



The Double-Edged Sword of Automation: Impact of Generative Ai Adoption on Student's Critical Thinking Skills in Higher Education Considering Cognitive Offloading as a Mediator

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ARTICLE INFO

Received:

March 22, 2026

Revision Received:

April 07, 2026

Accepted:

April 29, 2026

Available Online:

May 09, 2026

Keywords:

Generative AI tool usage,
Critical thinking skills,
Cognitive offloading.
Double edge sword of
automation

ABSTRACT

The rapid integration of Generative AI in education has ignited a critical debate regarding its impacts in education. Present study investigates the role of Generative AI as “double-edged sword” of automation on intellectual development of students. Specific objectives of the study were to examine the association of Generative AI tool usage with cognitive offloading and critical thinking skills after that examining the potential mediating role of cognitive offloading. A quantitative, cross-sectional research design was employed. Data was collected from 153 higher education student from four different universities of District Quetta. In order to test the association of Generative AI tools with cognitive offloading and critical thinking skills, a Pearson correlation & linear regression analysis was conducted. The results revealed i) a significant moderate to strong positive correlation among AI usage and cognitive offloading and ii) a significant inverse relationship among AI and critical thinking skills. Mediating effect of Cognitive Offloading was examined using Hayes’ PROCESS macro (Model 4) in SPSS. Results reveal that according to current sample cognitive offloading did not significantly mediate the relationship between AI usage and critical thinking. These findings suggest that the educational consequences of generative AI may depend on how students engage with the technology. Meanwhile AI is not a supernatural, self-regulating entity, it’s just a tool created, & guided by human intelligence. In order to sustain the role as architects of this technology, human must utilize their own unbeatable critical thinking rather than blindly relying on it.

1. Introduction

Advent of generative AI benefits everyone from global logistics to personal productivity from a worker to corporate professionals, and school student to academic researcher. Along with a number of tools Generative AI renowned as “cognitive extenders” as it automate difficult routine tasks within seconds and provide 24/7 personalized support (Vold & Orallo , 2022) . This frictionless availability of AI has introduced a profound tension between technological assistance and cognitive dependence (Amaya, et al., 2025). It serves as “double-edged sword” for learner by streamlining academic workflows (Wilkins, 2020); (Shafik , 2026); conversely creating “Sovereignty Trap” for learners (Jelinek, 2023); (Huw, Emmie, & Luciano, 2023).

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Authoritative manner of AI generated responses inspire students to rely completely on the tool rather than exercising their own critical judgments (Bullock, 2020). This state of dependency and over reliance often leads to passive cognitive behavior which affects the student's natural ability to analyze, evaluate, justify and verify the information logically (Asuncion & Natividad, 2025). The risk is particularly acute for students, whose academic habits and metacognitive schemes are still in formative stages (Bastani, et al., 2025)

A key factor to this dynamic is cognitive offloading, which is intentional transfer of mental demands to external tools (Gerlich M. , 2025). Generative AI serves as an effective mental workload reduction tool for students. While offloading is a free mental ability to engage in higher-order thinking tasks. Whereas unmediated use for reasoning tasks risks an "augmentation trap," (Caosun, & Aral, 2026) somehow short-term productivity gains may hide a long-term decline in critical thinking skills.

Objectives of the Study: The main objectives of the current study were; to distinguish student's Generative AI usage patterns among cognitive scaffolding versus task substitution. Secondly To identify the impact of generative AI on student's critical thinking skills. Finally To investigate if cognitive offloading acts as the major mediating mechanism surrounded by student's critical thinking and use of Generative AI.

2. Literature Review

2.1. Generative AI

Formerly used tools just retrieved information, (Dave T, 2023) but current systems synthesize, transform, and produce content according to the need and demand of user (Kosmyna, et al., 2025). Generative Artificial Intelligence is a branch of machine learning that creates new, original content by analyzing patterns in massive datasets. (UNESCO, 2023) (Feuerriegel, Hartman, Janiesch, & Zschech, 2023). AI is the capability of machines or computer programs to carry out operations alike human intellect (Dalalah & Dalalah, 2023) Generative AI empowers machines with human-like proficiencies, enabling them to work more effectively and efficiently, (Uday, Sangwan, Siva, & Vinay, 2024) according to results of their study "appropriate use of Generative AI can help students of higher education with an immersive education experience, encouraging them to learn and excel in accomplishing their educational goals". Generative AI adoption is accelerating more rapidly than previous technologies, (Amaya, et al., 2025) as it can synthesize massive amounts of data into coherent responses and support personalized learning. (Banh, 2023) Undoubtedly, this has drastic implications along with challenge sand risks that we need to tackle and manage in order to navigate the responsible and sustainable use of Generative AI. (Feuerriegel, Hartman, Janiesch, & Zschech, 2023).

2.2. Critical thinking: Selective Atrophy in the AI Era:

The cognitive skills are important for person to analyze, evaluate, and synthesize data. In order to make logical decisions it is essential to think critically. (Halpern, 2010) . It involves various cognitive processes, as problem-solving, decision-making, and reflective thinking, for navigating complex and dynamic environments. (Gerlich M. , 2025) When students over rely on AI for all types of academic tasks it effects their reasonable reflective thinking. (Moore, 2013) For instance, (Almulla, 2024) observed that regular usage of Generative AI tools increases cognitive engagement, they also noted that there is no significant positive effect on critical thinking. According to the study of (Bastani, et al., 2025) student's reliance on technology may underperform when access to AI is subsequently removed, representing reduced skill acquisition. Similarly (Surviyana & Nuryani, 2026) founded that immediate, automated feedback from AI negatively affect students, as it shakes their enthusiasm to engage in the challenging problem-solving activities. Instantaneous availability of fully formed answers with the help of AI decreases the student's natural efforts to process, analyze and evaluate data. (Azhar, 2026). Frequent utilization of Generative AI tools in the absence of any specific framework reduced Cognitive friction (Amaya, et al., 2025)

2.3. Cognitive offloading

It is the use of physical action to modify the information processing necessities of a task in order to lessen cognitive demand (Risko & Gilbert, 2016). Preliminary use of generative AI modify study workload by dividing mental tasks rather than changing or affecting core cognitive processing (Lindo & Cutad, 2024), Generative AI tools assists higher education students in managing workload and in achieving their study goals more efficiently. When students store and process the information outside the brain, they make free space in their brains which allows the brain to focus on complex problems. (Dalalah & Dalalah, 2023). Research specifies that transmitting information to external systems directly affects the inherent capacity limits of human working memory, thereby improving performance on tasks with high cognitive demand (Risko & Gilbert, 2016) Using automated systems is an adaptive coping approach to manage academic stress and maintain student well-being (Chirayath, Premamalini , & Joseph , Cognitive offloading or cognitive overload? How AI alters the mental architecture of coping, 2025) as excessive cognitive overload is closely associated with increased anxiety and cognitive fatigue. Generative AI arrives as "ultimate antidote" for cognitive offloading as it help out to reduce the administrative busywork and data overload, human error, inefficiency (Bell, 1999),. (Jeste, et al., 2020) AI supports immediately, automating clerical burdens, reorganizing multiple

tasking within seconds so that humans can utilize their potentials on other creative strategies more effectively and efficiently (Guo & Ye, 2026). The concept of task division transform primarily when students interacting with Generative AI tools as it can not only manage workflows rather cognitive offloading shifts into an invisible partnership. As articulated by (Chiriatti, Ganapini, & Riva, 2025) generative AI that acts as a cognitive “preprocessor” one who to filter out missing tasks, normalize response changes, and lessen behavioral indicators of cognitive offloading. Frequent use of Gen AI negatively effects student’s independently problem solving skills. In a mediation model, this perception indicates that cognitive offloading directly intercepts the learning process (De Jesus, Ibarra, Pasion, Villanueva, & Leyesa, 2024) the ignorance of student’s to crosscheck the material given by Gen-Ai tools weakens their reflective inquiry skills.

2.4. The Cognitive Paradox: Scaffolding vs. Substitution:

Rapid integration of Gen-AI has introduced a critical cognitive paradox, a significant investigation between its potential as an intellectual scaffold and its intimidation as an over-all substitution (Chirayath, Premamalini, & Joseph, 2025). In terms of scaffold, AI acts as an external supportive framework that in the short term offsets lower-level cognitive tasks, that improves instantaneous task performance, and in terms of Substitution its influence be a threat for user’s cognitive abilities. (Grinschgl & Neubauer, 2022). Conversely, when AI functions as a substitution, it entirely replaces the internal cognitive architecture of the learner. Gen-Ai tools are progressively perceived as cognitive scaffolds that support performance of learners as well as Learning process (Glickman & Sharot, 2025). In perspective of education and beyond, AI can serve as a guide or “more capable other,” (MCO) within Vygotsky’s Zone of Proximal Development framework for investigating how generative models either scaffold or substitute student cognition. (Wang & Fan, 2025) While Gen- AI as an MKO can improve learning process, whereas over-reliance on these tools leads to logical complacency and selective cognitive atrophy (Vaccaro, Almaatouq, & Malone, 2024). Gen-AI as a modified cognitive partner initially provides robust support but eventually, after that move human expertise towards AI dependency. According to a study of (Riva, 2025) AI systems, when designed thoughtfully, can perform as influential cognitive scaffolds that strengthen Students performance and learning process however safeguarding against the consequences of automation

Despite a growing body of research on adoption of Generative AI, the literature remains fragmented. Researchers frequently focusing on separated performance gains rather than the primary cognitive mechanisms. There is a significant gap in understanding psychological influence of Generative AI dependency on critical thinking and how cognitive offloading mediates the erosion of higher-order reasoning. Finally, there is a geographical difference in the data, with students in developing areas. Which shows there is a continuous underrepresentation in the literature, where the distinctive social responses of Pakistani university students remain absolutely unexamined. The present study aims to fill these gaps by suggesting a mechanism rich model that examines the impact of Gen-AI on specific critical thinking dimensions through the lens of cognitive offloading.

2.5. Research Hypotheses

Research hypothesis of the current study were as following;

- **RH1:** Student’s greater reliance on Generative AI tools will positively associate with cognitive offloading.
- **RH2:** Student’s increased reliance on Generative AI tools will lead to lower critical thinking scores
- **RH3:** Cognitive offloading will significantly mediate the association of Generative AI adoption and student critical thinking skills, whereas the positive or negative impact depends on the nature of the offloaded task.

3. Research Methodology

3.1. Research Design

Current research is conducted to examine the “Impact of Generative AI Adoption”, “on student’s Critical Thinking skills” in Higher Education considering “Cognitive Offloading as a Mediator”. In order to examine the relationship among variables a Quantitative Explanatory Cross-Sectional Survey Design was employed. The reason behind selecting quantitative approach was the systematic measurement of interactive variables and the performance of robust statistical testing. (Creswell & J. Creswell, 2023). An explanatory design was definitely utilized as the research aims to explain the “how” and “why” of the phenomenon by testing cognitive offloading as a mediating mechanism. As discussed by (Nardi, 2018) Explanatory research is aimed to answer “why” and “how” in variety of behaviors or opinions held among people surveyed. Furthermore, a cross-sectional survey method was adopted, which enables the collection of data from the target population at a single point in time to describe a population of interest. (Cummings, 2017). To ensure statistical accuracy for this explanatory model, the study will utilize mediation modeling (PROCESS Macro Model 4) which provides the predictive depth that is vital to validate the hypothesized pathways.

3.2. Population

The target population for current study includes BS.Edu students from the four universities of Balochistan, Quetta, District i.e. 1. University of Balochistan (UOB), 2. Sardar Bahadur khan women University (SBK WU), 3. Balochistan University of Information Technology, Sciences Engineering, and Management (BUIITEMS) and Alhamd Islamic University (AIU).

3.3. Sample Size

A total of 150 finalized survey responses were received via Google Forms and included in the final data analysis. According to standard statistical procedures of thumb for survey research a sample size above than 100 provides satisfactory statistical power to identify significant relationships among the study variables.

3.4. Sampling Technique

To align with the explanatory nature of the research, a non-probability purposive sampling strategy was employed. The main intention behind selection of purposive sampling technique is to select a best representative sample that possesses deep, direct significance to the core research objectives. Investigating future educators provides a unique academic viewpoint into the 'Cognitive Paradox as they will be the future curriculum developers and implementers of pedagogical strategies. According to (Rai & Thapa, 2015) The main goal of purposive sampling is to focus on particular characteristics of a population that are of interest, which will best empower you to achieve your research objectives.

3.5. Variables of the study

The main variables of the current study are as following:

- **Independent Variable (IV):** Adoption of Generative AI is the independent variable of the study defined as, “the extent to which students report using Gen-AI tools whether as a support or substitute for learning activities”, which can be measured by frequency of “AI tool usage scale” adopted from (Gerlich M. , 2025)
- **Mediating Variable (MV):** Cognitive Offloading is considered as the mediating variable of the current study. Based on Cognitive Load Theory it can be explained as the intentional allocation of mental demands to external digital tools to manage limited working memory resources. This variable was measured by predefined scale “cognitive offloading” adopted from (Gerlich M. , 2025)
- **Dependent Variable (DV):** Critical Thinking is the dependent variable of the current study and define as the self-regulated, persistent mental process of actively analyzing, evaluating, and synthesizing information to make logical decisions. For measuring dependent variable researchers adopted 9 items on a 6-point Likert scale from predefined validated subscales of (Terenzini,, Springer, Pascarella, & Nora , 1995) and (Halpern, 2010)

3.6. Research instrument

- i. **Informed consent form:** The consent form included a brief introduction of the research and the rights of the participant to participate or withdraw from the research.
- ii. **Demographic information:** comprise on information regarding gender, age, type of Gen-AI tool and frequency at which, respondent use these tools.

To measure Impact of Generative AI Adoption on student's Critical Thinking skills in Higher Education considering Cognitive Offloading as a Mediator, current study adopted standardized questionnaire from two predefined validated instruments.

3.7. AI Tool Usage

Frequency of AI usage and student's reliance on Generative AI Tools was assessed by adopting the “AI tool usage” subscale originally developed by (Gerlich M. , 2025). Which includes 5 items rated on a 6-point Likert scale (1 = strongly disagree/never/not at all, 6 = strongly agree/always/ completely). Higher scores indicate greater AI dependence.

3.8. Cognitive Offloading

Reliance on GEN-AI tools for learning tasks to free up the memory for other tasks were assessed by adopting the “cognitive Offloading” subscale originally developed by (Gerlich M. , 2025). This subscale consists of 5 items rated on a 6-point Likert scale (1 = strongly disagree/ not confident at all/ never/ very unlikely/ not dependent at all, 6 = strongly agree /very confident/always/ very likely/ completely dependent) where Higher scores indicate greater cognitive Offloading.

3.9. Critical Thinking

Self-reported and assessed critical thinking skills were measured by adopting by a predefined and valid scale of the Halpern Critical Thinking Assessment (HCTA) (Halpern, 2010) in order to evaluate perceived analytical development, (Terenzini, Springer, Pascarella, & Nora, 1995) self-reported measures of critical thinking was adopted. This subscale consists of 9 items rated on a 6-point Likert scale (1 = strongly disagree/ Not confident at all/ never/, 6 = strongly agree /Very confident/always/) where Higher scores indicate that a person has the optimal critical thinking capacity, peak cognitive self-efficacy and does not rely too much on AI to do their thinking for them

3.10. Data Collection procedure

As the target population consist of BS.Edu students from the four universities of Balochistan, Quetta, District i.e. 1. (UOB), 2. (SBK WU), 3. (BUIITEMS) and (AIU). Overall population is disseminated across diverse geographical regions, the entire data collection framework was achieved digitally through Google Forms. To avoid duplicate submissions the google form setting was "limit to only one response". Before data collection, official administrative permission was secured from the respective university coordinators. Following this authorization, the Google Forms link was shared directly with the Heads of Departments (HoDs) of the respective university's Education Departments. The HoDs then forwarded the survey link to (BS) Education students. The target sample size was completed within three weeks. Before data analysis researcher filter out incomplete submissions.

4. Data Analysis

4.1. Reliability analysis

A reliability analysis was conducted to examine the internal consistency of the study instruments using Cronbach's alpha. The results directed that all three constructs validated satisfactory to excellent reliability. The Generative AI Tool Usage scale along with 5 items showed acceptable internal consistency ($\alpha = 0.783$), whereas Cognitive Offloading scale with 5 items also having acceptable reliability ($\alpha = 0.780$). The Critical Thinking Skills scale along with 8 items demonstrated excellent internal consistency ($\alpha = 0.913$). Therefore, the measurement scales were deliberated reliable and appropriate for further analyses.

Table 1: Reliability Co-efficient of the questionnaire subscale (N=153)

S.No	Subscale	No. of Items	α
1	Complete Questionnaire	18	0.747
A	Critical thinking skills	08	0.913
B	Generative AI Tool usage	05	0.783
C	Cognitive Offloading	05	0.775

Note. N = 153. Cronbach's alpha values of .70 or higher indicate acceptable internal consistency.

After reliability analysis scale distribution of the questionnaire was analyzed table below shows mean Standard Deviation range and skewness of data so that if the data is appropriate further analyses can be run.

Table 2: Score distribution of single national curriculum questionnaire (N=153).

S.No.	Scale	No. of items	M	SD	Range		Skewness	
					Min	Max	Skew	Std. Error
1	G. AI Tool Usage	5	19.75	5.17	5	30	-1.03	.20
2	Cognitive Offloading	5	19.93	4.86	5	30	-0.65	.20
3	Critical Thinking Skills	8	31.82	9.04	8	48	0.02	.20

According to the descriptive analysis the mean score for Generative AI Tool Usage was 19.75 and SD = 5.17, indicating a moderate level of AI tool usage among the participants. The mean score for Cognitive Offloading was 19.93, SD = 4.86, signifying a adequate tendency to rely on digital tools for intellectual tasks. The mean score for Critical Thinking Skills was 31.82 SD = 9.04, reflecting a moderate level of critical thinking among the participants. The score were within acceptable range so we decided to further analyze our data.

RH1: Student's greater reliance on Generative AI tools will positively associate with cognitive offloading.: A Pearson correlation analysis was computed to test RH1, the results revealed a significant moderate to strong positive correlation among Generative AI Tool usage and cognitive offloading, $r=0.585$, $p<0.001$. Therefore, RH1 has supported, signifying that higher reliance on AI tools is associated with higher levels of cognitive offloading.

Table 3: Summary table of Correlation analysis between subscale (N=153)

	Generative AI Tool Usage	Cognitive Offloading	Critical Thinking Skills
Generative AI Tool Usage	-----		
Cognitive Offloading	.585**	-----	
Critical Thinking Skills	-.291**	-.166*	-----

** . Correlation is significant at the 0.001 level (2-tailed).

RH2: Student's increased reliance on Generative AI tools will lead to lower critical thinking skills: Firstly RH2 was supported by the results of correlation analysis according to which there is a significant negative correlation among Generative AI tool usage and critical thinking, $r = -0.291$, $p < 0.00$. Suggesting that over reliance on generative AI tools decreases the critical thinking skills.

Table 4: Linear Regression Analysis Predicting Critical Thinking Skills from Generative AI Tool Usage (N = 153)

Variable/ Predictor	B	SE	β	t	p
Constant	41.9	2.781	—	15.1	< .001
Generative AI Tool Usage	-0.51	.136	-.291	-3.74	< .001

Note. N=153, $R^2 = .085$; Adjusted $R^2 = .079$; $F(1,151) = 14.014$, $p < .001$.

According to the results, regression model was a statistically significant predictor of critical thinking skills, $F(1,151) = 14.014$, $p < .001$. Generative AI usage accounted for 8.5% of the variance in student's critical thinking scores ($R^2 = .085$). Similarly unstandardized coefficient ($B = -0.510$), indicates that for every one-unit increase in Generative AI reliance, critical thinking scores are predicted to decrease by 0.510 units. As the Standardized Beta ($\beta = -.291$) is negative and significant ($p < .001$), which support the RH2 i.e. Student's increased reliance on Generative AI tools will lead to lower critical thinking scores.

H3: Cognitive Offloading mediates the relationship between Generative AI Tool Usage and Critical Thinking Skills: In order to test the H3 a mediation analysis was conducted using Hayes' PROCESS macro (Model 4) in SPSS with 5,000 bootstrap samples and a 95% confidence interval to examine whether cognitive offloading mediated the relationship between Generative AI tool usage and critical-thinking skills. The results were as following;

Table 5: Mediation Analysis of Cognitive Offloading in the Relationship among Generative AI Tool Usage and Critical-Thinking Skills

Effect	B	SE	t	p	95% CI LL	95% CI UL
Outcome: Cognitive Offloading						
Generative AI Tool Usage (a)	0.550	0.062	8.86	< .001	0.427	0.672
Outcome: Critical-Thinking Skills						
Generative AI Tool Usage (path c')	-0.516	0.169	-3.06	.003	-0.849	-0.183
Cognitive Offloading (path b)	0.012	0.179	0.06	.949	-0.343	0.366
Indirect Effect($X \rightarrow M \rightarrow Y$) or (ab)	0.006	0.105	—	—	-0.193	0.229
Direct Effect ($X \rightarrow Y$) (c')	-0.516	0.169	-3.06	.003	-0.849	-0.183

Note. N = 153. For the cognitive-offloading outcome, $R = .585$, $R^2 = .342$, $F(1, 151) = 78.49$, $p < .001$. For the critical-thinking outcome, $R = .292$, $R^2 = .085$, $F(2, 150) = 6.96$, $p = .001$.

Path a: ($X \rightarrow M$): The results confirmed a significant positive relationship between AI tool usage and cognitive offloading along with $a = 0.550$, $t(151) = 8.86$, $p < .001$. The model explained 34.2% of the variance in offloading behavior ($R^2 = .342$). AI tool usage creates a variation of .3420 cognitive Offloading. Which supports the RH1. Path b($M \rightarrow Y | X$): : holding both variables in the model to observe the impact on critical thinking according to which cognitive offloading did not significantly predict critical thinking scores when In direct effect (c'): AI usage remained a significant negative predictor of critical thinking scores, when controlling for offloading, $c' = -0.516$, $t(150) = -3.064$, $p = .003$. Which again support the RH2. The bootstrapped indirect effect was 0.0063. Because the 95% Confidence Interval $[-0.193, 0.229]$ includes zero, the mediation is not statistically significant. Therefore, RH3 was rejected for current sample suggested that Cognitive Offloading did not mediates the relationship between Generative AI Tool Usage and Critical Thinking Skills

5. Discussion

The main aim of the current study was to investigate the impact of generative AI tool usage on student's critical thinking skills analyzing whether cognitive offloading mediates the variable. Researcher analyze the sample by Correlation analysis, regression analysis and mediation analysis using Hayes' PROCESS macro (Model 4) in SPSS. According to the results primarily higher reliance on AI tools is associated with higher levels of task substitution (cognitive offloading). Secondly Student's increased reliance on Generative AI tools will lead to lower critical thinking skills. And last one was Cognitive Offloading did not mediate the relationship between Generative AI Tool Usage and Critical Thinking Skills according to current sample.

5.1. Association of Generative AI tools with cognitive offloading

The results of current study about Student's Generative AI reliance is a powerful driver of cognitive offloading are consistent with the results of, (Liu, Fan, & Pan, 2026) increased reliance on generative AI causes students to adopt a "crutch" approach, resulting in task substitution (cognitive offloading) and if this reliance increased than turns in cognitive scaffolding. Similarly (Wang, Wang, Yang, & Ren, 2026) outlines that Generative AI acts as a double-edged sword, where practical offloading of tedious tasks improves learning, while dysfunctional offloading of core thinking generates dependency. Study of (Gerlich M. , 2025) shows that while unguided Generative AI tool usage grounds cognitive offloading and reduces reasoning quality.

5.2. Increased reliance on Generative AI tools will lead to lower critical thinking skills

The finding of the current study are consistent with earlier research works specifying that over reliance on Generative AI tool usage results in lower critical thinking skills. As in study by (Čiževska, 2025) increased reliance on generative AI tools leads to less deep thinking and higher automation bias, eventually follow-on in reduced critical capabilities. Similarly (Kulal, 2025) finds that frequent AI tool usage negatively effects critical thinking by fostering cognitive offloading, a progression where users rely heavily on technology for reasoning tasks. In another study by researchers (Patni, et al., 2025) find that excessive AI use can lead to reduced critical thinking and cognitive decline, To combat this "brain laziness," students should maintain a critical, questioning approach to AI-generated content, directing on independent analysis.

5.3. Mediating effect of Cognitive Offloading

While Generative AI reliance (X) significantly predicts cognitive offloading (M), this offloading does not function as a "link" or mechanism for critical thinking (Y) in current study sample. As the indirect effect ($ab=0.006$) was not statistically significant (95% CI $[-0.193, 0.229]$ included zero) which suggests that for the 153 students in current sample, Cognitive Offloading did not significantly mediate the relationship. According to the results of current study student's AI tool use is associated with cognitive offloading, but that offloading was not considerably related to critical thinking once AI use was controlled. This result is supported by the study of (Bhattarai, 2025) in which researcher explains that cognitive offloading partially mediates the impact of generative AI tool usage on critical thinking as it acts as a key, but not exclusive, mechanism, creating a corresponding mediation effect. While over-reliance on Generative AI destroys analytical skills. Structured "cognitive offload instruction" increases critical thinking by freeing mental resources for higher-order reasoning (Hong, 2025). However, the lack of a significant mediating consequence specifies that Cognitive offloading does not explain why greater AI reliance is associated with lower critical thinking. This finding suggests that cognitive offloading does not explain negative association among the AI reliance and higher-order reasoning. This supports the "Selective Atrophy" perspective and suggests that the way students use AI and monitor their thinking may play an important role in independent reasoning. Which was previously discussed by (Zhu, et al., 2026) students are at higher risk by losing their cognitive reasoning and independent analysis skills because of their over reliance on AI tools. . Which creates a wrong sense of security while actively causing human skills to weaken through selective atrophy.

6. Limitations and suggestions for future researchers

Despite its contributions, present research has some limitations. First, its cross-sectional design prevents causal conclusions about the variables of the study whereas selection purposive sampling technique limits the generalizability of the results. Secondly the present research surveyed Cognitive Offloading as the sole mediator. The non-significant indirect effect suggests that along with some other mechanisms, such as metacognitive monitoring, and depth of cognitive engagement, may better explain the relationship. The moderate R^2 value for the offloading model (34.2%) advocates that other significant predictors were not considered. Future researcher should focus on longitudinal or experimental research designs along with diverse samples to expand the generalizability of the data.

7. Conclusion

Current study examined the impact of Generative AI adoption on student's critical thinking skills in higher education, by considering Cognitive Offloading as a mediating factor. The findings highlighted the double-edged nature of Generative AI use in academic frameworks. Where on one side, greater Generative AI tool usage was significantly associated with greater Cognitive Offloading. On the other hand, Generative AI tool usage was significantly and inversely associated with critical thinking skills, suggesting that over reliance on AI negatively affect the critical thinking.

Results of RH1 confirm that Student's greater reliance on Generative AI tools will positively associate with cognitive offloading. According to the results Pearson correlation analysis there is a significant moderate to strong positive correlation among Generative AI Tool usage and cognitive offload. This demonstrates that AI is no longer a peripheral tool but a normalized strategy for delegating cognitive operations faster.

Results of RH2 confirms that there is a significant negative correspondence among Generative AI tool usage and critical thinking. When students overly on AI for their routine assignments, projects or for exam preparation they unconsciously creates a destructive pathway toward task substitution. Which supports the concept of "Selective Atrophy" physical or functional weakening of specific mental skills when they are no longer used.

The Rejection of Offloading as a Mediator RH3 indicates that the negative impact of AI on critical thinking is direct rather than operating through the mechanism of offloading itself. Indicating that student's over reliance on Generative AI is associated with cognitive offloading, but offloading alone does not account for the observed negative association with critical thinking. That can simply explained as for students in this sample, the "manner of engagement" with AI is likely unidimensional. Where treating AI as a completion engine (cognitive scaffold) rather than a dialectical partner". Because the act of offloading did not uniquely predict outcomes, it implies that the mere presence of an automated solution may be enough to discourage independent cognitive processing, regardless of the volume of tasks offloaded.

References

- Bullock, J. (2020). Artificial Intelligence: A Double-edged Sword.
- Chirayath, G., Premamalini, K., & Joseph, J. (2025). Cognitive offloading or cognitive overload? How AI alters the mental architecture of coping. *Frontiers in Psychology*, 16, Article 1699320.
- Chiriatti, M., Ganapini, M. B., & Riva, G. (2025). System o: Transforming Artificial Intelligence into a Cognitive Extension. *Cyberpsychology, Behavior, and Social Networking* 28(7).
- Dalalah, D., & Dalalah, O. M. (2023). The false positives and false negatives of generative AI detection tools in education and academic research: The case of ChatGPT. *The International Journal of Management Education*.
- De Jesus, F. S., Ibarra, M. L., Pasion, J. B., Villanueva, W., & Leyesa, M. (2024). ChatGPT as an Artificial Intelligence Learning Tool for Business Administration Students in Nueva Ecija, Philippines. *International Journal of Learning, Teaching and Educational Research*.
- Glickman, M., & Sharot, T. (2025). How human-AI feedback loops alter human perceptual, emotional and social judgements. *Nature Human Behaviour* volume 9, 345–359.
- Grinschgl, S., & Neubauer, A. C. (2022). Supporting Cognition With Modern Technology: Distributed Cognition Today and in an AI-Enhanced Future. PMCID: PMC9329671 DOI: 10.3389/frai.2022.908261.
- Jeste, D. V., Graham, S. A., Nguyen, T. T., Depp, C. A., Lee, E. E., & Kim, H.-C. (2020). Beyond artificial intelligence: exploring artificial wisdom. *International Psychogeriatrics*, 32(8), 993–1001. doi:10.1017/S1041610220000927
- Kosmyna, N., Hauptmann, E., Yuan, Y. T., Situ, J., Liao, X. H., Beresnitzky, A. V., . . . Maes, P. (2025). Your Brain on ChatGPT: Accumulation of Cognitive Debt when Using an AI Assistant for Essay Writing Task. *arXiv. arxiv.org*.
- Lindo, M. R., & Cutad, C. A. (2024). Impact of generative AI on self-regulated learning and cognitive offloading. *IMCC Journal of Science*, 4(2), 114–125.
- Rai, N., & Thapa, B. (2015). A STUDY ON PURPOSIVE SAMPLING METHOD IN RESEARCH. Kathmandu: Kathmandu School of Law, 5(1), 8–15.
- Shafik, W. (2026). *The Double-Edged Sword of Artificial Intelligence.. The Dark Side of AI*. Springer, Cham. doi:https://doi.org/10.1007/978-3-032-09130-7_2
- Surviyana, S., & Nuryani, P. (2026). The paradox of artificial intelligence in learning: The existence of technology and the challenges of critical thinking for high school students. *Jurnal Pendidikan Indonesia*, 15(1).
- Vold, K., & Orallo, J. H. (2022). AI extenders and the ethics of mental health. In *Artificial intelligence in brain and mental health: Philosophical, ethical & policy issues*. Cham: Springer International Publishing.
- Almulla, M. A. (2024). . . Exploring the effects of ChatGPT on students' engagement in higher education. *International Journal of Learning, Teaching and Educational Research*, 23(2), 221–242.

- Amaya, E. A., Zavaleta, A. R., Luján, I. G., López, E. G., Reyna, J. T., & Gonzales, J. D. (2025). Between Assistance and Dependence: Artificial Intelligence and Critical Thinking. A Study on First-Year University Students. *International Journal of Learning Teaching and Educational Research* 24(12), :118-134.
- Asuncion, I., & Natividad, L. (2025). the Double-Edge Sword of AI: Mitigating the Risk and Maximizing the Benefits of Artificial Intelligence in Education (AIED). SSRN.
- Azhar, A. (2026, march 31). How Algorithmic Dependency Erodes Human Critical Thinking Capacities. Retrieved from SSRN: Azhar, Abdullah, Cognitive Atrophy in the Age of Artificial Intelligence: How Algorithmic Dependency Erodes Human Critical Thinking Capacities <http://dx.doi.org/10.2139/ssrn.6442979>
- Banh, L. &. (2023). Generative artificial intelligence. . *Electronic markets*, 33(1, 63.
- Bastani, H., Bastan, O., Sungu, A., Ge, H., Kabakçı, Ö., & Mariman, R. (2025). Generative AI without guardrails can harm learning: Evidence from high school mathematics. *PNAS (Proceedings of the National Academy of Sciences)* 2025 Vol. 122.
- Bell, A. J. (1999). Levels and loops: the future of artificial intelligence and neuroscience. *Philos Trans R Soc Lond B Biol Sci.* 1999 Dec 29;354(1392):2013-20. . PMID: 10670021; PMCID: PMC1692705. doi:doi: 10.1098/rstb.1999.0540
- Bhattarai, K. (2025). MEDOF COGNITIVE OFFLOADING: LINKAGE BETWEEN GENERATIVE AI USAGE AND CRITICAL THINKING. LUTPub. lut.fi.
- Caosun,, M., & Aral, S. (2026). The Augmentation Trap: AI Productivity and the Cost of Cognitive Offloading. *Computer Science in Human-Computer Interaction* arXiv preprint arXiv:2604.03501.
- Chirayath, G., Premamalini, K., & Joseph, J. (2025). Cognitive offloading or cognitive overload? How AI alters the mental architecture of coping. *Front. Psychol.* 16:1699320. doi: 10.3389/fpsyg.2025.1699320.
- Číževska, A. (2025). Overreliance on AI and Its Effects on Student Cognition: What Can Teachers and Students Do? TRANSPORT AND TELECOMMUNICATION INSTITUTE .
- Creswell, J. W., & J. Creswell, D. (2023). *RESEARCH DESIGN Qualitative, Quantitative, and Mixed Methods Approaches* Sixth Edition. Los Angeles, New Delhi, Singapore, Washington DC, Melbourne: SAGE Publications, Inc.
- Cummings, C. L. (2017). *The SAGE Encyclopedia of Communication Research Methods*. Thousand Oaks: SAGE Publications, Inc.
- Dave T, A. S. (2023). ChatGPT in medicine: an overview of its applications, advantages, limitations, future prospects, and ethical considerations. *ChatGPT in medicine: an overview of its applications, advantages, limitations, future prospects, and ethical considerations.* *Front. Artif. Intell.* 6:1169595. doi: 10.3389/frai.2023.1169595.
- Davies, M. (2014). A model of critical thinking in higher education. In *Higher Education: Handbook of Theory and Research: . Cham: Springer International Publishing. Volume 30 , (pp. 41-92).*
- Feuerriegel, S., Hartman, J., Janiesch, C., & Zschech, P. (2023). Generative AI. *SSRN Electronic Journal*.
- Gerlich, M. (2025). AI tools in society: Impacts on cognitive offloading and the future of critical thinking. . *MDPI Societies*, 15(1), 6.
- Gerlich, M. (2025). AI Tools in Society: Impacts on Cognitive Offloading and the Future of Critical Thinking. *Societies*. 215(1):6. doi:<https://doi.org/10.3390/soc15010006>
- Gerlich, M. (2025). From offloading to engagement: An experimental study on structured prompting and critical reasoning with generative AI. *Data*, 10(11),, 172.
- Guo, Y., & Ye, Q. (2026). Guo, Y., Ye, Q. Meta-cognitive insights into cognitive offloading: mechanisms, interventions, and educational implications. *Humanit Soc Sci Commun* 13, 772, <https://doi.org/10.1057/s41599-026-06621-5>.
- Halpern, D. (2010). *The Halpern critical thinking assessment. Manual.* Vienna, Austria: Schuhfried GmbH.
- Hong, H. (2025). Interactive cognitive offload instruction with generative AI in English essay writing. . *Proceedings of the Intrnational Conference Artificial Intelligence in Education and Engineering (AIEE)*, 147-152.
- Huw, R., Emmie, H., & Luciano, F. (2023). Digital sovereignty, digital expansionism, and the prospects for In Quo Vadis, sovereignty? New conceptual and regulatory boundaries in the age of digital ChinaIn. Switzerland: (pp. 51-75). Cham: Springer Nature .
- Jelinek, T. (2023). *The Digital Sovereignty Trap.* Cham: Springer.
- Kulal, A. (2025). . Cognitive Risks of AI: Literacy, Trust, and Critical Thinking. . *Journal of Computer Information Systems*,, 1-13. doi:<https://doi.org/10.1080/08874417.2025.2582050>
- Lai, E. R. (2011). Critical thinking: A literature review. *Pearson's research reports*, 6(1), 40-41.
- Liu, D., Fan, G., & Pan, L. (2026). Tool, tutor, or crutch?: A grounded theory of cognitive scaffolding and offloading in AI-assisted programming education. *International Journal of STEM Education*, 13(1).
- Melisa, R., Ashadi, A., Triastuti, A., Hidayati, S., Salido, A., Ero, P. E., . . . Fuad, Z. A. (2025). Critical Thinking in the Age of AI: A Systematic Review of AI's Effects on Higher Education. *Educational Process: International Journal (EDUPIJ)*, 1-22.
- Moore, T. (2013). Critical thinking: Seven definitions in search of a. *Studies in Higher Education*, 38(4), 506-522.
- Nardi, P. M. (2018). *Doing survey research: A guide to quantitative methods.* . Routledge.

- Patni, N., Choerul, U. M., Anton, S., Winarno, Winarno, Risanti, . . . Jumiyanto, W. (2025). valuating the impact of AI on the critical thinking skills among the higher education students by combining the TAM model and critical thinking theory. *Frontiers in Education* 10-2025.
- Risko, E. F., & Gilbert, S. J. (2016). Cognitive Offloading. *Trends in cognitive sciences*, .
- Riva, G. (2025). Enhanced Cognitive Scaffolding as a Resolution to the Comfort-Growth Paradox in Human AI Cognitive Integration. *The Architecture of Cognitive Amplification*:.
- Terenzini, P. T., Springer, L., Pascarella, E. T., & Nora , A. (1995). Influences affecting the development of students' critical thinking skills. *Res High Educ* 36,, 23-39. doi:<https://doi.org/10.1007/BF02207765>
- Uday, M., Sangwan, D., Siva, S., & Vinay, C. (2024). A Comprehensive Review on Generative AI for Education,. *IEEE Access*, vol. 12, pp. 142733-142759, 2024, doi: 10.1109/ACCESS.2024.3468368.
- UNESCO. (2023). Guidance for generative AI in education and research. United Nations Educational, Scientific and Cultural Organization,.
- Vaccaro, , M., Almaatouq, A., & Malone, T. (2024). Vaccaro, M., Almaatouq, A., & Malone, T When combinations of humans and AI are useful: A systematic review and meta-analysis. *Nature Human Behaviour*, 8(12), 2293-2303.
- Wang, G., Wang, W., Yang, D., & Ren, J. (2026). (2026). Generative AI, Cognitive Offloading, and Learner Agency in Higher Education: . A Scoping Review.
- Wang, J., & Fan, W. (2025). Wang, J., Fan, W. RETRACTED ARTICLE: The effect of ChatGPT on students' learning performance, learning perception, and higher-order thinking: insights from a meta-analysis. *Humanities and Social Sciences Communications* volume 12, Article number: 621.
- Wilkins, U. (2020). Artificial intelligence in the workplace – A double-edged sword". *International Journal of Information and Learning Technology*, Vol. 37 No. 5, 253-265,. doi:<https://doi.org/10.1108/IJILT-02-2020-0022>
- Zhu, M., Guo, Y., Zhao, M., Sun, T., Shi, R., Zheng, X., & Chen, T. (2026). Artificial Intelligence Empowers Monitoring, Assessment, and Management in Exercise. . *Health and Metabolism*, 3(2), 5.