Digital technologies and cognitive approaches in the development of critical thinking and creativity: Factual analysis of the artificial intelligence and neuroscience-based learning processes of university students

Ipek MAASOGLU, Didem İSLEK

Near East University, Ataturk Faculty of Education, Nicosia

ipek.maasoglu@neu.edu.tr, didem.islek@neu.edu.tr

Abstract: *The current research seeks to comprehensively analyse the comparative interaction between artificial intelligence-assisted learning and neuroscience-based cognitive strategies in developing the critical thinking and creativity skills of higher education students. The research employed comparative case study pattern, which is a qualitative research method. The study group consisted of 120 university students in total who participated in a university-level course focusing on critical thinking and problem-solving skills. The study collected qualitative data through semi-structured interviews, which the researchers then analyzed thematically to detect recurring trends and insights. The analyses showed that Artificial Intelligence (AI) assisted digital group enjoyed higher diversity of opinions and developed faster problem-solving skills. However, the Cognitive Group displayed more depth, originality, and conceptual integrity of ideas. As a critical finding, it has been determined that students who use AI show the tendency to transfer part of their cognitive responsibility to AI tools, whereas the meta-cognitive awareness and self-regulatory skills of the Cognitive Group are more developed. These findings indicate that although AI-assisted learning supports creativity, it manifests different effects on the nature of the autonomous cognitive efforts of students. The study presents recommendations for structuring the AI integration in higher education with pedagogical approaches which protect the autonomy and cognitive participation of students.*

Keywords: AI-assisted learning, Neuroscience-based cognitive strategies, Critical thinking, Creativity, Case study, Meta-cognitive awareness.

1. Introduction

The usage of AI-supported learning tools has gained popularity in recent years both with the purpose of promoting learning processes and increasing the usage of technology at higher education (Suh,2025; Zuo et al. 2025). In this context, usage of AI-assisted learning settings provides fast feedback to learners, and aims to increase the academic success and learning motivation of students by offering customized contents (Luckin et al., 2016; Holmes et al., 2019).

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On the other hand, literature review reveals that it is emphasized that the adoption of AI tools in learning and teaching processes can constrain the decision-making skills of learners as well as their higher cognitive abilities such as critical and creative thinking and generating original ideas (Selwyn, 2019; Williamson & Eynon, 2020). In this context, it is essential that learners preserve their cognitive responsibilities and improve strategical and meta-cognitive skills in course-learning processes. Nevertheless, approaches where artificial intelligence is included in the processes in a limited manner but rather is more integrated into the learning settings of cognitive strategies need to be adopted. In this way, learners will be allowed to perform deeper analyses and direct the learning processes more consciously (Elnaffar et al., 2025; Mohamed et al., 2025). In addition, performing studies involving comparative assessment of AI-assisted learning and cognitive approaches in higher education bears importance for both featuring the pedagogical applications and effectively developing the critical thinking and creativity students' competencies. Review of the relevant literature indicates that studies involving comparative assessment of AI-assisted learning and cognitive approaches are given only limited coverage. Within this framework, it is believed that comparative examination of the impact of digital technologies and neuroscience-informed methods in university-level education on the learner outcomes will make contribution to the development of pedagogical applications and conscious management of learning processes.

1.1 Literature review

Artificial intelligence tools accelerate the learning process and offer students personalized content (Luckin et al., 2016; Holmes et al. 2019). On the other hand, neuroscience-based cognitive strategies guide students towards both in-depth thinking and the development of original ideas, contributing to their metacognitive awareness (Duran & Er, 2019; Elnaffar, Rashidi & Abualkishik, 2025). A review of the literature reveals a limited number of studies examining the comparative effects of AI-assisted learning and cognitive strategies (Williamson & Eynon, 2020; OUCI DNTB, 2024). Furthermore, the limiting effects of AI tools on decision-making and critical thinking skills have not been sufficiently investigated (Selwyn, 2019). This research aims to fill this gap in the literature and to comparatively examine the effects of AI and cognitive strategies on the critical thinking and creativity skills of university students.

1.2 The importance of the study

This study aims to deeply analyze the comparative interaction of AI-assisted tools assisted learning and neuroscience-based cognitive strategies on Critical Thinking and Creative Problem-Solving Skills. In this regard, it is believed that this research will make essential theoretical contribution to the pedagogical transformation in university-level education. The study also presents suggestions for structuring the artificial intelligence integration processes with a view to protect

the autonomous learning abilities and active cognitive participation levels of students. Within this scope, it is expected that this study will present a normative framework for curriculum developers and educators. In line with this expectation, this study aims to perform an in-depth analysis of the comparative impact of Artificial Intelligence (AI)-assisted learning and neuroscience-based cognitive strategies on the development of the critical thinking and creativity skills of tertiary education students. Answers are sought to the following questions so that the research could reach its general purpose:

1. What are the general learning experiences of students in the Digital Group (AI-assisted) and Cognitive Group (Neuroscience-based) regarding the activities in Critical Thinking and Creative Problem-Solving course?
2. What are opinions of students as regarding the impact of Artificial Intelligence-Assisted and Neuroscience-Based learning experiences on the development of their Critical Thinking and Creativity Skills?

2. Method

This section details the methodology and research processes of the study. The research was conducted using a comparative case study design, and the methodological framework of the research was structured around two different learning approaches that form the basis of the study. The first of these approaches is the artificial intelligence-supported digital learning approach. In this approach, students used artificial intelligence tools such as GPT-4 and Gemini for educational purposes in the learning-teaching processes. These tools were positioned as digital cognitive tools that support problem-solving, idea generation, generating alternative solutions, and reflective thinking. Thus, it was aimed to support students' higher-order thinking, critical analysis, and creativity skills through these applications. In the second learning approach, a neuroscience-based cognitive learning approach was adopted. In line with this approach, based on cognitive neuroscience and metacognition theories, it was aimed to enable students to become aware of, regulate, and manage their own thinking processes. Thus, using cognitive strategies such as metacognitive monitoring, transfer of cognitive responsibility to the learner, mind maps, and creativity-supporting techniques such as SCAMPER, it was aimed to develop students' self-regulated learning skills and increase their cognitive awareness. In line with this conceptual framework, this section provides detailed information on the research design, study group, implementation process, data collection process and tools, and data analysis.

2.1 Research model

The study employed a comparative case study design, which is widely used to explore and compare multiple cases in depth (Yin, 2018). In such studies, each case is examined holistically, and the findings are systematically compared to

reveal similarities, differences, and patterns. Within the scope of this study, students' learning experiences in AI-assisted digital learning and neuroscience-based cognitive learning approaches were compared using this method. The study focused on examining the effects of these two distinct learning interventions on the development of critical thinking and creativity skills through a detailed and holistic analysis. Key analytical themes included transfer of cognitive responsibility and metacognitive awareness, which reflect the underlying cognitive mechanisms of both approaches.

2.2 Study group

The participant group of the research included 120 undergraduate participants at education faculty of Near East University who were enrolled at the course on critical thinking and creative problem-solving (n=120). The study employed criterion sampling to select participants, which involves purposefully choosing individuals who meet specific research criteria. When determining the sampling criteria, attention was paid to ensure that students had participated in AI-assisted learning applications and neuroscience-based cognitive strategy interventions within the scope of the relevant course so that comparative analysis could be performed. Within additional criteria, participants were urged to show active participation in the course on critical thinking and creative problem-solving and fill in their learning logs regularly. Within this framework, two groups with high originality which were suitable for comparison were created for comparative case study, which is the research pattern employed in this research. The first group was formed by participants who use AI tools actively in their learning processes (N=60) whereas the second group included students who applied neuroscience-based cognitive strategies during learning process (N=60). These groups were enrolled at different departments of the university but took the relevant course as an elective. With these characteristics, the study group exhibits a structure fit for comparatively examining different learning approaches to the development process of critical thinking and creativity skills at the tertiary education level.

2.3 Application process

The study group was identified in the preliminary phase of the research and the students were divided into two natural groups without random assignment taking into account their academic success levels. Accordingly, 60 students were categorized as the Digital Group and the other 60 students formed the Cognitive Group. The study was based on comparative case study model, where the Digital Group used artificial intelligence assisted learning tools and the Cognitive Group was subjected to neuroscience-based cognitive strategies. Semi-structured interview and learning log forms were given their final shape after validation process including expert opinions and a pilot study. Prior to the application, an orientation training of 4 hours was offered to both groups on the usage of their respective methods. Digital group was focused on AI tools whereas the Cognitive

Group concentrated on neuroscience-based cognitive strategies (mind-maps, meta-cognitive monitoring). The application process took 8 weeks and each week the students were given real-life scenarios to develop their Critical Thinking skills. At this stage, members of the Digital Group actively conducted analyses using AI-assisted tools such as GPT-4 and Gemini, which are specifically customized for educational and academic use. The Cognitive Group, in contrast, did not employ digital learning tools and generated solutions by relying on neuroscience-based cognitive strategies, including metacognitive monitoring, mind mapping, and creativity techniques such as SCAMPER. During the study, students' learning logs were regularly monitored, and semi-structured interviews were conducted to collect qualitative data. These data were subsequently analyzed in detail through thematic analysis to uncover key patterns and themes.

2.4 Data collection process and tools

To achieve the objectives of this study, a semi-structured interview was conducted to explore students' cognitive awareness, perceptions of AI, and evaluations of learning strategies. Additionally, students' learning logs were employed to closely monitor their learning processes throughout the study. The collected qualitative data were prepared for analysis using thematic analysis method.

2.4.1 Semi-Structured Interview Form

A semi-structured interview form was prepared with the purpose of in-depth examination of the experiences of students regarding artificial intelligence-assisted learning and neuroscience-based cognitive strategies within this research. This form consists of five open-ended questions in total. When preparing the form, 15 academics were consulted who are experts in the fields of education technologies, education sciences, cognitive psychology, and measurement-evaluation. Lawshe (1975) content validity ratio (CVR) technique was used in the evaluation of expert opinions. In this technique, participants' comprehension was evaluated using response categories that indicated varying levels of understanding, from partial understanding to no understanding at all. Spaces were left under the difficult-to-understand items so as to obtain suggestions. The analysis found the CVR value of the form as +1. Finally, necessary corrections were made to develop the final version of the form.

2.4.2 Learning Logs

Participants were asked to keep learning logs, which served as the second data collection method in the research. It was aimed that students could reflect their cognitive, emotional and meta-cognitive experiences throughout the process using these logs. Within this framework, students were asked to write down their learning experiences, their evaluations regarding AI-assisted or cognitive strategy-based activities, and the difficulties they encountered on a weekly basis.

2.5 Data analysis

The data obtained from the study were analyzed using Thematic Analysis, which is a qualitative research method. In thematic analysis, the repetitive significant themes, patterns and topics in the collected data are systematically defined and analyzed (Yıldırım & Şimşek, 2018). The first stage of the analysis consisted of reading the qualitative data in line with research questions and conceptual framework, and meaningful codes were created. In the second stage, the relations and commonalities between the determined codes were examined, and the main themes and sub-themes reflecting the critical findings of the study (i.e. diversity of opinions, transfer of cognitive responsibility, meta-cognitive awareness, conceptual integrity) were categorized in a systematic manner. In the final stage, the obtained themes were defined, analyzed and interpreted in accordance with the purposes of the study. This analysis focused on the interactions which diverge especially between AI-supported learning Assisted Digital Group and Cognitive Group.

3. Findings

3.1 Learning experiences of digital and cognitive groups in critical thinking and creativity

According to the first sub-purpose of the study, general learning experiences of Digital (AI-assisted) and Cognitive (neuroscience-based) students in the course on critical thinking and creative problem-solving were examined. As presented in Table 1**,** the main themes included Participation in the Learning Process *and* Challenges and Limitations.

Table 1. General learning experiences of digital group and cognitive group students as regards the activities in the course on critical thinking and creative problem-solving

Main theme	Sub-theme	Digital Group (AI-assisted)	Cognitive Group (Neuroscience-based)
1. Participation in the Learning Process	Participation Pace and Adaptation	Rapidly adapted to the process; idea generation began quickly.	They were involved in the process in a slower but planned and step-by-step pattern.
	The Nature of Participation	They showed high motivation and interaction.	They displayed in-depth questioning and intense problem-solving effort.
2. Challenges and Limitations	Technological and cognitive challenges	A sense of excessive dependency on AI; confusion of decisions due to abundancy of options	Strategies being challenging and time-consuming in the beginning; requiring excessive mental effort

In the first theme, the groups shared their opinions regarding how they engaged in the learning process (see Table 1). Within this theme, the focus was on two areas: students' adaptation to the pace of learning and the characteristics of their participation. According to the digital group, their involvement in the course accelerated as they became more accustomed to the pace and organization of the class activities. At this point, it can be argued that rapid feedback provided by artificial intelligence tools facilitates the participation of students in activities without wasting time. An example opinion related to this finding is presented below:

"*With instant responses from the AI, we were able to progress through our assignments without unnecessary delays*." (S76)

Nevertheless, Cognitive Group members stated that they were involved in the learning process in a slower but more systematic manner. This finding shows that the learning approach of the cognitive group is based on sense-making, planning, and step-by-step progress. A sample view is given below:

"*At the start of each critical thinking task, I focus on understanding the problem. While this takes some time and limits my initial speed, it enables me to participate thoughtfully and follow a planned approach."* (S15)

In the second sub-theme titled "The Nature of Participation", the Digital Group members stated that they showed high motivation and interaction in the learning process (see Table 1). Based on this finding, it can be argued that the instant interactions of the digital group during learning process creates high motivation, which results in an intense and qualified learning experience. A sample view can be seen below:

"AI-supported feedback let on us to stay engaged, participate more fully in the lesson, and remain motivated throughout the learning process." (S 57)

However, Cognitive Group members argued that they could display in-depth questioning and intense problem-solving efforts during learning process. This finding displays that the cognitive group addresses learning not only as an effort to reach a solution, but also to understand and evaluate the process itself. An example opinion is provided below:

"*In class activities and presentations, we focus on understanding the reasoning behind each problem. We analyze each step thoughtfully and explore different possible solutions before reaching a conclusion."* (S 25)

In addition, the groups shared their views regarding the challenges and limitations they encountered under the second theme (see Table 1). In relation to the second theme, digital group members indicated that they experienced challenges of a technological and cognitive nature, such as over-dependence on AI and decision-making difficulties caused by the large volume of data. This finding indicates that student experiences such as data abundance and dependency on artificial intelligence can lead to potential problems including attention deficit and decision-making difficulties during learning processes. An example statement is given below:

"*Because AI tools provide so much information, I often struggle to decide which data to attend to first, making it more difficult to concentrate and make informed choices while learning."* (S 69)

Cognitive group, on the other hand, argued that they encountered some difficulties in the beginning such as the strategies requiring high mental effort due to their challenging and time-consuming nature. This finding can be the reason of students perceiving the process as cumbersome and exhaustive, which impairs their willingness to learn. An example opinion is provided below:

"*Working through some of the strategies was time-intensive and demanded constant reflection, which at times lowered my motivation and hindered my ability to move forward efficiently."* (S 6)

The obtained findings indicate that digital group members participate in class activities rapidly and in a motivated manner thanks to artificial intelligence-assisted rapid feedback, although they suffered from limitations in decision-making and superficiality. On the contrary, the cognitive group progressed more slowly but followed a more planned and in-depth learning process.

3.2. Students' views on ai-assisted and neuroscience-based learning for critical thinking and creativity

Within the second sub-objective, students' perceptions of the impact of AI-assisted and neuroscience-based learning on critical thinking and creativity were examined. As shown in Table 2, the main themes were Development of Critical Thinking, Development of Creativity, and Meta-cognitive Awareness.

Table 2. Opinions of students on the impact of artificial intelligence-assisted and neuroscience-based learning experiences on the development of their critical thinking and creativity skills

Main Theme	Sub-Theme	Digital Group (AI-assisted)	Cognitive Group (Neuroscience-based)
1. Development of Critical Thinking	Speed of Analysis	AI tools accelerated analysis and idea-generation process.	Strategies slowed down the analysis process but gave it more depth.
2. Development of Creativity	Originality of Ideas	Although the solutions were produced rapidly, originality varied depending on the suggestions made by AI.	Solutions of the students are more original, and conceptually more holistic.
3. Meta-cognitive Awareness	Strategy Usage Consciousness	Strategy awareness is low, AI direction is more evident.	Students chose and applied strategies more consciously.

The groups shared their views on how the course activities contributed to the development of their critical thinking skills as part of the first theme (see Table 2). Accordingly, the digital group indicated that AI-supported instant feedback helped them interpret problems in the course activities more efficiently, enhancing the speed at which they could analyze the tasks. This finding indicates that students can focus on the solution process in a very short time using artificial intelligence-assisted tools. An example statement is as follows:

"*In the course activities, I found that artificial intelligence assisted me in working through challenging topics, enabling quicker and more effective problem-solving."* (S 47)

However, the Cognitive Group members argued that the strategies they used slowed down the analysis process but added depth to it. This finding proves that strategies used in the cognitive group are essential, and that they highlight deliberation and detailed analysis skills instead of the speed of analysis. A sample opinion is given below:

"T*he use of cognitive strategies helps us think more comprehensively. While analyzing each problem requires time, methodically planning every step allows for meaningful and deep learning."* (S24)

Within the second theme, the groups discussed the ways in which the course activities helped develop their creative abilities (see Table 2). In terms of generating original ideas, the digital group noted that AI helped them produce concepts rapidly, although most of their ideas tended to reflect the suggestions offered by the system. This finding can be interpreted as digital tools contributing to productivity whereas the creativity of students is confined to the information offered by AI. An example view is given below.

"*AI-supported class activities help us generate ideas quickly, yet we often find that these ideas are limited to the framework suggested by the tool, and it remains difficult to develop genuinely original concepts.*" (S 114)

By contrast, the Cognitive Group stated that they found problem-solving in course-related activities more original and conceptually more integrated. This finding displays that students can develop more creative and conceptually holistic approaches to problem-solving using strategic and deep-thinking processes. An example opinion is given below.

"*Working through problems step by step with cognitive strategies allowed me to combine different viewpoints and produce solutions that were more creative and unique."* (S 84)

The groups shared their opinions on their meta-cognitive awareness as part of the third theme (see Table 2). Accordingly, students in the digital group explained that their awareness of strategy use is low and that they primarily require AI-assisted guidance during the learning process, as part of the discussion on strategy usage awareness. This finding implies that the self-regulation and strategic decision-making learner outcomes is not adequately supported due to the assistance provided by artificial intelligence. A sample expression is given below.

"While AI tools were helpful in selecting strategies for class tasks, relying on them too much made it challenging for me to design my own learning plan." (S45)

By contrast, students in the Cognitive Group stated that they were able to choose their strategy consciously and that they could adapt it to their personal learning processes. This finding shows that students in the cognitive group have higher meta-cognitive awareness compared to other group and that they could manage their learning process more consciously. Below is a sample expression.

"I can plan ahead to select the most appropriate cognitive strategy for classroom tasks, and if necessary, modify my strategy or take personal control of my learning." (S 112)

The obtained findings show that the members of the digital group can perform analysis rapidly using the ideas generated by artificial intelligence but that they suffer from limitations in strategy utilization and originality. Nevertheles, the cognitive group was able to use strategies consciously by progressing more slowly and thus they enjoyed an original and stronger learning process in terms of meta-cognition.

5. Discussion, conclusions & recommendations

In accordance with the first sub-objective of the study, general learning experiences of digital group and cognitive group students as regards activities in critical thinking and creative problem-solving course was examined. Students in the digital group stated that their participation in the learning process of the course was rapid. An examination of the literature shows that Şimşek's study (2025) found that artificial intelligence tools contributed to personalized and effective learning. Another finding of the study indicates that students in the digital group encountered limitations in terms of decision-making and superficiality. Research by Zhai et al. (2024) concluded that, parallel to our finding, artificial intelligence tools might hinder the analytical thinking and autonomous decision-making learner outcomes, which could result in rather superficial learning experiences. However, other findings display that cognitive group progressed slowly but experienced a more planned and deeper learning process. Similarly, Duran and Er (2019) stated that learning strategies make positive contribution to the academic success and learning process of students. Regarding the second sub-objective, the opinions of students on the impact of artificial intelligence-assisted and neuroscience-based learning experiences of students on their critical thinking and creativity skills have been examined. The obtained findings indicate that digital group members were able to perform analysis easily with the help of the ideas generated by artificial intelligence but that they had difficulty in employing a strategy. Parallel to this finding, Elstad's study (2024) argued that the usage of artificial intelligence made positive contribution to the individual learning and problem-solving students' competencies, whereas its excessive use could weaken the cognitive skills such as original and critical thinking. Another obtained finding shows that the cognitive

group progressed more slowly and was able to use cognitive approaches more consciously, as a result of which they could reinforce original and meta-cognitive learning processes. From this perspective, Çöğenli and Güven (2015) underlined that using meta-cognitive approaches the students could perform planning, monitoring and evaluation of the courses more easily and use strategies more consciously.

In light of the findings obtained in the study, training can be given to students on the conscious usage of artificial intelligence tools. In addition, courses can be added to the curricula on the limitations of artificial intelligence. Structured activities that allow them to progress slowly in digital learning environments can also be designed to support students' in-depth and planned learning approach. Finally, usage of artificial intelligence tools can be planned by balancing them with autonomous problem-solving and original idea-generating processes so as to improve the critical thinking and creative problem-solving students' competencies.

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