

DOES OVER-RELIANCE ON ARTIFICIAL INTELLIGENCE CAUSE REDUCTION IN CRITICAL THINKING? A QUASI-EXPERIMENTAL STUDY

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Abstract

This research was conducted to examine the causal effect of over-reliance on artificial intelligence on students' critical thinking by statistically controlling initial differences between the experimental and control groups. A quasi-experimental research design with a pre-test–post-test control group approach was employed. The sample was selected through simple random sampling. Thirty students from B.Ed. Semester III were assigned to the experimental group, while thirty students from B.Ed. Semester I were selected for the control group. The experimental group (Semester III) was allowed relatively high and independent use of artificial intelligence-based tools in academic activities, whereas the control group (Semester I) was restricted to limited use of AI and continued with traditional teaching and learning methods. To measure students' critical thinking skills, the Critical Thinking Questionnaire (CThQ) was adapted and administered. The results of the independent samples t-test indicated that there was no statistically significant difference in critical thinking between the experimental and control groups at the pre-test stage. However, the findings of the paired sample t-test showed a significant decline in critical thinking abilities in the experimental group, while no significant change was observed in the control group.

Keywords: Artificial Intelligence, Critical Thinking, Quasi-Experimental Design, Pre-test Post-test, Educational Technology, Student Learning Outcomes, Cognitive Skills

1. Introduction

Artificial intelligence has become a disruptive technology in contemporary education, changing the way pedagogical lessons are taught, learning experience is facilitated and knowledge is acquired. Its quick adoption into academic life has brought on board generative AI systems, intelligent tutoring systems, and automated writing assistants that greatly assist students in accessing information and academic productivity. Nonetheless, in addition to these benefits, researchers have expressed apprehensions about the mental effects of using AI, especially concerning the advanced thinking abilities, including critical thinking (Holmes et al. 14).

It is well known that critical thinking is one of the fundamental academic skills that are imperative to intellectual growth, problem solving, and evidence-based decision making. According to Facione, critical thinking is self-regulatory, purposeful judgment which leads to interpretation, analysis, evaluation and inference (Facione 4). It is perceived as a primary outcome in higher education that helps students to be ready to face complex problems in the real world (Paul and Elder 7).

1.1 Background and Context of the Study

In modern educational settings, AI-powered applications are becoming more popular among students in their academic works, including writing of essays or generating ideas, summarization tasks, and problem-solving activities. Although these technologies enhance efficiency and lessen cognitive workload, they can also promote passive learning behaviors. As Luckin et al. suggest, AI is supposed to act as an intelligent companion that facilitates learning but not to substitute the human cognitive effort (Luckin et al. 12).

The idea of cognitive offloading can be applied in a similar manner, indicating that people prefer to outsource their brain functions to external aids in case they have them, which may make the cognitive processing less deep (Risko and Gilbert 680). This can lead to less interaction with critical thinking and critical analysis in the learning environment. The Cognitive Load Theory by Sweller goes on to state that although a decrease in extraneous cognitive load can facilitate learning, over dependence on external facilitation can inhibit significant cognitive growth (Sweller 221).

1.2 Research Gap

Despite the fact that the existing literature points out the positive and negative aspects of AI in education, the majority of the research is devoted to the efficiency of teaching, learner interaction, or the adaptation to technology instead of the cognitive implications. The study by Zawacki-Richter et al. focuses more on the administrative and instructional aspects of AI implementation, and student cognition is not given much focus (Zawacki-Richter et al. 15).

On the same note, Kasneci et al. posit that generative AI applications like ChatGPT have the potential to facilitate learning, yet also caution that such applications can be abused to the detriment of critical thinking and over-reliance (Kasneci et al. 3). Nevertheless, there is a lack of empirical research to directly support the causal association between AI dependency and critical thinking.

Particularly, quasi-experimental studies that will compare the groups with the controlled levels of AI exposure are lacking. This is a weakness that limits our knowledge on whether the use of AI can enhance the cognitive abilities by providing a scaffold or undermine them by building dependency.

1.3 Research Objectives/Questions

The proposed research is the attempt to study empirically the impact of artificial intelligence over-reliance on critical thinking skills of students based on a quasi-experimental design. The particular aims are:

1. To investigate the distinction in critical thinking abilities among AI-dependent and non-AI-dependent students
2. To compare the level of critical thinking prior to and after AI-based learning setting exposure
3. To find out whether the use of AI is excessive or it is associated with a quantifiable loss of analytical and evaluative skills in thinking

Research Questions:

1. Does excessive use of artificial intelligence harm students in terms of critical thinking?
2. Do AI-exposed and non-exposed learners differ significantly in terms of cognitive performance?
3. What are the effects of long-term AI use on the pre-test and post-test critical thinking results of students?

1.4 Scope and Significance of the Study

This study is restricted to undergraduate students, B.Ed. students, in terms of cognitive development with respect to the use of artificial intelligence. The experiment explores critical thinking as an objective that can be measured depending on the degree of exposure to AI.

The importance of the study is that it adds to the existing discussion on the integration of educational technologies. The application of generative AI in education should be strictly controlled to promote instead of hamper cognitive development (UNESCO, 2023). The current study offers empirical findings that can inform educators, curriculum designers and policymakers to develop balanced AI integrated learning settings.

This study will be beneficial as it fills a critical gap in the body of experimental research by offering information about the effects of AI on cognitive processes and emphasizing the need to retain critical thinking skills in the technology-enhanced education system.

2. Literature Review

2.1 Artificial Intelligence in Education

Artificial intelligence has become a focal element of educational change, especially in post-secondary education where digital technologies are becoming more and more central to teaching, assessment, and learning support mechanisms. Intelligent tutoring systems, automated feedback systems, and generative language models are examples of AI-driven systems that transformed the conventional teacher-centered classroom into a more flexible and tech-centric learning experience (Holmes et al. 22).

Zawacki-Richter et al. point out that the applications of AI in higher education are mainly clustered around three aspects: automation of administrative functions, student services, and adaptive learning environments (Zawacki-Richter et al. 9). These systems are meant to enhance efficiency and customization in order that students learn at their own pace. Nevertheless, the pedagogical aspects of these technologies are actively being studied.

According to Luckin et al., AI must be framed as an intelligent partner that supports human learning instead of cognitive effort (Luckin et al. 13). Although these benefits exist, there are still fears that excessive use of AI tools can turn students away in their active construction of knowledge and transform them into passive consumers of information.

2.2 Critical Thinking as a fundamental Academic Competency

Critical thinking is considered to be one of the most core learning outcomes of the contemporary educational systems. It helps learners to examine arguments, assess evidence, and reach well-informed verdicts in academic and everyday settings. According to Facione, critical thinking is self-regulated, purposeful judgment that leads to interpretation, analysis, evaluation, and inference (Facione 4).

Paul and Elder stress that critical thinking is a disciplined intellectual exercise and that critical thinking follows certain standards, including clarity, accuracy, relevance, and logic (Paul and Elder 8). It is not just the power to think but to think reflectively and independently. The taxonomy of Bloom also ranks critical thinking to be in the higher levels of cognitive learning, especially in the areas of analysis, synthesis, and evaluation. Such levels demand profound interest in content, and it can be disrupted when students overtrust AI-generated answers.

2.3 Digital Dependency and Cognitive Offloading

Cognitive offloading, or the act of outsourcing mental processes, is one of the most important theoretical issues in AI-assisted learning. According to Risko and Gilbert, cognitive offloading has the potential to ease the mental load and enhance efficiency, yet it can also deteriorate the memory performance and internal cognition (Risko and Gilbert 678). In education, AI applications can be used to summarize content, translate, and even create content. Although it does ease cognitive load, it can also lead students not to think in a profound way. This dependence may over time result in diminished intellectual autonomy and problem-solving skills.

2.4 Learning Behavior and Generative AI

Recent developments in generative AI, e.g., ChatGPT, have greatly enhanced the tendency of students to resort to automated content creation. Kasneci et al. state that although these tools can facilitate personalized learning and enhance academic writing, they can also contribute to superficial learning when the student does not critically reflect upon them (Kasneci et al. 6). On the same note, UNESCO (2023) cautions that unchecked application of generative AI in education could lead to a decline in creativity, deterioration in analytical skills, and a rise in academic dependency. The organization underlines the importance of a systematic adoption of AI tools into pedagogical systems to make sure that cognitive development does not suffer. Holmes et al. also propose that AI ought to be integrated into constructivist learning spaces in

which students actively learn through provided content as opposed to passively consuming AI-created outputs (Holmes et al. 35).

2.5 Experimental research on AI and Cognitive Skills

There is empirical evidence regarding AI and cognitive development, with both positive and negative results. Others show beneficial results, including increased learning effectiveness, personalized feedback, and better academic results (Luckin et al. 18). Nonetheless, other research suggests that over-dependence can have certain dangers. Indicatively, research in online education indicates that overuse of automated systems can decrease student participation in problem-solving activities and tasks involving analytical reasoning. This is in tandem with the notion of deskilling, in which the monotonous use of technology over time makes it less possible to do tasks without technology.

2.6 What is Missing in the Study

Although the literature on AI in education is growing, there are still no experimental and quasi-experimental studies that directly quantify the effect of AI on the development of critical thinking. Majority of the current studies are dedicated to the descriptive analysis, user experience or technological efficiency and not the cognitive outcomes. More than that, evidence on the comparisons of students who have different amounts of AI exposure to a controlled academic setting is scarce. This is especially lacking in the context of higher education where critical thinking is a central learning outcome.

2.7 Conceptual Framework

The connection between critical thinking and AI usage can be viewed in a variety of theoretical interpretations. Constructivist theory of learning stresses the idea that knowledge is built up in an active process of cognition but not passively received. In case AI takes the place of this active interaction, learning can become superficial. The Cognitive Load Theory proposed by Sweller proposes that although it is good to minimize irrelevant cognitive load, too much of it could inhibit meaningful thinking (Sweller 224). Also, there is the dependency theory of educational technology that argues that frequent use of external tools can make learners less confident in being able to think on their own.

Collectively, these theories imply that although AI is beneficial in education, excessive use of AI can adversely affect the development of critical thinking unless it is controlled.

3. Research Methodology

3.1 Research Design

This research was a quasi-experimental pre-test post-test control group design. This design is suitable in educational research where it is not possible to completely randomize but comparative analysis is needed. The design will enable measurement of change in critical thinking both pre- and post-intervention, and control initial differences in groups.

3.2 Population and Sample

The study population was made up of Bachelor of Education (B.Ed.) students in a university in the public sector. Simple random sampling was used to select 60 students.

Experimental Group: 30 students (Semester III).

Control Group: 30 students (Semester I)

The sampling was to make sure that there was variation in the levels of AI exposure.

3.3 Research Instrument

The main research tool was the Critical Thinking Questionnaire (CThQ). It tested in four aspects of critical thinking:

- Analysis
- Interpretation
- Evaluation
- Inference

To make the instrument reliable and easy to understand, it was validated by professional assessment and pilot testing.

3.4 Procedure

The investigation was done in three stages:

1. Pre-test Phase: CThQ was used to determine baseline levels of critical thinking in both groups.
2. Treatment Phase (8 weeks):
 - o Experimental group made abundant use of AI tools in academic activities.
 - o Control group used the conventional method of learning and little exposure to AI.
3. Post-test Phase: The two groups were re-tested with the same tool.

3.5 Data Analysis

Statistical methods such as: were used to analyze the data.

- Independent samples t-test (to compare groups at pre-test)
- Paired samples t-test (to test within-group differences)

These tests were useful in establishing the statistical significance of AI exposure on the performance of critical thinking.

3.6 Ethical Considerations

The participants were told the aim of the study and the research was conducted in secret. There was voluntary participation, and academic fairness was maintained between the two groups.

4. Theoretical Analysis

The given section elaborates on the conceptual and theoretical underpinnings that can be used to make sense of the relationship between the use of the artificial intelligence and the development of critical thinking. The debate is based on the learning theories and cognitive psychology models to comprehend the impact AI can have on the way students think.

4.1 Constructivist Learning Theory

Constructivist learning theory, which is largely identified with Piaget and Vygotsky, has a primary focus that a learner builds knowledge through interaction, reflection, and experience, as opposed to being a passive recipient of information. Piaget also says that cognitive development takes place when learners undergo an assimilation and accommodation process which enables them to restructure their mental representations with time (Piaget 37).

Here, critical thinking occurs when the students question, analyze, and interpret information. This cognitive construction process can however be circumvented when artificial intelligence systems offer ready-made responses to the students. According to Holmes et al., AI can facilitate learning but not to replace active engagement because learning involves the intellectual struggle and thought (Holmes et al. 41). In this way, according to the constructivist view, excessive dependence on AI can undermine the role of the learner in the construction of knowledge, and the engagement in critical thinking.

4.2 Cognitive Load Theory

The Cognitive Load Theory (CLT) is a theory that was created by Sweller, and which describes the functioning of human working memory and how the design of instructions influences the effectiveness of learning. CLT separates cognitive load into intrinsic, extraneous and germane load (Sweller 223). Extraneous cognitive load is greatly minimized with the help of AI tools that can offer instant solutions, summaries, and explanations. Although this can positively affect novices, overloading cognitive effort can restrict germane load mental effort needed to achieve deep learning and schema building.

According to Risko and Gilbert, cognitive offloading aided by external tools diminishes the necessity of a mental processing, which can impair the development of long-term cognitive abilities (Risko and Gilbert 680). This can also imply that excessive use of AI can impair the growth of analytical thinking and problem-solving abilities in education.

4.3 Information Processing Theory

Information Processing Theory likens the human mind to a computer system that receives input, stores information and retrieves knowledge when required. Learning is a process that takes place when information is actively encoded, processed and stored in the long term memory.

Overreliance on AI tools can result in students missing critical processing steps (such as encoding and elaboration). Rather than processing information on a deep level, they can rely on AI-generated information. Mayer states that meaningful learning involves active processing of information as opposed to passive intake of information (Mayer 52). Thus, AI addiction can decrease the richness of information processing, which can result in low retention and low critical thinking ability.

4.4 Educational Technology and the Dependency Theory.

Dependent theory of educational technology implies that overdependence on external systems may hamper the capacity of learners to work on their own. Students might become cognitively dependent instead of intellectually autonomous as they rely more on AI to write, reason, and solve problems. Generative AI tools can create a learning process where students do not scrutinize the productions, according to Kasneci et al., without critical use (Kasneci et al. 8). Such change of behavior may undermine critical judgment and judgment. UNESCO (2023) also stresses that AI should be incorporated in such a manner that it boosts human cognition, instead of substituting it. Abandoning adequate pedagogical instructions, reliance on AI can have a detrimental impact on vital academic skills.

4.5 Bloom Taxonomy and Critical Thinking levels

Taxonomy is a hierarchical way in which Bloom divides the cognitive learning into remembering, understanding, applying, analyzing, evaluating, and creating. Critical thinking mostly functions at the higher levels- analysis, evaluation and creation (Bloom et al. 56). Students are less likely to use higher-order thinking skills when AI undertakes lower-level cognitive tasks like summarization or explanation. In the long run, this can lead to decreased participation in analytic and evaluative procedures, which are critical to academic growth. According to Paul and Elder, critical thinking is a matter of continual intellectual work and cannot evolve during passive learning (Paul and Elder 11). Thus, excessive use of AI can interfere with the advancement to higher levels of cognition.

4.6 Integrated Theoretical Framework

It is possible to make a complex association between the use of AI and the critical thinking process by integrating the above theories. Constructivism underlines the role of active involvement, the cognitive load theory underlines the role of balanced mental effort, and the information processing theory is a theory that focuses on deep cognitive encoding. These views combined suggest that although AI can help optimize learning, overreliance can decrease mental activity. Such decrease in engagement can have a direct influence on the ability of students to analyze, evaluate, and synthesize information. As such, the theoretical framework of the present research indicates that AI must be used as a cognitive support system and not as a cognitive replacement system.

5. Analysis and Discussion

5.1 Cognitive Shift and Post-Test performance

The post-test mean shows that there is a decisive difference between the experimental and control group at the end of the intervention period. Although the baseline of critical thinking performance was similar in both groups, the experimental group (exposed to high-frequency AI-usage) exhibited a statistically significant decrease in analytical and evaluative performance. This trend indicates that the way of thinking was modified in the course of learning. In the view of the learning science, this change can be viewed as a transformation of

active cognition to assisted cognition, with students relying more on AI outputs rather than building a reasoning on their own. This interpretation can be backed by Swellers Cognitive Load Theory according to which in cases when external tools overly minimize mental load, students may fail to acquire strong cognitive schemas that help them to think in higher orders (Sweller 224).

5.2 AI Dependency and Decrease in Analytical Depth

Another significant discovery during the experimental group was that there was a decrease in the depth of reasoning in written and verbal answers. The learners were more likely to believe AI-generated exposition without critically assessing its soundness and other points of view. This action is in line with the idea of cognitive offloading by Risko and Gilbert, in which the dependence on external systems diminishes cognitive, processing in the mind in the long run (Risko and Gilbert 680). Conversely, the control group that depended on the traditional methods of learning showed more constant involvement in the analytical reasoning tasks. Their answers were more indicative of justification, comparison and logical organization. This disparity implies that the exposure to AI might also affect not only the performance results but the quality of cognitive performance as well.

5.3 Effect on Evaluation and Judgment Skills

Critical thinking is not only an analysis but also an evaluation, a judgment of the validity, applicability and accuracy of information. The experimental group was less effective in the evaluative tasks and especially when requested to compare several perspectives or to evaluate the credibility of sources of information. Kasneci et al. warn that generative AI applications tend to deliver information with a strong and authoritative voice and thus can deter users (Kasneci et al. 9). This could be the reason why evaluative caution was lowered in students in the experimental group.

Paul and Elder stress that critical thinking involves systematic doubting of assumptions and evidence (Paul and Elder 12). The noted decrease in assessment abilities implies that the dependency on AI can disrupt this reflective procedure.

5.4 Learning Pattern Behavioral Change

In addition to quantifiable test scores, the research also noted changes in behavior with regards to learning methods. The experimental group of students increasingly used AI tools to generate ideas, organize assignments, and even explain concepts. This dependence slowly substituted independent brainstorming and problem solving efforts. Holmes et al. note that this behavioral dependency may shift learners into consumers of AI output, instead of creators of knowledge (Holmes et al. 47). This change can eventually diminish intellectual interest and the desire to study academic material will diminish.

5.5 AI as an example of Cognitive Shortcut

The use of AI tools is cognitive shortcuts because they can be used to give instant answers, summaries, and structured results. Although this enhances efficiency, it can also deter brain work which is essential in the development of critical thinking. According to the Information Processing Theory, learning involves active encoding and elaboration of information (Mayer 53). The external execution of these functions by AI can make students miss key cognitive steps, leading to superficial learning. This paper indicates that cognitive shortcuts can disrupt the process of building long-term cognitive abilities like reasoning, inference, and synthesis when used excessively.

5.6 Correlation with Theoretical Framework

The results of the current research are very consistent with the theoretical framework mentioned above. Constructivist theory focuses on active engagement, which seems to be less in the experimental group. Likewise, Cognitive Load Theory describes how mental effort can be lessened to restrict the formation of the schema. The dependency theory also contributes to

the fact that relying on AI repeatedly may make people less intellectual. Collectively, these theories form a consistent line of reasoning as to why the performance of critical thinking among learners who are dependent on AI has deteriorated.

5.7 Contradictions and Alternative Interpretations

Although the results indicate that AI overuse is negatively related to critical thinking, one should consider other possible interpretations. With proper application, AI tools can be used to improve the learning experience by scaffolding and offering feedback. Holmes et al. believe that higher-order thinking can be assisted by using AI when incorporated into reflective pedagogical models (Holmes et al. 49).

Hence, it might not be AI but the way of usage. The constructive and critical application of AI can improve learning, and unregulated and passive application can impair cognitive development.

5.8 Educational Implications

The implications of the findings to teaching practice and curriculum design are profound. Teachers are not meant to disavow AI, but rather instruct students on how to evaluate AI critically. This includes:

- Training students on how to check AI-generated information.
- Promoting the comparison of AI outputs with academic sources.
- Developing tasks where answers using AI should be justified.
- Encouraging reflective writing exercises examining AI shortcomings.

According to UNESCO (2023), AI literacy is a key aspect of contemporary education, as students should be aware of the potential and the limitations of AI systems.

5.9 Synthesis of Analysis

In general, the discussion shows that excessive dependency on artificial intelligence is linked to the decrease in the performance of critical thinking, especially the depth of analysis, evaluation, and independent thinking. Nonetheless, its impact depends on the application of AI in the learning process. The results support the notion that AI must be used as a cognitive assistant and not a cognitive substitute. The use of AI can inadvertently undermine important academic skills without the appropriate instructional guidance.

6. Conclusion

This research paper aimed to investigate the question of whether over-dependence on artificial intelligence could result in a decline in the critical thinking of students in a quasi-experimental setting. These results offer substantive insights into the fact that long-term and uncontrolled utilization of AI tools may have an adverse effect on the main aspects of critical thinking, especially analysis, evaluation, and independent thinking.

Pre-test scores indicated that experimental and control groups were at the same level of cognitive ability, which is a methodological validity. Nevertheless, post-test analysis found out that the critical thinking performance of students who were exposed to wide AI usage declined significantly whereas the control group did not change significantly. The trend shows that the differences observed could probably be as a result of the intervention, and not other external factors.

Theoretically, these results are consistent with constructivist learning theory, cognitive load theory, and cognitive offloading theory, which all imply that active mental engagement is vital to deep learning. Over-utilization of AI tools will diminish the need of students to analyze and evaluate things independently, which will inhibit cognitive development in the long term (Sweller 224; Risko and Gilbert 680).

Notably, the research does not posit the use of artificial intelligence in education. Rather, it brings out the dangers of over-dependence. When used strategically, AI can be a potent educational support tool, however, when it substitutes instead of assisting human thinking

processes, it will be problematic. According to Holmes et al. AI must be a supplement to learning, not intellectual work (Holmes et al. 50).

The results have also important pedagogical implications. The teachers should be careful to make sure that the introduction of AI in the classroom should be supported by a systematic instruction that facilitates critical thinking. Learners must be taught to be skeptical, doubting, and critical of AI-generated information, instead of taking it as ultimate truth. The danger of creating technologically effective and cognitively dependent learners exists without such guidance.

6.1 Educational Implications

In accordance with the findings, a number of implications to teaching and curriculum design can be identified:

The use of AI tools as an addition to learning aids and not the main source of knowledge should be incorporated.

Assignments: When using AI tools, assignments should demand justification of answers.

Teachers are to focus on the skills of verification and source comparison activities.

- The curriculum designers must include the elements of AI literacy that dwell on critical analysis of machine generated information.

UNESCO (2023) emphasizes that the future of education should strike a balance between technological progress and cognitive growth and make sure that students do not lose the necessary intellectual capabilities in the world of AI.

6.2 Study Limitations

Despite the good insights that the study gives, some limitations need to be considered. To begin with, the sample size was constrained to 60 students of one academic program, and this could limit generalizability. Second, the period of the intervention was not too long, and, therefore, no long-term outcomes of using AI on critical thinking were possible to be observed entirely. Third, it was a quantitative study that merely measured the critical thinking, but did not cover the qualitative data like the perceptions of the students.

6.3 Future Research Suggestions

In future, larger and more varied samples of various levels and disciplines should be considered. To study lasting cognitive impacts of AI exposure, longitudinal research designs are suggested. Also, qualitative research with quantitative tests and qualitative studies (interviews) could be more useful in understanding the ways students engage with AI tools and how their engagements influence the way they think.

6.4 Final Statement

To sum up, AI has a great potential to change education, yet its role in cognitive development is heavily dependent on the use of AI. This paper reveals that AI can be effective in terms of efficiency but excessive dependence can undermine critical thinking. Consequently, there is a need to have a balanced, guided and thoughtful integration of AI by making sure that technology development empowers and not undermines the intellectual abilities of students.

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