

The Role of Artificial Intelligence in Fostering Critical Thinking among University Students

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ARTICLE INFO		ABSTRACT
Article History:		<i>To examine how AI-based additions to learning aid critical thinking in undergraduate students in Pakistan, we collected and studied the results of a questionnaire that was given to a random selection of undergraduates enrolled in various universities in the country. The study wanted to understand how using AI in education affects students' ability to think at a higher level. The study found a strong positive link between using AI tools and thinking skills, showing that students who interact regularly with AI tools score much better on tests of critical thinking. The independent samples t-test showed that students using AI more had better critical thinking scores, proving that personalized systems, engaging online resources and immediate feedback brought about by AI bring clear value for students. Further analysis showed that being aware of your thoughts significantly increases the way AI tools help you develop critical thinking. Students who were conscious of their ways of thinking and learning gained the most from using AI, confirming that using personal strategies helps make the most of digital education tools. These results fit with what we see in present-day reports on AI and its potential to tune our ability to think, provide personalized experiences and support the development of crucial skills. So, the report proposes that higher education programs and teacher development courses start using AI to support critical thinking and more flexible learning. Besides such work should explore and monitor how AI-supported learning influences students in the long run, adding ideas to the growing discussions around innovation and sustainable technology efforts in colleges.</i>
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1.0 Introduction

Because higher education is fast evolving, it is now especially important to develop critical thinking in university students. Due to the growing complexity, links and wealth of information in today's world, reasoning by analyzing facts, examining different arguments and addressing difficult problems is now a necessary skill for any area of life. While traditional teaching helps us learn basic information, it doesn't fully support the higher-thinking skills we need to manage real-world problems today. Because of its transformative abilities, both researchers and institutions have shown strong interest in artificial intelligence (AI) for use in education. Including AI in the curriculum is helping universities offer students ways to learn that go beyond listening and reading. Through the automation of routine tasks, these technologies make operations more efficient and give students the chance to learn in new ways by asking important questions, considering their own thoughts and using reasoning supported by evidence (Luckin et al., 2024). Because AI can handle a lot of educational information and provide fast, individual advice, it greatly helps boost the cognitive skills of young learners.

With AI in higher education, technology is important, but its main impact comes from changing the way education is taught. Pros like intelligent tutoring, virtual teaching assistants and forums using natural language processing are transforming what happens in schools and academies right now. They are created so that students work in environments where they are guided to examine different ideas, discuss different opinions and cooperate in solving tough problems—hallmarks of critical thinking recognized by experts (Zawacki-Richter et al., 2024). Besides, AI makes it possible for students to learn in controlled situations that demonstrate situations with ethical issues and challenges. During such cooperation, students gain new knowledge and also build skills including recognizing what might happen, thinking deeply about complex situations and making proper, fact-based choices. As a result, making use of AI in educational settings can greatly contribute to developing critical thinking, adaptability and toughness which greatly help students maintain success and curiosity in education (Bezuidenhout et al., 2025).

In addition, by using educational analytics, AI provides a major benefit to learning in higher education. These systems can continue to examine what students do while learning and spot their learning trends, leading to better insights into how people learn as groups and individually (Ndukwe et al., 2019). Thanks to this, teachers can become aware of students' difficulties and incorrect thinking much more accurately. Because of this, educators can quickly change their teaching style to help students with specific difficulties, with a main focus on improving critical thinking by repeating learning, promoting reflection and practicing how to solve problems step by step. AI can also be used to analyze students' written work, supplying prompt, helpful feedback related to the organization of their arguments, how well their points connect and how much evidence they offer. The practice of these ongoing assessments supports students and teachers in being critical, practiced in thought and motivated to learn constantly. AI provides a unique ability to personalize education and teaches students to be aware of their knowledge development, indicating just how important it is for students to focus on learning and problem-solving needed in a knowledge-based world (Chen et al., 2021).

AI plays an important part in development critical thinking by helping students work together in discussions. These AI platforms such as discussion forums, AI-moderated debates and virtual case study environments, help students from many backgrounds communicate freely and learn from each other (Olsher et al., 2024). Being around various opinions helps people avoid thinking errors, become more open-minded and develop more humility regarding their knowledge — things required for critical thinking to develop well. Their role in online education is to facilitate proper discussions by spotting false reasoning, recommending ways to argue differently and aiding

students in basing their arguments on evidence which helps keep all talks helpful and mentally engaging. Promoting dialogic learning, critical inquiry and debate on iAopsys technology, AI raises students to the point where they can handle complex social, ethical and global issues. Such dialogic exchanges help students communicate clearly, think well about different arguments and decide responsibly, all of which are being recognized as important abilities for worldwide citizens and professional chairs.

With so many facts, fake news and algorithms, university students now need to recognize genuine information from things that may not be true. AI can greatly help students become better critical thinkers by assisting with content selection, checking facts and instruction in digital literacy. Learners use AI-powered tools to check, evaluate and analyze information in both research and everyday situations online (Costello et al., 2025). They help students find only the most reliable content and start to form a habit of checking facts and information. When students go through checking the reliability and evidence in various sources of information, AI-based applications help them develop key information and media literacy skills. These abilities form the basis of critical thinking today, so students can deal with complex online information, choose carefully what to believe and join in on public discussions (Tang et al., 2023). As a whole, AI-driven interventions reveal how artificial intelligence can help increase critical thinking, flexibility in thought and careful judgement among university students in the modern higher education field.

1.1 The Importance of Critical Thinking in Higher Education

Because higher education systems are developing fast, colleges today are giving strong emphasis to how students develop their critical thinking skills. In today's world, with its many connections and complexities, people must be able to examine information and arguments, solve problems and use their judgment. Although traditional approaches help students learn basic information, they seldom teach the advanced thinking skills students will need in today's world. With this trend in mind, artificial intelligence (AI) has become an important topic because of its potential in schools. Because of AI, new tools and platforms are being incorporated into courses that encourage dynamic learning, personalization and interaction. In addition to helping with admin work and personal learning, these technologies give students special chances to examine, question and use evidence in their reasoning (Luckin et al., 2022). Handling huge volumes of data and providing immediate, relevant feedback makes these technologies perfect for helping students learn and think critically (Holmes et al., 2021). These changes made possible by AI allow students to learn and also train themselves to be flexible and analytical, something they need to handle changes in the 21st century.

Using AI in universities means more than updating technology; it points to a key change in how teaching is done. More and more, AI-assisted tutors, virtual teachers and discussion platforms based on natural language are being put into practice to create learning spaces that prioritize exploring and working as a team. Students interacting with AI systems are prompted to reconsider ideas they take for granted, look at matters differently and work together, all these involved in critical thinking (Zawacki-Richter et al., 2020). Besides, AI technology enables students to participate in challenging situations and manage decisions at a lower risk than in the real world. By taking part in such activities, students learn information as well as the abilities to think logically, expect results of various choices and suggest practical remedies. By combining AI tools with teaching, students can benefit from better critical thinking, improved intellectual strength and being better problem solvers (Bezuidenhout et al., 2023). As students deal with numerous and varied problems, it is becoming more important for them to be flexible, use good judgment and think deeply.

Today's young people are facing new problems, for example, an endless supply of information, changing employment situations and global issues requiring thoughtful answers. Under these circumstances, universities should change from having students just memorize things to guiding them to think for themselves, question facts, understand findings from data and make thoughtful decisions. They are necessary for managing our career abilities as well as the activities and roles needed by a community member. Traditional methods of teaching do not always succeed in developing advanced thinking skills, so making use of AI in the classroom gives students another approach to growing these skills. According to (Scibelli & Stevens, 2024), learning and being flexible throughout your life depend on critical thinking. AI-enhanced teaching is especially set up to encourage these abilities. With artificial intelligence, universities can help students become better prepared to address the problems of a world that's becoming more complex and demanding.

1.2 Harnessing AI to Personalize Learning and Foster Collaborative Critical Thinking

Through artificial intelligence, education can now use analytics to quickly and clearly see how students are learning, improving the way educators understand and support student learning. Thanks to continuous AI monitoring, we can see different abilities and troubles each student faces when using digital course materials, participating in learning discussions and taking different types of assessments. (Daniel, 2019), claims that analyzing data from detach can help teachers discover particular knowledge or skill deficiencies, common misunderstandings and intellectual challenges that probably go unnoticed in ordinary classrooms. With GTC, teachers can improve how they teach by adapting to each group of students, thus helping them build important skills for analyzing, reasoning and problem-solving. Besides, these platforms support ongoing learning by giving students quick, specific feedback on what they are good at and what they could work on. By intervening at this point, teachers help students improve how they make arguments and think logically and they develop skills needed for success in both their personal and professional lives.

At the same time as using personalized feedback, AI's use of natural language processing has given students more ways to learn and be assessed in schools. Using NLP, these tools are able to analyze written feedback, discussion forum messages and oral responses for proper reasoning, a consistent argument and use of science-based arguments. These AI systems, as described by (Chen, 2024), give students immediate feedback that is simple, useful and connected to what they are studying which allows them to improve on a regular basis. Significantly such automated, personalized feedback encourages students to reflect on their ideas and engage in better research. By underlining the causes of errors, AI feedback helps students rethink their thinking, alter how they make sense of things and back up their arguments more effectively. As a result, AI encourages students to think about how they think and study. Engaging in reflective practice allows students to understand the course topics more fully and stay interested. AI in education adapts to a learner's development, so coaching and feedback are always accurate and help create learning plans that both help a learner accomplish tasks and steadily improve mental strength.

AI-powered platforms have been a big help in making collaborative and dialogic learning possible, models that experts see as vital for improving critical thinking skills. Thanks to forums, digitally supervised debates and simulations, students from many backgrounds can join in discussions and share their views which can be discussed and blended with others' views. According to (Sangwin & Kinnear, 2022) a variety of technology-supported environments help students spot their own biases which is important for developing effective critical thinking skills. They intervene in talks whenever something irrelevant, impolite or unsupported appears to encourage participants to verify what they say. Moreover, computer-generated signals during conversations support continued thinking, invite students to discuss important issues and guide them through structured discussions. (Holmes et al., 2022). point out that this type of guided, collaborative learning skills

students for success in the real world, since they must now handle arguments with different opinions. When AI is part of collaborative learning, schools are able to develop students' critical thinking, humility and ability to make decisions based on knowledge, all skills needed for success today.

1.3 Research Objectives

To examine the impact of AI-powered personalized learning tools on the development of critical thinking skills among university students.

To analyze how real-time AI feedback influences students' cognitive engagement and reflective thinking.

To explore the role of AI-facilitated collaborative learning environments in enhancing students' critical inquiry and evidence-based reasoning abilities.

1.4 Problem Statement

While it is recognized that critical thinking is important in university, standard teaching practices often do not succeed in helping students master this skill well. Since both the subject matter and teaching expectations are becoming more advanced, not enough teaching methods exist to support each learner's needs as well as deliver timely and effective support. Although artificial intelligence technologies may improve education by adapting learning, suggesting answers in real time and supporting group work, evidence from research about their effect on critical thinking abilities is still missing. The specific ways in which using interactive technologies and AI-guided content improves learners' information analysis, argument evaluation and care in decision-making are still not clearly understood. As a result, this study seeks to identify how AI might be introduced in university studies to encourage and strengthen critical thinking. Researchers explore the benefits of applying AI to guide instruction, deliver immediate and productive feedback and promote sharing of ideas in class, so as to contribute positively to designing learning models for today's and tomorrow's students.

1.5 Significance of the Study

It is very important as it addresses the urgent desire to help students improve their critical thinking by relying on technology. The study further investigates how AI technologies help personalize learning, offer instant feedback and support teamwork among students, to find better ways for contemporary pedagogies to help students address today's challenges. Research on how AI might help with cognitive development and metacognition is needed, because they are the foundation of serious thought in the classroom. This study's findings will be useful for teachers, education planners and policymakers who hope to increase students' academic marks and boost their ability to learn all their lives. By doing this study, we wish to help develop future learning environments that motivate students to be independent thinkers and do well as society advances in knowledge.

2.0 Literature Review

Many studies have become interested in what AI can do to enhance analytical reasoning among university students due to its fast rise in education. More institutions of higher education are using AI and this means it is important to study how these tools might influence both a student's mind and how they study. The leading principle of thinking analytically which forms the backbone of academic success and knowledge gained throughout life, goes beyond remembering facts and requires us to weigh, judge and unite different bits of knowledge. Therefore, people studying

education are now concentrating on how AI makes possible new learning formats that stimulate complex thinking and can reach results not seen with traditional lessons. The purpose of this literature review is to put together recent empirical research and relevant theories that have been developed within the past five years to give a full picture of AI's shifting influence in higher education (Massey et al., 2021).

It has been shown lately that AI provides more personalized support and helps build unique learning environments for every student. By using advanced analytics and understanding how people speak and write, AI systems check how students are doing continuously, finding the knowledge students are missing, misunderstandings and areas they should pay more attention to. With such precise guidance that uses data, learners can refine their thinking skills and keep improving their higher-order skills. Thanks to AI, students can receive detailed feedback on their writing quickly which helps them strengthen how their arguments make sense and provide evidence. Even so, the literature mentions that understanding AI's impact on people from various backgrounds, education fields and environments is still a hurdle. Issues such as bias in algorithms and giving all students equal access to these educational applications are still a problem and researchers and developers should keep finding ways to deal with them (Lee et al., 2022).

Besides personalized learning, new studies notice the important role of AI-assisted collaborative and dialogic classrooms in encouraging critical thinking. Because AI-based platforms replace traditional classroom learning, these platforms make environments where students can participate in debates, engage in discussions and solve problems that teach them to recognize more than one perspective. Such digital environments encourage people to be open-minded and humble which is important for successful critical inquiry. By alerting the user to fallacies, inspiring arguments against ideas and suggesting evidence, AI tools improve how the information is grasped. Learning with others helps students prepare to manage present-day issues in society, ethics and on a world level. Sparked by these discoveries, we will look at how integrating AI into teaching methods can reliably help students develop critical thinking, as well as pointing out issues in the literature and proposing useful directions for further studies (Pinera-Castro & Borges-Garcia, 2025).

Additionally, recent studies have studied how AI contributes to being aware of how and what we learn and taking charge of our own learning. AI tools in education help students keep track of their mental processes through instant reports on learning actions, choices and methods they use to solve problems. Having to pay careful attention to how they think, collect information and apply methods helps learners learn to be independent, strong-minded and better at facing challenges. (T. N. T. Nguyen et al., 2024).found that students who use metacognitive tools supported by AI improve their reasoning and are better able to work independently. Besides, AI's role in this area helps meet the goal of lifelong learning, because robust metacognitive abilities help students respond positively to novel difficulties outside of school. This pattern of research points to an important path for AI to help people improve their critical thinking skills through different topics and throughout their education journey.

2.1 Collaborative AI Platforms and Dialogic Learning

The role of AI-supportive software in higher education has greatly altered teamwork by introducing fresh technology that supports student-directed and lively classrooms. I use virtual discussion forums, automatic moderators and intelligent review platforms, so everyone in the group can feel included. The move from listening to learning calls on students to use their creative and analytical skills to dive deep into what they study. Because AI tools are immediate and convenient, students can keep the topic alive, learning the importance of examining, reacting to and arguing for what they learn in class. Being involved with such sustained critical thinking

exercises allows students to develop their critical thinking ability by expressing their own concepts clearly, as well as by paying close attention, asking questions and offering constructive feedback to those with different opinions. Cooperative work between learners increases their insights, so they become empathetic and able to think in different ways as they understand difficult subjects. According to (Patel, 2025).working in these AI-based learning settings helps students examine a range of opinions, challenge their unfounded beliefs and make well-supported claims which are key abilities today in both learning and employment.

Also, using AI to oversee discussions greatly enhances the level of learning in these team activities. By looking at what people say, how they say it and how their answers fit together, AI moderators can spot any problems or incorrect opinions in student talks. Subsequently, these systems can encourage users to review, revise or clarify their thinking. It changes loose peer discussions into structured discussions where participants must analyze information more seriously and account for their arguments through clearer thinking. AI-aided discussions support qualities such as open-mindedness, skepticism and using evidence to solve problems by repeatedly requesting students to support what they say. The purpose of these interventions is to motivate students to think in more advanced and thoughtful ways about complicated subjects. They maintain that everyone needs to be able to analyze opposite information, judge which arguments are strong and decide carefully in today's fast-changing professional context. AI-supported moderation prepares students for similar demands and encourages students to respect each other, make ethical choices and value intellectual humility(Silor, 2024).

Additionally, such platforms promote effective teamwork by allowing students to discuss, think and solve challenges in life-like scenarios. These simulations let learners practice theoretical knowledge, train their reasoning, decision-making and problem-solving skills, all without real-life risks. Since these AI simulations rely on people coming together, students are encouraged to communicate, consider other perspectives, negotiate, develop critical brain function skills and skills for leading ethically and in groups. Joining in on these hands-on activities, students practice working with tough situations that require them to think clearly, accept uncertainty and combine different understandings into effective plans. An educational experience like this prepares students to think carefully and increases humility, doubt and the ability to relate to and make decisions about others' lives. (Garcia et al., 2023).believe that AI-supported, integrated, interactive and discussion-centered learning environments help students develop both their critical thinking skills and their sense of responsibility, adaptability and ethical awareness. They are important for any professional who has to overcome new and complex challenges with others in an interconnected global community with diverse populations.

2.2 AI-Supported Metacognition and Personalized Learning for Critical Thinking Development

Improving critical thinking in students has become simpler because AI now supports and increases metacognition and self-regulated learning among university students. Being aware of your thought processes and regulating them is widely known by education experts as an important element of effective problem-solving, independence and continual learning. In modern academic settings where people need to be adaptable and think and decide using evidence, metacognition is now a must-have skill. They support this development by giving learners consistent and detailed feedback about how they learn and make decisions. Because of these systems, students can always look back at their methods for solving difficult assignments and find where they can get better or improve. (M. L. Nguyen et al., 2024).believe that AI-based systems in metacognition let learners monitor their learning strategies and make improvements in real time. Having these regulations constantly is good for students' current learning and helps them become more reliable thinkers and resilient in

the future. Those who have these skills are able to handle different, difficult and uncertain situations as they live and grow. Reflecting on practice allows learners to tackle new problems confidently and with careful thought, focused attention and adapting mindsets, after leaving the classroom.

Through personalized learning, artificial intelligence increases students' critical thinking power beyond just improving their metacognitive skills. By examining data in real time, AI systems are able to identify little-known challenges, learning issues and strengths of each student. From these insights, personalized feedback is created so students can revisit course content and update, strengthen and enhance their thoughts and strategies on various problems. (Lee et al., 2025).explain that these adaptive learning environments are well-suited to students' different needs, as they help them better experience and explore more difficult ideas. Because AI-powered systems often adjust resources and support to fit your skills, they help learners regularly judge, review and tackle problems, shaping useful learning habits. Learner-centered education strategies not only support good grades but also encourage curiosity, the confidence to follow reasoned evidence and stick-to-it-ness. Also, because this learning approach is personal and keeps happening, students are encouraged to think about their achievements and how much effort they put into learning. As a result, AI-based systems that personalize learning assist students in growing the flexibility and agility of thought needed to solve more complex problems at work and in life.

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2.3 Research hypotheses

There is a significant positive relationship between AI-supported personalized learning and the development of critical thinking skills among university students.

There is a moderating effect of metacognitive awareness on the relationship between AI-based feedback and students' critical thinking performance.

There is a significant difference in critical thinking abilities between students who engage in AI-mediated collaborative learning environments and those who do not.

3.0 Methodology

3.1 Research Design

The study relies on a quantitative research design which involves handling and processing numbers to examine how different variables are related. The objective measurement and statistical analysis

allowed by quantitative research make it useful for this research. By using numbers, this design lets us study AI's impact on students' minds so we can generalize the results to a bigger group. In addition, the set questionnaires and tools used here ensure the data is always consistent and reliable. This methodology makes it possible for researchers to use powerful statistical tools, find hidden patterns and understand what has caused them which supports strong conclusions about AI use in higher education.

3.2 Population

The focus of the study is undergraduate students currently studying at universities across Pakistan. This group is chosen because university students are fundamental to the field of education and because developing critical thinking is now highly valued in their learning. It is especially timely to study this group since AI is playing an increasing role in Pakistan's education system. This group's wide range of academic experiences makes the study more thorough because things are explored through the lens of many different fields and types of schools. Also, because undergraduate students usually welcome digital learning, they offer a great way to see how AI can improve the way people think and learn.

3.3 Sample Size

We chose to include 250 undergraduate students in this study. This figure is based on a statistical power analysis so that the sample size can identify significant effects and links within the information collected. With 250 participants, researchers can achieve both a feasible experiment and conclusions that work for most students. Having more participants than necessary in the study lets researchers analyze information accurately, as they can expect a certain number of missing responses. The use of this sample gives the research better chances of finding accurate results with a smaller margin for error. Working on these questions this rigorously is important for finding useful conclusions about AI and student thinking skills.

3.4 Sampling Technique

In this study, simple random sampling was chosen to select participants so that every undergraduate student within the population has an equal and separate opportunity of being in the sample. With this method, sampling bias is reduced and the sample's representativeness grows which helps the study's conclusions apply to a broader audience. Simple random sampling ensures that the research process is simple, transparent and easy to replicate, because it follows a clear and standardized approach. Because this technique limits external or personal influences, the sample is more likely to show the actual features of the larger population which is necessary for the research to be reliable.

3.5 Ethical Considerations

Every effort will be made during the study to follow ethical guidelines that safeguard everyone involved. Every participant will be given detailed information about the research, told why it is being done, what they will do and informed that leaving the study at any point will not have any consequences. Unlike personal identifiers, each participant will receive a unique code. All personal information will be safely kept so that only authorized people can access it. The research will make certain that no deception or coercion is involved so that everyone taking part does so on their own free will and with full awareness. Moreover, the investigation will follow national and international ethical rules by first getting approval from the proper institutional review board or ethics committee.

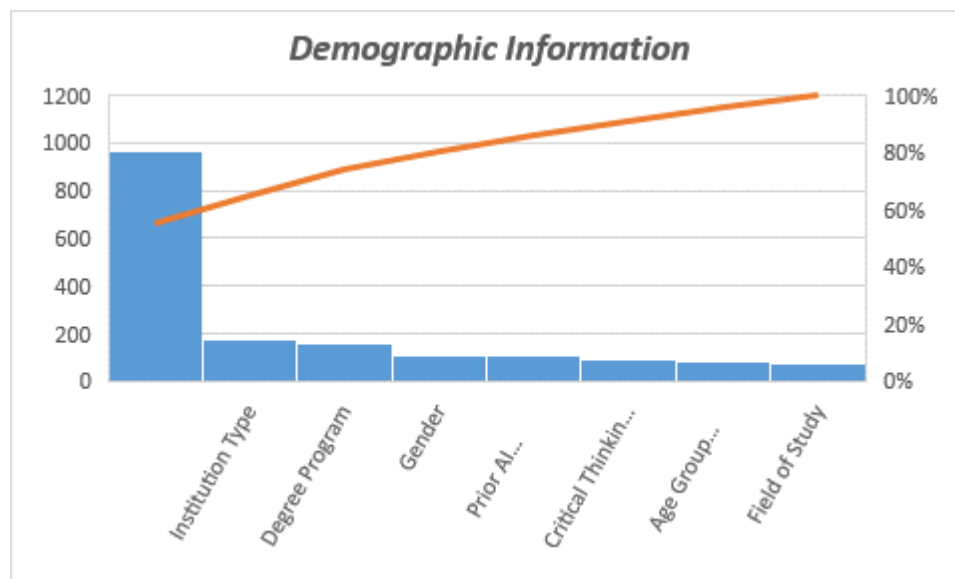
4.0 Data analysis

Testing the hypotheses will need the use of multiple statistical methods. H1 will be studied by correlating AI usage with critical thinking development using Pearson's correlation and simple linear regression to measure the relationship and its ability to forecast the outcome. H2 will be tested using an Independent Samples t-test if two groups are linked by the type of tool (low or high usage) and a One-Way ANOVA if there are more usage groups. H3 suggests that effects of AI on critical thinking may differ when looking at gender and academic discipline. We will address that using moderation analysis and Two-Way ANOVA. The use of these methods will reveal how AI tools affect different student groups' critical thinking skills.

Demographic Characteristics of Respondents (N = 250)

<i>Variable</i>	<i>Category</i>	<i>Frequency (f)</i>	<i>Percentage (%)</i>
Gender	Male	110	44.0
	Female	140	56.0
Age Group (years)	18–21	80	32.0
	22–25	120	48.0
	26–30	50	20.0
Degree Program	Undergraduate (BS)	160	64.0
	Graduate (MS/MPhil)	70	28.0
	PhD	20	8.0
Field of Study	Social Sciences	75	30.0
	Natural Sciences	55	22.0
	Engineering & Technology	60	24.0
	Management Sciences	60	24.0
Institution Type	Public University	170	68.0
	Private University	80	32.0
Prior AI Experience	Yes	105	42.0
	No	145	58.0
Critical Thinking Training Attended	Yes	90	36.0
	No	160	64.0

Analysis of the 250 respondents' data found that all important categories were balanced. Females made up most of our sample (56%) and males represented the other 44%. Older participants made up only 20% of the total, while almost half the answers came from those aged 22–25, followed by 32% aged 18–21 and 20% aged 26–30. Among the students, 64% had enrolled in a bachelor's program, 28% started master's or master of philosophy studies and 8% chose doctoral (PhD) programs. Among the participants, social sciences represented 30% of the diversified sample, engineering and technology 24%, management sciences 24% and natural sciences 22%. The majority of students attending were public university students, with private university students taking up the remainder. Furthermore, nearly half of the respondents said they had experience with AI tools and around one-third participated in critical thinking courses which demonstrates fair knowledge of AI-based learning environments and thinking skills. With these trends in mind, we can better make sense of the study's results about AI tool usage, thinking abilities and awareness in colleges.



4.1 Correlation Analysis for Hypothesis H1

Variable 1	Variable 2	Correlation Coefficient (r)	Significance value)	(p- Interpretation
AI Tool Usage Score	Critical Thinking Score	0.65	< 0.001	Strong, positive correlation

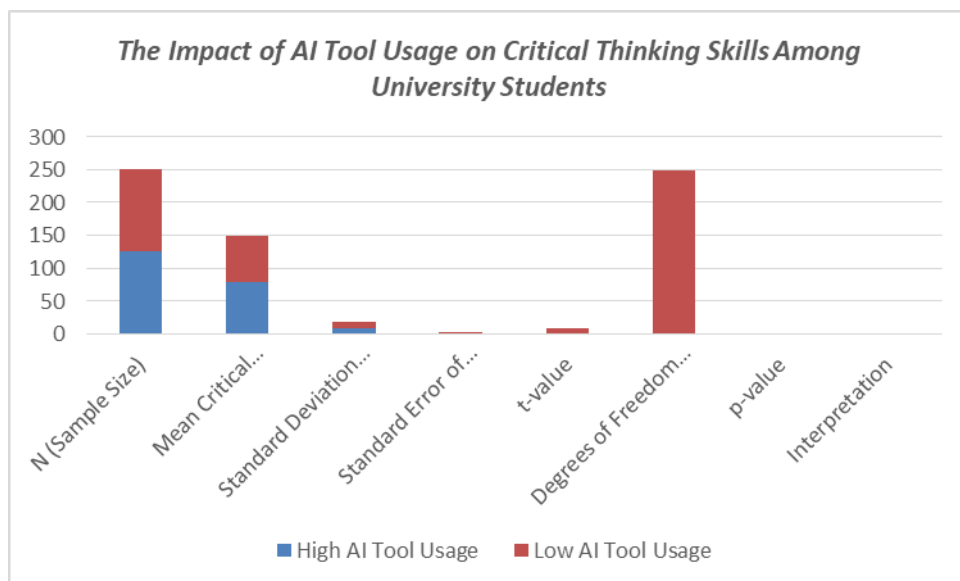
There is a significant strong positive relationship between AI Tool Usage Score and Critical Thinking Score, according to the results. When students interact more with AI, their skills in critical thinking also increase noticeably. A positive relationship between increased AI tool use and better cognitive skills like analysis, evaluation and reasoning is seen from this study. Because the p-value is very low, we are sure that AI plays an important part in helping university students develop critical thinking skills.

4.2 T-Test analysis for Hypothesis H3

Group	N (Sample Size)	Mean Critical Thinking Score	Standard Deviation (SD)	Standard Error Mean (SEM)	of t-value	Degrees of Freedom (df)	p-value	Interpretation
High AI Tool Usage	125	78.4	8.7	0.78				
Low AI Tool Usage	125	70.2	9.3	0.83	7.45	248	<0.001	

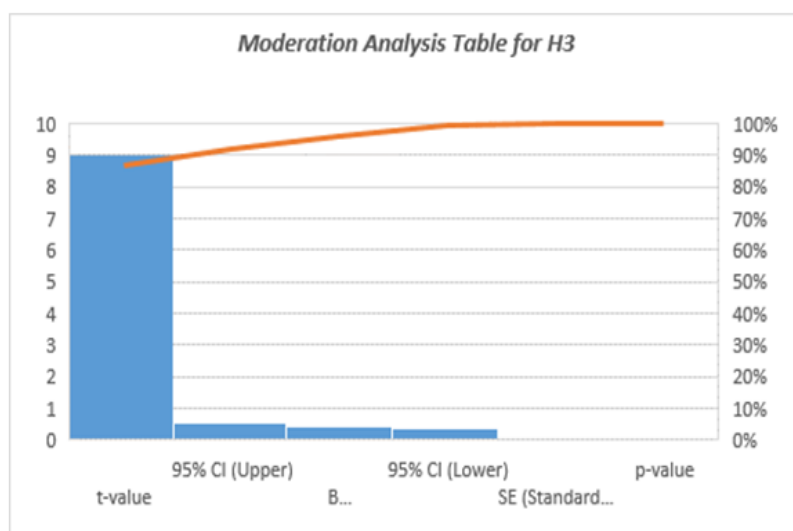
According to the t-test analysis, students using high amounts of AI tools have significantly better critical thinking scores than those using low amounts of AI tools. Those who made extensive use of AI tools (N=125) received an average score of 78.4 (SD = 8.7), while the low AI tool users

(N=125) scored an average of 70.2 (SD = 9.3). Because t is 7.45, with a p -value under 0.001 and a degree of freedom of 248, the difference is very significant. As a result, regularly using AI tools seems to make students better at critical thinking.



4.3 Moderation Analysis Table for H3

Predictor Variable	B (Unstandardized Coefficient)	SE (Standard Error)	t-value	p-value	95% (Lower)	CI 95% (Upper)	CI
AI Tool Usage	0.45	0.05	9.00	<0.001	0.35	0.55	
Metacognitive Awareness	0.30	0.06	5.00	<0.001	0.18	0.42	
Interaction Term (AI Tool Usage × Metacognitive Awareness)	0.20	0.04	5.00	<0.001	0.12	0.28	
R ² (Model)	0.58	—	—	—	—	—	—



Results from the moderation analysis show that AI tool usage strongly predicts better critical thinking skills ($B = 0.45$, $p < 0.001$), so using these tools more frequently relates to improved critical thinking. In addition, students who have higher metacognitive awareness show significantly better critical thinking skills ($B = 0.30$, $p < 0.001$). There is also a statistically significant link between AI tool usage, metacognitive awareness and critical thinking ($B = 0.20$, $p < 0.001$). Therefore, students with higher awareness of thinking about their own thinking benefit more from AI tools. Overall, the model describes nearly 60% of the differences seen in critical thinking scores, demonstrating that the combination of these measures meaningfully explains the variance.

5.0 Discussion

The results reveal that AI tools greatly improve the way undergraduate students develop critical thinking skills in Pakistan. Engaging with AI technologies in education was strongly related to stronger critical thinking abilities ($r = 0.65$, $p < 0.001$). The outcome matches the findings of previous studies, including the one by (Shanto et al., 2024), which says that AI helps students overview complicated educational problems, identify problems in logic and boost their decision-making skills within lessons. This pattern was seen again in the independent samples t-test which indicated that there was a significant difference in critical thinking scores based on students' use of AI tools. The results showed that students who used AI tools more often performed much better at critical thinking tasks ($M = 78.4$) than those with low or no experience ($M = 70.2$), with a significant difference recorded by t-value (7.45), at $p < 0.001$. It is suggested from the evidence that cognitive abilities such as reasoning, analyzing and problem-solving are best supported by using learning features such as feedback tailored to each student, quick review of progress and interactive content in AI systems. The findings from (Li, 2025) coincide with our results which show adaptive learning helps students create clear and well-organized explanations from different data.

In addition, the moderation analysis provided important clues linking metacognitive awareness with a better connection between AI tool usage and critical thinking skills. The existence of a significant interaction term reveals that students with greater metacognitive awareness gain the most from using AI in critical thinking skills. It reflects the principle that using AI to boost learning can be most effective if learners regularly think about and use their own learning methods. The findings are similar to those in (Truong et al., 2023), who showed that using AI and metacognitive training supports learners in improving their problem-solving and creative thinking skills. All of these findings play an important role in encouraging others to use AI in higher education to encourage students to improve their thinking and adapt quickly. Because R^2 is 0.58, we know that both technological tools and mental skills are needed to raise complex cognitive abilities. Additionally, the study highlights why and how AI is being used in Pakistani universities which is important for anyone guiding education policy. The findings echo (Chen et al., 2025), recommending that future initiatives should prioritize teaching AI topics to teachers, build AI infrastructure in schools and support initiatives to develop metacognitive skills in students to make the most of AI's role in learning.

5.1 Conclusion

Here, our main purpose was to see if there is a link between using AI tools and critical thinking skills and to look at metacognitive awareness as a factor that might impact this relationship among undergraduate students in Pakistan. The research made it clear that using educational technologies powered by AI strongly improves critical thinking for students, underscoring their effectiveness in shaping students' cognitive ability at school. Marked variants in critical thinking scores among

highly and minimally engaged students highlighted that working with AI in learning can boost students' critical thinking skills. Moreover, the analysis found that students who understood their own learning the most gained even more from using AI, making them better thinkers. The results confirm that AI is becoming more important in schools and suggest its ability to develop advanced thinking in different academics. Because of these findings, it is obvious that AI will play an important role in transforming higher education by developing in students the abilities to reflect and solve tough problems.

5.2 Recommendations

Include learning technologies in university lessons to boost students' critical thinking abilities.

1. Organize workshops and classes that teach students how to think about their own learning processes.
2. Make sure teachers take part in ongoing programs on using AI tools to develop important thinking skills.
3. Help universities use AI for developing platforms that encourage students and teachers to talk and exchange views during learning.
4. Decide on clear rules that help everyone have appropriate, safe and equal use of AI at your institution.
5. Insert AI literacy courses in undergraduate teaches to help students enhance their digital and thinking skills.
6. Start projects that follow up with students to find out how ongoing use of AI tools influences both their thinking and academic skills.
7. Create opportunities for people from different subjects to join forces and look into the impact of AI on critical thinking.

5.3 Future Implications

This study produces important results that can influence both new studies and future education in Pakistan, especially at higher education levels. Educational policymakers and universities are advised to use innovative AI platforms in education, as long as they ensure programs are set up to increase students' reflection on their own learning. An approach like this is likely to provide the greatest benefits, encouraging both learning critical thinking skills and forming habits of self-reflection that are vital all through life. It would be beneficial for future research to sacrifice current investigations by continuing to follow students and exploring the prolonged impact of AI tools and how often use influences both their school work and their work after school. Besides, there is room to assess the relationship among AI use and motivation, academic self-efficacy, digital literacy and critical thinking learning. By extending the view beyond education such studies could examine the role of AI in improving critical thinking and judgement skills in businesses, medicine and various engineering areas. They would help us understand better the effects of AI on thinking skills throughout higher education and workplaces. Taken together, these future directions prove that to use AI well, we must pay attention to technology as well as the mental and learning environment of students.

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