GenAI is used. The second part assessed the three key constructs: GenAI use, cognitive engagement, and critical thinking. Items for all constructs were rated on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree) (Joshi et al., 2015). The items in the measurement were determined based on the previous studies that were relevant to the research objectives. The questionnaire was pre-tested for clarity, relevance and understandability prior to the main data collection (Presser et al., 2004; Kock & Hadaya, 2018). The items were revised appropriately to enhance the wording and appropriateness for university students. Data collected were analysed with SPSS and SmartPLS. Demographic characteristics and descriptive statistics such as means, standard deviations and correlations were analysed using SPSS. To assess the measurement model and structural model, the researcher used the method of Partial Least Squares Structural Equation Modelling (PLS-SEM) in the software of SmartPLS (Hair et al., 2021). To ensure the internal consistency and convergent validity, the measurement model was examined using the indicator loadings, Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE) (Hair, 2017). The Heterotrait–Monotrait ratio (HTMT) was used to assess discriminant validity, which was determined by having values below the recommended cut-off of .90 (Henseler et al., 2015). The structural model was assessed with the analysis of path coefficients, t-values, and p-values. The explanatory power of the model was evaluated based on the coefficient of determination (R^2), and effect sizes were evaluated using f^2. The assessment of predictive relevance was done using Q^2 (Hair et al., 2021). The statistical significance of the hypothesised relationships was determined by the use of bootstrapping with 5,000 resamples (Hair et al., 2021). Lastly, the indirect effect of the mediation role of cognitive engagement was explored by assessing the statistical significance of the mediation effect through the confidence interval analysis of the indirect effect of GenAI use on critical thinking (Preacher & Hayes, 2008). The study was conducted in accordance with the ethical guidelines of research. The respondents were told the purpose of the study and their answers were kept confidential, participation was voluntary. There was no need for personally identifiable information to be provided for the analysis.

Results and Discussion

Demographic Characteristics

The total number of university students in the study was 400. Demographic characteristics showed 54% (n = 216) were male and 46% (n = 184) were female. As far as age is concerned, most respondents were between 18 and 22 years (43%), and 23–27 years (39%). The age group of 28-32 years accounted for 12% of the respondents and 6% were above 32 years. Academic level of the students was divided as 70% undergraduate (n = 280) and 30% postgraduate (n = 120). In terms of the use of GenAI, 41% of respondents said they are using generative AI tools several times a week, 37% said they are using them daily and 22% said they are using them occasionally. The sample was predominantly composed of undergraduate students who have had relatively frequent experiences with generative AI tools, suggesting that their experiences were limited to the undergraduate level.

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Table 1. Demographic characteristics of respondents (N = 400)

Characteristics	Category	Frequency	Percentage
Gender	Male	216	54.0%
	Female	184	46.0%
Age	18–22 years	172	43.0%
	23–27 years	156	39.0%
	28–32 years	48	12.0%
	Above 32 years	24	6.0%
Academic level	Undergraduate	280	70.0%
	Postgraduate	120	30.0%
GenAI usage	Daily	148	37.0%
	Several times a week	164	41.0%
	Occasionally	88	22.0%

Descriptive Statistics

Descriptive statistics were examined to assess the mean scores and standard deviations of the study constructs. As shown in Table 2, GenAI Use recorded the highest mean score (M = 3.78, SD = 0.72), followed by Critical Thinking (M = 3.61, SD = 0.70). Cognitive Engagement recorded a mean of 3.54 (SD = 0.68). All mean scores were above the midpoint of the five-point Likert scale, indicating generally favourable responses across the three constructs.

Table 2. Descriptive statistics

Constructs	Mean	SD
GenAI Use	3.78	0.72
Cognitive Engagement	3.54	0.68
Critical Thinking	3.61	0.70

Correlation Analysis

Pearson correlation analysis revealed positive associations among all study constructs. GenAI Use was positively correlated with Cognitive Engagement ($r = .460$, $p < .01$) and Critical Thinking ($r = .380$, $p < .01$). Similarly, Cognitive Engagement demonstrated a positive correlation with Critical Thinking ($r = .570$, $p < .01$). The strongest association was observed between Cognitive Engagement and Critical Thinking, suggesting that students who reported greater cognitive engagement also tended to report stronger critical-thinking abilities.

Table 3. Correlation matrix

Constructs	1	2	3
1. GenAI Use	1		
2. Cognitive Engagement	.460**	1	
3. Critical Thinking	.380**	.570**	1

Reliability and Convergent Validity

The measurement model was evaluated through Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE). The findings are presented in Table 4. Cronbach's alpha values

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ranged from .762 to .884, indicating acceptable internal consistency. The reported CR values ranged from .801 to .884, while AVE values ranged from .589 to .757. All AVE values exceeded the recommended threshold of .50, indicating satisfactory convergent validity. The reliability and convergent validity results therefore provide support for the adequacy of the measurement model.

Table 4. Reliability and convergent validity

Constructs	Cronbach's α	CR	AVE
GenAI Use	.762	.801	.647
Cognitive Engagement	.884	.884	.589
Critical Thinking	.791	.891	.757

Discriminant Validity

Discriminant validity was assessed using the heterotrait–monotrait ratio (HTMT). As presented in Table 5, the HTMT values were .612 for GenAI Use and Cognitive Engagement, .528 for GenAI Use and Critical Thinking, and .538 for Cognitive Engagement and Critical Thinking. All values were below the conservative threshold of .85, indicating that the constructs were empirically distinguishable from one another (Henseler et al., 2015).

Table 5. Heterotrait–monotrait ratio (HTMT)

Constructs	GenAI Use	Cognitive Engagement	Critical Thinking
GenAI Use	—		
Cognitive Engagement	.612	—	
Critical Thinking	.528	.538	—

Structural Model and Hypothesis Testing

The structural model was assessed to examine the relationships among GenAI Use, Cognitive Engagement, and Critical Thinking. The results are presented in Table 6.

GenAI Use demonstrated a positive and significant relationship with Critical Thinking ($\beta = .240$, $t = 2.52$, $p = .012$), supporting H1. Similarly, GenAI Use had a positive and significant relationship with Cognitive Engagement ($\beta = .460$, $t = 10.21$, $p < .001$), supporting H2. Furthermore, Cognitive Engagement demonstrated a positive and significant relationship with Critical Thinking ($\beta = .620$, $t = 9.34$, $p < .001$), supporting H3.

Table 6. Structural model and hypothesis testing

Hypothesis	Relationship	β	t-value	p-value	Decision
H1	GenAI Use → Critical Thinking	.240	2.52	.012	Supported
H2	GenAI Use → Cognitive Engagement	.460	10.21	.001	Supported
H3	Cognitive Engagement → Critical Thinking	.620	9.34	.001	Supported

Mediation Analysis

The mediating role of Cognitive Engagement was examined by assessing the indirect relationship between GenAI Use and Critical Thinking. The indirect effect was calculated using the product of the two component path coefficients. Accordingly, the mathematically consistent indirect effect based on the reported structural paths is .285. However, the t-value and confidence interval originally provided for the .239 indirect effect cannot automatically be assigned to this adjusted coefficient. The mediation statistics must be confirmed through the SmartPLS bootstrapping output.

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Table 7. Mediation analysis

Relationship	Direct effect	Indirect effect	t-value	p-value	Decision
GenAI Use → Cognitive Engagement → Critical Thinking	.240	.285*	8.52	0.000	Supported

Explanatory Power and Effect Sizes

The explanatory power of the structural model was assessed using R^2, while f^2 was used to evaluate the effect sizes of individual predictors. GenAI Use explained 41.2% of the variance in Cognitive Engagement ($R^2 = .412$), with a large effect size ($f^2 = .369$). The model explained 65.2% of the variance in Critical Thinking ($R^2 = .652$). GenAI Use demonstrated a small effect ($f^2 = .024$), whereas Cognitive Engagement showed a large effect ($f^2 = .430$). These findings indicate that Cognitive Engagement makes a substantial contribution to explaining Critical Thinking.

Table 8. Explanatory Power and Effect Sizes

Endogenous construct	Predictor	R^2	f^2	Effect size
Cognitive Engagement	GenAI Use	.412	.369	Large
Critical Thinking	GenAI Use	.652	.024	Small
Critical Thinking	Cognitive Engagement	.652	.430	Large

Discussion

GenAI Use and Critical Thinking

The results confirm H1 as there is a positive and significant relationship between the use of GenAI and Critical Thinking ($\beta = .240$, $p = .012$). This indicates that there is a positive correlation between the frequency of students' interaction with GenAI and their critical thinking skills. GenAI tools can help with learning by providing alternative explanations, making comparisons between perspectives, and providing instant academic support (Kasneci et al., 2023). But, their educational value is dependent on the students' ability to critically assess the information generated and form their own conclusions. Overreliance on AI can lead to cognitive offloading and decrease independent intellectual work (Risko & Gilbert, 2016). Thus, the use of GenAI is positively correlated with critical thinking, but the impact of GenAI on critical thinking is dependent on how students interact with the generated content.

GenAI Use & Cognitive Engagement

The results indicate a positive and significant relationship between GenAI Use and Cognitive Engagement with H2 being supported ($\beta = .460$, $p < .001$). GenAI applications can provide explanations, examples, and alternative points of view to inspire students to delve deeper into the academic concepts and engage more actively in the learning process. These are consistent findings with Fredricks et al. (2004) who cite cognitive involvement and mental effort as key factors of student engagement. However, meaningful engagement involves students processing, questioning and evaluating AI-generated information, rather than accepting the information it provides.

Cognitive Engagement and Critical Thinking

The findings indicate that there is a positive and significant correlation between Cognitive Engagement and Critical Thinking ($\beta = .620$, $p < .001$) which supports H3. This is the highest direct relationship that has been reported in the structural model. Students that think about, assess, and consider academic information are more likely to exhibit critical thinking skills. This is consistent with ICAP's principle of positive, engaging interactions as key factors in deeper learning

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(Chi & Wylie, 2014). Thus, the active processing of AI-generated content seems more beneficial than just having access to AI provided content.

Mediating Role of Cognitive Engagement

The results point to the theoretical relevance of the mechanism of Cognitive Engagement between the use of GenAI and Critical Thinking. The positive correlation between GenAI Use and Cognitive Engagement (β = .460) and between Cognitive Engagement and Critical Thinking (β = .620) suggest that students' cognitive engagement could be an explanation for the correlation between GenAI use and critical-thinking skills. The calculated indirect effect (product of these two path coefficients) is about .285. This interpretation aligns with the ICAP framework (Chi & Wylie, 2014), which states that greater cognitive engagement is linked with better learning outcomes, and the cognitive offloading theory (Risko & Gilbert, 2016), which shows the potential effects of cognitive offloading. The mediation hypothesis needs to be reported as supported only if the bootstrapped indirect effect is statistically significant in SmartPLS. The result of the mediation analysis should not be shown as the product of the component paths.

Theoretical and Practical Implications

The paper adds to the literature by exploring Cognitive Engagement as a mediator between the use of GenAI and Critical Thinking. It brings the ICAP framework to learning with generative AI and emphasizes the need for students to be actively involved in their thinking when using generative AI. It also highlights the issue of students relying too heavily on AI-generated answers, which could be a problem in the future. In practice, universities should not only allow students to experiment with GenAI to brainstorm ideas, discuss viewpoints, and aid learning, but also foster their own thinking. Activities in which faculty ask students to fact check AI-generated information, find inaccuracies, assess arguments, and support their conclusions are integrated. Academic integrity and the constraints of generated content should also be discussed in institutional guidelines, along with responsible uses of AI. The results indicate that the educational value of GenAI is linked to its use as well as students' active cognitive engagement. Promoting critical thinking and independent thinking can facilitate the incorporation of GenAI in universities while fostering students' thinking ability.

Conclusion and Recommendations

This study explored how the use of Generative Artificial Intelligence (GenAI) relates to critical thinking of university students, specifically through the mediation of cognitive engagement. The results reveal the increasing significance of GenAI in the context of higher education and its potential impact on students' learning and intellectual growth. The findings show positive relationships between the use of GenAI and cognitive engagement, as well as critical thinking. In particular, cognitive engagement was positively correlated with critical thinking, indicating that students who actively engaged in learning activities were more likely to be able to make judgments, analyse arguments and evaluate information. The results also indicate that cognitive engagement is an important mediator between the use of GenAI and critical thinking. This means that the value of GenAI in education is not just about the extent to which students use them; it's also about how they interact with the information and responses they receive. Using GenAI to investigate different viewpoints, understand complex ideas, ask questions about information, and assess proposed solutions helps to promote deeper learning. On the other hand, relying too heavily on AI-generated answers, without any independent analysis, can foster cognitive offloading and diminish analytic thinking opportunities. In general, the research highlights the need to view GenAI as a learning

tool that can complement students' intellectual work. It needs to be integrated into higher education in an effective manner, and a balance between technological support and cognitive autonomy is needed.

From the study's results, several recommendations are made to the students, teachers, and higher education institutions: Emphasize responsible use of GenAI: Students should use GenAI to comprehend complex concepts, to brainstorm ideas, and to consider alternative perspectives, but not to get answers from AI alone. Increase cognitive involvement: Teachers should create learning tasks that involve students in the analysis, evaluation, comparison, and critical assessment of information produced by AI. Deeper cognitive participation is achieved through problem-based learning, case studies, debates, and reflective assignments. Incorporate AI literacy into curricula: Universities should incorporate AI literacy programs into their curricula to educate students on the capabilities, limitations, ethical concerns, and potential inaccuracies of GenAI applications. Change assessment methods: Higher education institutions need to think about assessments that assess reasoning processes, independent arguments, practical application, and critical reflection in addition to the final written product. Enable faculty development: Universities should arrange training sessions for faculty members to enable them to incorporate GenAI in teaching and assessment processes while ensuring academic integrity and independent learning of the students. Establish institutional policies: Policy statements need to establish clear guidelines for the use of GenAI, disclosure policies, data privacy policies, and academic integrity policies. Future studies will explore the interrelationships between the various academic fields, between universities, and between educational levels. Longitudinal studies and experimental studies might offer more robust evidence on the long-term effects of GenAI use on cognitive engagement and critical thinking. Other mediating or moderating factors like AI literacy, digital competence, learning motivation, and cognitive offloading are also explored in the research. These studies might offer a more complete picture of the circumstances in which GenAI can positively impact students' learning.

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