SCIENTIFIC CULTURE
www.sci-cult.com

SCIENTIFIC CULTURE, Vol. 12, No. 4, (2026), pp. 10534-10549
Open Access. Online & Print

DOI: 10.5281/zenodo.124261017

INVESTIGATING THE IMPACT OF USING CHATGPT ON LATERAL THINKING IN ABSTRACT ALGEBRA CONCEPTS AMONG PRE-SERVICE MATHEMATICS TEACHERS

Estabrq Ahmed Al-Saadi[1]*, Radman Mohammed Saeed[2]

[1]PhD Researcher, Department of Mathematics, Faculty of Education, Sana'a University, Yemen
[2]Prof. of Abstract Algebra, Department of Mathematics, Faculty of Education, Sana'a University, Yemen

Received: 13/09/2025
Accepted: 10/02/2026

Corresponding Author: Estabrq Ahmed Al-Saadi

ABSTRACT

This study aimed to investigate the impact of using ChatGPT on lateral thinking in abstract algebra concepts among prospective mathematics teachers. To achieve this aim, a mixed-methods approach was employed, integrating a quantitative quasi-experimental design with two groups (experimental and control) and a qualitative approach to examine how ChatGPT enhances instructional practices. The study sample consisted of 17 fourth-year students from the Faculty of Education at Sana'a University. Two research instruments were developed: a lateral thinking test in abstract algebra concepts and an observation protocol. The findings revealed that the use of ChatGPT had a positive effect on students' lateral thinking in abstract algebra concepts. The study recommends integrating various artificial intelligence applications into teaching practices to keep pace with contemporary developments.

KEYWORDS: ChatGPT, Lateral Thinking, Abstract Algebra.

INTRODUCTION

Abstract algebra is considered one of the core components of mathematics teacher education, as it provides the intellectual depth necessary for understanding algebraic structures and teaching them from a comprehensive perspective. It focuses on the study of abstract algebraic structures, as well as the relationships and operations that govern them, such as groups, rings, and fields. Nevertheless, this branch remains one of the most challenging academic subjects due to its highly abstract nature. It goes beyond dealing with numbers or conventional arithmetic operations to encompass the analysis of properties of mathematical systems and the investigation of the laws that regulate the interactions among their elements.

This development has led to a profound paradigm shift in mathematics, as abstract algebra introduced a new perspective centered on abstract concepts, interconnected facts and principles, the construction of diverse proofs, and logical reasoning through the use of examples and non-examples, thereby moving beyond the classical principles of general algebra (Alam & Mohanty, 2024).

Furthermore, learning abstract algebra concepts brings about a substantial shift in teachers' beliefs and their classroom practices, as it reshapes their understanding and perspectives on the nature of mathematics as a whole. It provides a logical foundation for many of the procedures underlying school mathematics and fosters the cognitive development of prospective mathematics teachers (Veith & et al, 2022).

To achieve the learning objectives of abstract algebra, learners must be able to master a set of essential competencies, including mathematical reasoning, connecting facts and concepts to derive multiple conclusions, and engaging in various forms of thinking (Agustyaningrum & et al, 2019).

Thinking represents a fundamental pillar and an essential tool for addressing the demands and problems of the present era and its continuous development. This ongoing advancement requires individuals to reflect carefully before taking any action, ensuring comprehensive awareness and informed thinking, in order to achieve progress and advancement at both the individual and societal levels (Al- Jarrah & Al- Tarawneh, 2021).

According to Bishay (2018), in order to prepare a generation capable of meeting the demands of the current era, it is essential to equip students with thinking skills, particularly lateral thinking skills, as it represents a new approach to research and cognition. Lateral thinking helps students think in diverse ways that enable them to go beyond traditional patterns of thought, address problems with more effective ideas, generate new ideas, and develop their abilities to transform problems into opportunities for creativity and innovation.

Given the importance of lateral thinking, several studies, such as (Al-Luhabi, 2019; Al-Khazraji, 2021; Qasim & Al-Zoubi, 2023; Nur et al., 2022; Nair & Mohan, 2023), have recommended the necessity of developing its skills in order to produce learners who are capable of utilizing their cognitive and behavioral potentials, discovering their latent abilities, and improving their lives for the better through positive activities and practices.

As a result of the rapid transformation occurring worldwide in the field of digital technology, artificial intelligence has emerged as one of the most prominent technologies that have brought significant changes across various domains of life, particularly in education. Different artificial intelligence applications are characterized by their ability to infer, handle incomplete data, and continuously evolve over time.

One of the most prominent artificial intelligence applications is the chatbot ChatGPT, which has rapidly gained widespread popularity. This may be attributed to its ability to generate high-quality text, produce diverse research-related content, and respond effectively to users' inquiries. Moreover, ChatGPT has demonstrated its efficiency across various domains, including, but not limited to, education and scientific research (Ajlouni & et al, 2023).

ChatGPT has the potential to enhance various aspects of learning, including writing skills, research and self-directed learning, learner autonomy, engagement and critical thinking, problem-solving and practice-based learning, summarizing key ideas, reconstructing explicit knowledge, and clarifying tacit knowledge (Wang & Guo, 2025).

Genelza (2024) indicated in his study that ChatGPT has great potential to revolutionize educational and instructional methods. He further emphasized the necessity of exploring and understanding its capabilities in order to apply it appropriately, thereby significantly enhancing students' academic performance.

Similarly, Ajlouni, et al. (2023), in a study conducted to examine students' attitudes toward the use of ChatGPT as an educational tool, found that 73.2% of the participants reported that ChatGPT facilitates the learning process. The study further encouraged the integration of ChatGPT into curricula

and educational practices, while taking into consideration students' concerns and the risks of misuse.

A number of studies, such as (Egara & Mosimege, 2024; Roisha et al., 2024; Getenet, 2024; Polakora&Ivenz, 2024), have reported that students who received instruction supported by ChatGPT showed significant improvement compared to control groups. Specifically, they demonstrated increased proficiency in various aspects of the courses they studied, including organization, comprehension, and academic achievement. They also exhibited higher levels of active engagement in learning tasks, alongside a notable enhancement in their interest. Furthermore, the researchers recommended the integration of various artificial intelligence applications into the educational process to meet the evolving needs of contemporary learners.

Research Problem

Despite the critical importance of abstract algebra in preparing and qualifying mathematics teachers to understand abstract algebraic structures, Al-Saadi (2024) indicated in her study that students face difficulties in thinking while studying abstract algebra. In addition, their use of non-traditional thinking strategies when dealing with problems is limited.

The researchers also observed a low level of lateral thinking among students. In order to identify their areas of weakness, the researchers administered a questionnaire to assess the level of participants' lateral thinking. The results revealed that students' overall level of lateral thinking was weak. Furthermore, several studies, such as (Susilawati, et al., 2018; Shodiq et al., 2025; Yusmin et al., 2022) have indicated that students suffer from deficiencies in lateral thinking skills. In light of the current rapid developments, it has become necessary to develop students' lateral thinking skills to keep pace with contemporary demands.

In light of the growing integration of artificial intelligence technologies in education, the main challenge facing teacher preparation today is no longer limited to "solving algebraic problems," but rather extends to investigating the impact of these intelligent tools on developing teachers' lateral mindset. This enables teachers to shift from being transmitters of knowledge to designers of learning experiences who effectively employ ChatGPT to support students' learning by providing a stimulating educational environment based on dialogue and guidance, encouraging self-discovery, and facilitating the simplification of instructional practices while offering personalized learning and immediate feedback.

ChatGPT was selected over other artificial intelligence applications based on the findings of Opesemowo & Adewuyi (2024), who conducted a study aimed at identifying the most effective AI applications in mathematics education. The researchers carried out a comprehensive review of studies published in Scopus and Google Scholar between 2015 and 2023. They found that ChatGPT is the primary artificial intelligence application used in mathematics education among other AI tools. This is attributed to its ability to address learning differences, enable students to grasp fundamental concepts more quickly, and accurately present mathematical equations.

Research Question

The research problem was addressed through the following question:

What is the effect of investigating the use of ChatGPT as an educational tool on developing lateral thinking skills related to abstract algebra concepts among prospective mathematics teachers?

Research Hypotheses

Based on the research questions, the following null hypotheses were tested:

1. There are no statistically significant differences at the significance level ($\alpha < 0.05$) between the mean scores of the experimental and control groups on the overall lateral thinking skills test.
2. There are no statistically significant differences at the significance level ($\alpha < 0.05$) between the mean scores of the experimental and control groups on each lateral thinking skill separately.

Significance of the Study

1. The study provides a contemporary theoretical framework linking artificial intelligence technologies, particularly ChatGPT, with lateral thinking skills in university-level mathematics.
2. It offers the Faculty of Education applied models for training prospective teachers to keep pace with the artificial intelligence revolution as a form of educational process engineering.
3. It develops a lateral thinking skills test specific to abstract algebra, which can be utilized by researchers and academic institutions in future studies.

Delimitations of the Study

This study was limited to fourth-year

mathematics students at the Faculty of Education, Sana'a University, enrolled in the academic year 2025/2026. It was also restricted to the use of the ChatGPT Plus application. Furthermore, the study was confined to lateral thinking skills, namely: generating new perceptions, generating new concepts, generating new ideas, and generating new alternatives. In addition, it was limited to topics in group theory.

Research Terms

ChatGPT: It is an artificial intelligence application launched in 2022, and is considered a powerful natural language processing tool due to its ability to understand and generate natural language that is indistinguishable from human speech. In addition, it can engage in extended conversations by providing information on various topics, owing to the large amount of data on which it is trained (Ajlouni & et al, 2023).

Operational Definition

ChatGPT is a language model based on artificial intelligence that utilizes natural language processing techniques to generate textual responses to user inputs. In this study, it is used as an interactive educational tool to support the teaching of abstract algebra. It is employed to provide simplified explanations of mathematical concepts, and to generate a variety of instructional questions aimed at enhancing students' lateral thinking skills through discussion of solutions, and the provision of immediate feedback.

Lateral Thinking

Khafallah and Nasr (2020) defined lateral thinking as a cognitive process that directs the learner toward an idea with the aim of understanding and solving it by generating as many different ideas as possible in a way that differs from others' perceptions, without imposing constraints on the mind (p. 751).

Operational Definition

Lateral thinking is a cognitive activity that involves learners' ability to think beyond conventional patterns, generate non-routine solutions and multiple alternatives, and seek unconventional approaches to solving mathematical problems encountered in the study of abstract algebra. It is measured through students' responses to a specifically designed lateral thinking test.

Theoretical Framework and Previous Studies

ChatGPT is an artificial intelligence–based chatbot that represents a revolutionary tool in the teaching and learning of mathematics. It supports the generation of diverse responses, lesson planning, and answering students' questions. It also facilitates personalized learning and adaptive learning systems that meet individual students' needs and align with their learning pace (Almarashdi et al, 2024, Wardat et al, 2023).

It has also demonstrated effectiveness in enhancing student engagement and improving learning outcomes through personalized learning and immediate assessment, as it supports solving mathematical problems, answering questions, and customizing instructional communication. Furthermore, it enables teachers to design effective assessments for evaluating students' levels, as well as accurately identifying potential areas for improvement in order to enhance the efficiency of the educational process (Al-Shahrani, 2025; Nguyen & Pham, 2025).

Advantages of Using ChatGPT in Education

Hasanbasoglu & Balogu (2026), Heung & Chiu (2025), and Romero-Rodriguez et al. (2023) stated that the advantages of using ChatGPT in education are manifested in the following:

1. It effectively contributes to creating personalized learning experiences tailored to the individual needs of each student.
2. It reduces the cognitive effort required to understand difficult materials, and simplifies complex concepts by providing immediate feedback and customized explanations.
3. It encourages a shift from rote learning to inquiry-based and dialogic learning, making the educational process more flexible, efficient, and responsive to the rapidly evolving technological demands of the digital age.
4. It serves as a strategic tool for teachers in curriculum design and the development of innovative instructional materials, as it helps generate ideas for classroom activities, efficiently plan lessons, design quizzes, and improve the quality of academic assessments, making them more diverse and comprehensive.
5. It assists teachers in analyzing students' performance levels and identifying strengths and weaknesses through the processing of textual data from assignments and assessments.

PREVIOUS STUDIES

(Al-Hariri, 2024): The study aimed to investigate the effect of using ChatGPT chatbots on academic achievement, motivation, and classroom

interaction in learning mathematics. To achieve this, the study adopted a quasi-experimental design based on two groups: an experimental group and a control group. The study sample consisted of 50 tenth-grade female students in Irbid Governorate. The research instruments included an achievement test, a motivation scale, and a classroom interaction observation checklist. The study findings revealed several results, the most important of which was the effectiveness of ChatGPT chatbots in improving academic achievement, motivation, and classroom interaction. The study recommended the use of ChatGPT in teaching mathematics.

(Fardian& et al, 2025): The study aimed to examine the possibility of integrating ChatGPT as a supplementary educational tool to enhance the learning experience of linear algebra. To achieve this, a mixed-methods approach was adopted, combining both quantitative and qualitative methodologies. The study sample consisted of 30 male and female students from three Indonesian universities. The research instruments included a student learning test, observation, and interviews. The findings revealed several results, the most important of which was that the use of ChatGPT can provide step-by-step explanations for solving mathematical problems and make learning mathematics more engaging and easier. The study recommended the use of ChatGPT as a primary educational tool for teaching fundamental concepts.

Lateral Thinking

Lateral thinking is considered a new model of thinking that focuses on solving problems in non-traditional ways. This type of thinking aims to change fixed mental patterns, reconstruct them in new ways, and generate as many alternative solutions as possible (Al-Masoudi& Al-Maliki,2021)

Characteristics of Lateral Thinking:

Jabr (2020) and Musa (2023) stated that lateral thinking has several key characteristics, including:

1. Solving various problems and generating non-traditional solutions.
2. Viewing problems from different perspectives rather than relying on a single approach.
3. Developing learners' reasoning, experience, analytical skills, and logical thinking.
4. Helping learners break free from established patterns, restructure their thinking, and create new patterns.
5. Generating innovative ideas and new outcomes for solving complex problems.

Lateral Thinking Skills

Lateral thinking skills can be illustrated as follows, as stated by Khafallah& Nasr (2020), Qasim & Al-Zoubi (2023), Al-Rashdan (2024), and Hassoun (2025):

1. **Generating new perceptions:** a cognitive skill that involves understanding a given idea or solving a problem in a way that differs from others' understanding, moving away from traditional patterns of thinking.
2. **Generating new concepts:** the ability to derive and construct abstract concepts, interpret relationships among components, and clarify generalizations and rules used in solving a problem.
3. **Generating new ideas:** an intellectual effort aimed at producing and developing as many different ideas as possible for a given problem without mental constraints, without evaluating ideas during the initial generation phase.
4. **Generating new alternatives:** a skill through which available information is reorganized to solve a problem and explore new pathways; the emphasis is not on the superiority of alternatives but rather on their diversity and multiplicity.

Previous Studies

(Susilawati & et al, 2018)**:** The study aimed to enhance students' lateral thinking abilities through challenge-based learning in a geometry course. To achieve this, a quasi-experimental design was adopted based on two groups: an experimental group and a control group. The study sample consisted of 73 male and female students from the Department of Mathematics at the State Islamic University of Bandung. The research instruments included a lateral thinking test, a basic knowledge test, and a questionnaire. The findings indicated an improvement in the overall lateral thinking abilities of students in the experimental group compared to those in the control group. The study also recommended integrating lateral thinking skills into teacher preparation programs.

(Qasim & Al-Zoubi, 2023): The study aimed to investigate the effect of Kagan structures on improving lateral thinking ability in mathematics among eleventh-grade female students. To achieve this, the study adopted a quasi-experimental design based on two groups: an experimental group and a control group. The study sample consisted of 48 female students from Sukaina Bint Al-Hussein Secondary School for Girls in Zarqa Governorate. The research instrument was a lateral thinking test. The findings revealed several results, the most

important of which was the effectiveness of Kagan structures in improving lateral thinking ability. The study also recommended the necessity of developing lateral thinking, as it helps students rely on their positive engagement and encourages active participation during the learning process, thereby promoting student-centered learning.

(Hassoun, 2025): The study aimed to investigate the effect of the Felder and Silverman learning style model on the achievement of fifth-grade scientific female students and their lateral thinking in mathematics. To achieve this, the study adopted a quasi-experimental design based on two groups: an experimental group and a control group. The study sample consisted of 46 female students from Khawla Secondary School for Girls. The research instruments included an achievement test and a lateral thinking test. The findings revealed several results, the most important of which was the effectiveness of the Felder and Silverman model in improving both students' achievement and their lateral thinking. The study recommended paying greater attention to developing lateral thinking skills at different educational stages.

Abstract Algebra

Abstract algebra is a fundamental branch of modern mathematics that focuses on the study of algebraic structures, such as groups, rings, and fields. Unlike elementary algebra, which is concerned with solving numerical equations, abstract algebra deals with abstract mathematical systems and the relationships among their elements, providing a general framework for understanding a wide range of mathematical concepts.

The Importance of Abstract Algebra in Preparing Mathematics Teachers

Alam & Mohanty (2024) summarized the importance of abstract algebra in mathematics teacher education as follows:

1. It brings about a fundamental shift in understanding and exploring mathematical structures and their various applications.
2. It enhances deep conceptual understanding, critical thinking, and mathematical reasoning.
3. It improves problem-solving skills and strengthens a comprehensive understanding of different algebraic principles.
4. It enables learners to participate effectively in mathematical practices and to respond flexibly to students' future questions and inquiries.
5. It supports the transition from concrete thinking to abstract thinking.

The Relationship between Abstract Algebra and Lateral Thinking

Abstract algebra is one of the mathematical branches that requires high levels of thinking, as it is not limited to performing direct numerical operations. Rather, it involves dealing with abstract structures such as groups, rings, and fields, along with their associated definitions, axioms, and logical relationships. From this perspective, a strong relationship emerges between abstract algebra and lateral thinking. Lateral thinking enables learners to move beyond traditional solution patterns, reorganize given information, and generate multiple conceptual alternatives for understanding mathematical structures.

Instead of merely applying definitions in a linear manner, lateral thinking allows students to discover new relationships among concepts, construct multiple representations of a mathematical idea, view a single problem from different perspectives, and generate new ideas and alternative concepts that deepen their understanding of algebraic structures. This aligns with the nature of abstract algebra, which is based on abstraction, generalization, and constructive reasoning.

Moreover, abstract algebra problems require cognitive flexibility in moving between examples and non-examples, as well as in constructing new patterns of understanding. In addition, the nature of proof in abstract algebra, which relies on indirect reasoning and the connections between different structures, provides a rich learning environment for developing this type of thinking. It encourages students to move beyond the direct memorization of proofs toward their cognitive reconstruction and application in new and non-routine contexts.

RESEARCH METHODOLOGY AND PROCEDURES

Research Design

The researchers adopted a research design that combines a quasi-experimental approach and a qualitative approach within an integrative framework aimed at developing a deep and comprehensive understanding of the effect of the proposed instructional intervention. The quasi-experimental method was employed to investigate the impact of using ChatGPT in teaching group theory topics by comparing the performance of the experimental and control groups, and by analyzing differences in lateral thinking skill levels using appropriate quantitative measurement instruments.

In parallel, the qualitative approach was

employed as an interpretive lens to go beyond numerical data. A qualitative analysis was conducted of students' behavior during the learning of ring theory topics, including the observation of their interaction patterns with non-routine problems, their methods of generating alternatives, and their level of flexibility in re-representing group theory concepts. It also included an analysis of their written responses and classroom discussions.

This integration of quantitative measurement and analysis of learning behaviors enabled a deeper understanding of the actual impact of ChatGPT, not only in terms of statistical significance, but also in terms of the cognitive processes underlying the development of lateral thinking. This, in turn, enhances the interpretive validity of the study's findings and provides them with a richer educational dimension.

Population of the Study

The population of the study consisted of all mathematics students enrolled in the academic year 2025/2026, totaling 115 male and female students.

Sample of the Study

The study sample consisted of fourth-year mathematics students at the Faculty of Education, Sana'a University, totaling 17 male and female students. They were selected purposively, as they represent the level at which the Group Theory course is taught. The participants were also divided purposively into two groups: an experimental group consisting of 8 students and a control group consisting of 9 students.

Research Instruments

The study relied on a lateral thinking test and an observation tool. Each is explained as follows:

1. Lateral Thinking Test

The lateral thinking test was developed according to the following steps:

1.1 Objective of the test:

The test aims to measure lateral thinking skills among prospective mathematics teachers. It was constructed to investigate the effect of using ChatGPT on the development of lateral thinking skills.

1.2 Determining the test dimensions:

After reviewing educational literature and previous studies addressing lateral thinking skills, such as Khafallah & Nasr (2020), Al-Khazraji (2021), Ibrahim & Abdulameer (2024), Hassoun (2025), and Abdul Latif (2025), the following lateral thinking skills were identified: generating new perceptions, generating new concepts, generating new ideas, and generating new alternatives.

1.3 Test items formulation:

The test items were formulated in a way that is consistent with the nature of the skills being measured. The test consisted of 15 items distributed across the identified lateral thinking skills.

1.4 Validity of the test:

The test was presented to a group of experts and specialists for validation, who reviewed the extent to which the items represented the lateral thinking skills according to the provided definitions. Based on their valuable feedback, some items were modified, others were deleted, and new items were added.

1.5 Reliability of the Test:

To ensure the reliability of the test, Cronbach's Alpha coefficient was calculated. The reliability coefficient of the overall lateral thinking skills test was computed, as well as the reliability coefficients for each skill separately. The results are presented in Table (1):

Table (1): Cronbach's Alpha Reliability Coefficients for the Overall Lateral Thinking Test and Each Skill Separately

	Skill	Reliability coefficient
1	Generating new perceptions	0.926
2	Generating new concepts	0.857
3	Generating new ideas	0.862
4	Generating new alternatives	0.938
5	Overall test	0.952

It can be observed from Table (1) that the reliability coefficients for the skills ranged between (0.857–0.938), while the overall reliability coefficient of the test reached (0.952). This indicates a high level of reliability, which suggests that the test is suitable for application in the current study.

2. Observation:

The study relied on direct observation as a complementary qualitative tool, aiming to monitor changes in students' thinking patterns and cognitive behavior during the learning of ring theory topics. The researchers conducted the observation in an unstructured manner, without a pre-prepared observation checklist, in order to allow greater flexibility in tracking spontaneous behaviors associated with lateral thinking in natural learning contexts.

The observation covered three main contexts:

1. **Classroom interaction during lectures:** focusing on the nature of questions posed, students' ability to present unconventional assumptions, and their level of flexibility in reformulating algebraic concepts.
2. **Assignments and learning activities:** through analyzing students' approaches to solving non-routine problems, the diversity of proposed alternatives, and their ability to connect concepts in non-standard ways.
3. **Written examinations:** by tracking solution strategies and students' ability to generate different ideas when facing new situations.

The observations were documented in a descriptive-analytical manner after each instructional situation and categorized according to lateral thinking skills. This instrument contributed to supporting and interpreting the quantitative results by providing qualitative evidence that reflects the nature of the cognitive processes associated with students' performance.

Equivalence Procedures of the Experimental and Control Groups

1. **Equivalence of the experimental and control groups in prior mathematical knowledge required for the course:**

To ensure the equivalence of the experimental and control groups, a test of prior mathematical knowledge required for studying the course was developed and administered to both groups before the commencement of instruction. An independent samples t-test was then used to compare the mean scores of the experimental and control groups. The results are presented in Table (2):

Table (2): Independent Samples t-test Results for the Differences Between the Mean Scores of the Experimental and Control Groups Before the Intervention

Group	N	mean	Std. Deviation	t	Sig
Experimental	8	7.000	5.806	0.347	0.389
Control	9	6.111	4.755		

It can be observed from Table (2) that the t-value is not statistically significant, indicating that there are no statistically significant differences between the mean scores of the experimental and control groups in the prior knowledge test required for the course.

2. **Equivalence of the experimental and control groups in lateral thinking skills prior to the intervention:**

To ensure the equivalence of the experimental and control groups, a lateral thinking skills scale was developed and administered to both groups before the commencement of instruction. An independent samples t-test was then used to compare the mean scores of the experimental and control groups. The results are presented in Table (3):

Table (3): Independent Samples t-test Results for the Differences Between the Mean Scores of the Experimental and Control Groups on the Lateral Thinking Scale Before the Intervention

Group	N	mean	Std. Deviation	t	Sig
Experimental	8	3.25	1.16	0.607	0.554
Control	9	2.87	0.10		

It can be observed from Table (3) that the t-value is not statistically significant, indicating that there are no statistically significant differences between the mean scores of the experimental and control groups on the lateral thinking skills scale.

Statistical Methods Used

The following statistical methods were employed in this study:

- Cronbach's alpha coefficient was used to estimate the reliability of the lateral thinking test.
- Independent samples t-test was used to examine the significance of differences between the mean scores of the experimental and control groups in the lateral thinking skills test.
- Multivariate analysis of variance (MANOVA) was used to compare and determine the differences between the experimental and control groups in lateral thinking skills.

RESEARCH RESULTS

Quantitative analysis related to the lateral thinking skills test

To verify the first hypothesis, which stated that: "There are no statistically significant differences at the significance level ($\alpha < 0.05$) between the mean scores of the experimental and control groups on the overall lateral thinking skills test." an independent samples t-test was used after verifying that the assumptions and conditions for using this test were met. This was done to calculate the means and standard deviations of the two groups' scores on the overall lateral thinking skills test, as well as the t-value at the 0.05 significance level, as shown in Table (4):

Table (4): Independent samples t-test results for the differences between the mean scores of the experimental and control groups on the overall lateral thinking skills test

Group	N	mean	Std. Deviation	t	df	Sig
Experimental	8	20.00	2.67	12.982	15	0.000
Control	9	6.22	1.64			

It is evident from Table (4) that there are statistically significant differences at the significance level (0.05) between the mean scores of the experimental and control groups on the lateral thinking skills test, where the significance value (0.000) is less than (0.05). It is also observed that the mean score of the experimental group (20.00) is higher than that of the control group (6.22). Therefore, the differences were in favor of the experimental group.

This indicates that the null hypothesis, which states that "there are no statistically significant differences at the significance level ($\alpha < 0.05$) between the mean scores of the experimental and control groups on the overall lateral thinking skills test," is rejected. Accordingly, the alternative hypothesis is accepted, which states that "there are statistically significant differences at the significance level ($\alpha < 0.05$) between the mean scores of the experimental and control groups on the overall lateral thinking skills test."

To determine the effect size of using ChatGPT in developing students' lateral thinking skills, Eta squared (η^2) was calculated using the following formula:

$\eta^2 = t^2 / (t^2 + df)$The obtained value was (0.918), which is considered a very large effect size. This result can be interpreted as indicating that ChatGPT significantly contributed to the development of students' lateral thinking skills.

This finding is consistent with the results of studies by Susilawati et al. (2018), Qasim & Al-Zoubi (2023), and Hassoun (2025), which emphasized the development of lateral thinking skills through different instructional strategies.

This result may be attributed to the use of ChatGPT in stimulating students to generate multiple ideas about mathematical concepts through the use of open-ended questions that require constructing examples and non-examples, proposing alternative hypotheses, and reformulating definitions in non-traditional ways. This, in turn, enhanced the skill of generating alternatives, broke stereotypical thinking patterns, and expanded the range of possible solutions.

To verify the second hypothesis, which stated that: "There are no statistically significant differences at the significance level ($\alpha < 0.05$) between the mean scores of the experimental and control groups on each lateral thinking skill separately." Multivariate Analysis of Variance (MANOVA) was used after verifying that its assumptions and conditions were met. This analysis was conducted to calculate the means and standard deviations of the two groups' scores on the lateral thinking skills test, as well as the F-values at the 0.05 significance level, as shown in Table (5):

Table (5): MANOVA results for independent samples to determine the significance of differences between the mean scores of the experimental and control groups on each lateral thinking skill separately

Skill	Group	N	Mean	Std. Deviation	Sum of squares	Mean squares	F	sig	Partial Eta squared
Generating new perceptions	Experimental	8	4.875	0.991	46.667	46.667	76.948	0.000	0.837
	Control	9	1.556	0.527					
Generating new concepts	Experimental	8	4.375	0.744	28.569	28.569	37.491	0.000	0.714
	Control	9	1.778	0.972					
Generating new ideas	Experimental	8	5.625	1.408	59.118	59.118	52.898	0.000	0.779
	Control	9	1.889	0.600					
Generating new alternatives	Experimental	8	5.125	0.641	72.066	72.066	157.235	0.000	0.913
	Control	9	1.000	0.707					

It is evident from Table (5) that:

First: There are statistically significant differences at the significance level (0.05) between the mean scores of the experimental and control groups in the skill of generating new perceptions, where the significance value (0.000) is less than (0.05). It is also observed that the mean score of the experimental group (4.875) is higher than that of the control group (1.556). Therefore, the differences were in favor of the experimental group.

This indicates that the null hypothesis, which states that "there are no statistically significant differences at the significance level ($\alpha < 0.05$) between the mean scores of the experimental and control groups in the skill of generating new perceptions," is rejected. Accordingly, the alternative hypothesis is accepted, which states that "there are statistically significant differences at the significance level ($\alpha < 0.05$) between the mean scores of the experimental and control groups in the skill of generating new perceptions."

To determine the effect size of using ChatGPT in developing the skill of generating new perceptions, Eta squared (η^2) was used, yielding a value of (0.837). This value is considered large, indicating a strong effect. This result can be interpreted as evidence that artificial intelligence contributed to the development of students' ability to generate new perceptions.

This finding is consistent with the results of studies by Susilawati et al. (2018), Qasim & Al-Zoubi (2023), and Hassoun (2025), which emphasized the development of generating new perceptions through various instructional strategies.

This result may be attributed to the role of ChatGPT in helping students reconsider concepts or problems from multiple perspectives through exploratory questions such as: What happens if one condition is changed? Can the idea be interpreted differently? or How can this concept be connected to a different context? This type of interactive dialogue helped students move beyond superficial understanding toward deeper awareness of underlying relationships and implicit assumptions.

Second: There are statistically significant differences at the significance level (0.05) between the mean scores of the experimental and control groups in the skill of generating new concepts, where the significance value (0.000) is less than (0.05). It is also observed that the mean score of the experimental group (4.375) is higher than that of the control group (1.778). Therefore, the differences were in favor of the experimental group.

This indicates that the null hypothesis, which states that "there are no statistically significant differences at the significance level ($\alpha < 0.05$) between the mean scores of the experimental and control groups in the skill of generating new concepts," is rejected. Accordingly, the alternative hypothesis is accepted, which states that "there are statistically significant differences at the significance level ($\alpha < 0.05$) between the mean scores of the experimental and control groups in the skill of generating new concepts."

To determine the effect size of using ChatGPT in developing the skill of generating new concepts, Eta squared (η^2) was calculated, yielding a value of (0.714). This value is considered large, indicating a substantial effect. This result can be interpreted as evidence that ChatGPT contributed to enhancing students' ability to generate new concepts.

This finding is consistent with the results of studies by Susilawati et al. (2018) and Hassoun (2025), which emphasized the development of the skill of generating new concepts through various instructional strategies.

This result may be attributed to the role of ChatGPT in stimulating students to reformulate existing concepts and reconstruct them in an expanded or modified form. This was achieved by guiding them to propose alternative definitions, integrate two concepts within a new conceptual framework, or generalize an idea across different contexts. Such processes encourage students to move from merely receiving concepts to actively producing and reconstructing them.

Third: There are statistically significant differences at the significance level (0.05) between the mean scores of the experimental and control groups in the skill of generating new ideas, where the significance value (0.000) is less than (0.05). It is also observed that the mean score of the experimental group (5.625) is higher than that of the control group (1.889). Therefore, the differences were in favor of the experimental group.

This indicates that the null hypothesis, which states that "there are no statistically significant differences at the significance level ($\alpha < 0.05$) between the mean scores of the experimental and control groups in the skill of generating new ideas," is rejected. Accordingly, the alternative hypothesis is accepted, which states that "there are statistically significant differences at the significance level ($\alpha < 0.05$) between the mean scores of the experimental and control groups in the skill of generating new ideas."

To determine the effect size of using ChatGPT in developing the skill of generating new ideas, Eta squared (η^2) was calculated, yielding a value of (0.779). This value is considered large, indicating a strong effect. This result can be interpreted as evidence that ChatGPT contributed to enhancing students' ability to generate new ideas.

This finding is consistent with the results of studies by Qasim & Al-Zoubi (2023) and Hassoun (2025), which emphasized the development of the skill of generating new ideas through various instructional strategies.

This result may be attributed to the role of ChatGPT in stimulating students' "out-of-the-box" thinking through the provision of open-ended questions that encourage proposing unconventional solutions, interpreting conceptual phenomena in multiple ways, or formulating new hypotheses. This, in turn, expanded their thinking horizons and helped break cognitive rigidity.

Fourth: There are statistically significant differences at the significance level (0.05) between the mean scores of the experimental and control groups in the skill of generating new alternatives, where the significance value (0.000) is less than (0.05). It is also observed that the mean score of the experimental group (5.125) is higher than that of the control group (1.000). Therefore, the differences were in favor of the experimental group.

This indicates that the null hypothesis, which states that "there are no statistically significant

differences at the significance level ($\alpha < 0.05$) between the mean scores of the experimental and control groups in the skill of generating new alternatives," is rejected. Accordingly, the alternative hypothesis is accepted, which states that "there are statistically significant differences at the significance level ($\alpha < 0.05$) between the mean scores of the experimental and control groups in the skill of generating new alternatives."

To determine the effect size of using ChatGPT in developing the skill of generating new alternatives, Eta squared (η^2) was calculated, yielding a value of (0.913). This value is considered very large, indicating a strong effect. This result can be interpreted as evidence that ChatGPT contributed significantly to enhancing students' ability to generate new alternatives.

This finding is consistent with the results of studies by Susilawati et al. (2018) and Hassoun (2025), which emphasized the development of the skill of generating new alternatives through different instructional strategies.

This result may be attributed to the use of ChatGPT in presenting open-ended problems, which allowed students to think about alternative solutions, compare them, and select the most appropriate ones, or even generate new alternatives that were not previously proposed. This, in turn, enhanced cognitive flexibility and the ability to produce multiple options.

Qualitative Analysis

Students' behaviors were observed during the completion of various activities in the ring theory course, and their responses were analyzed to highlight differences between the experimental and control groups. Ring theory was selected because group theory is not an isolated component from ring theory; rather, it represents a foundational element within its structure. Accordingly, any improvement in students' understanding of group theory concepts is expected to be directly reflected in their performance within the context of ring theory.

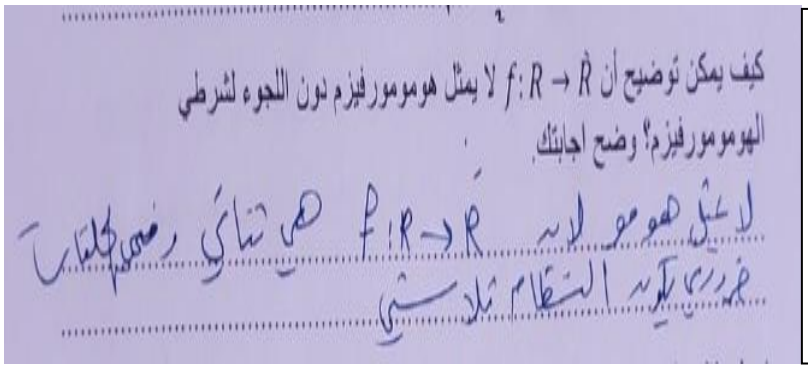
Accordingly, the selection of ring theory during the observation phase was not intended as the study of an independent new topic, but rather as a test of the extent to which the effect of the instructional intervention transferred from the foundational level (group theory) to a higher and more complex level that fundamentally depends on it. Students' successful and flexible handling of ring theory concepts is considered an indicator that lateral thinking skills were not limited to the content targeted by the intervention, but rather became integrated into their cognitive structures, and functioned as an analytical tool applicable to more complex algebraic structures.

A sample of one student's responses from each group was selected in order to provide a clear illustration of the effectiveness of the ChatGPT-based instructional intervention on their lateral thinking skills.

First: The skill of generating new perceptions:

The response of the control group was characterized by a traditional pattern that was limited to perceiving only the apparent relationships without reaching unconventional dimensions of the concept. The student focused solely on the operations and considered them nonexistent, while neglecting the analysis of the properties of the elements. This reflects a limitation in her thinking, as illustrated in the following response:

Example (1):
Figure (1): Student's response



How can it be shown that $f: R \to \dot{R}$ is not a homomorphism without directly using the homomorphism conditions? Explain your answer.

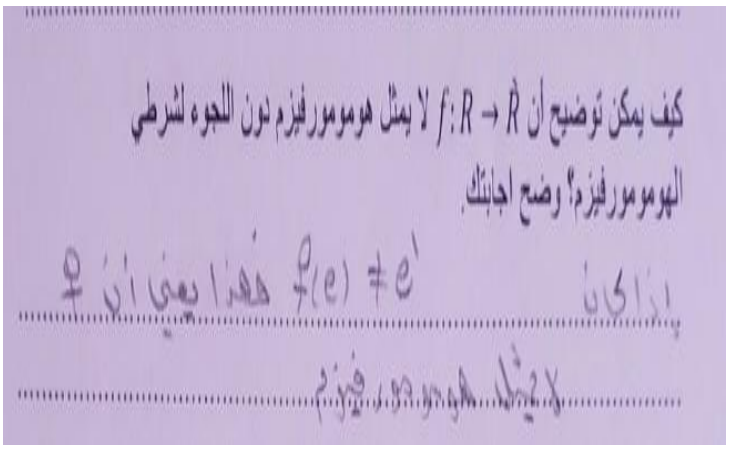
It is not a homomorphism because $f: R \to \dot{R}$'is binary, whereas in rings the operation must be ternary.

In contrast, the response of the experimental group was characterized by a clear ability to reorganize concepts. and view the mathematical situation from multiple perspectives. Their responses demonstrated cognitive flexibility in identifying non-explicit relationships and providing alternative

interpretations that go beyond the direct meaning of the concept. The student presented unconventional insights that had not previously been introduced in this form within the context of studying ring homomorphisms, reflecting her ability to think flexibly and innovatively in generating alternative pathways for proving or disproving mathematical structures. This indicates an advanced level of generating new perceptions, as illustrated in the following example:

Example (2):

Figure (2): Student's response



How can it be shown that $f: R \to \dot{R}$ is not a homomorphism without directly using the homomorphism conditions? Explain your answer.

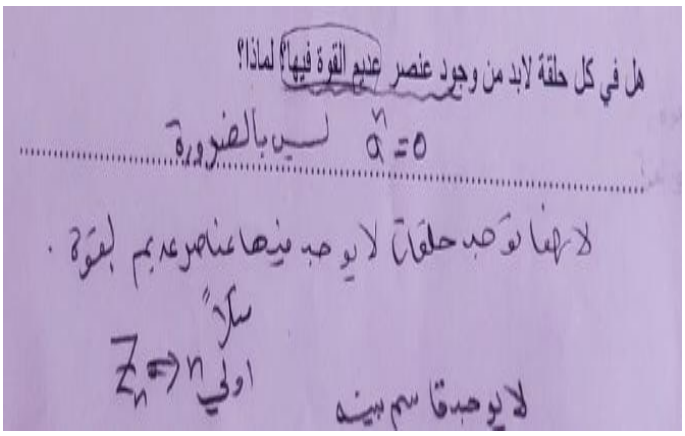
If $f(e) \neq \dot{e}$then f is not a homomorphism.

Second: Generating new concepts:

The response of the control group was characterized by reliance on directly presented concepts, as their answers were limited to repeating familiar definitions and properties without providing innovative conceptions derived from their understanding of the mathematical situation. The student's response, as shown in the figure, demonstrated difficulty in applying concepts flexibly, as she was unable to connect concepts to reach an appropriate generalization and also relied on an incorrect example.

Example (1):

Figure (3): Student's response

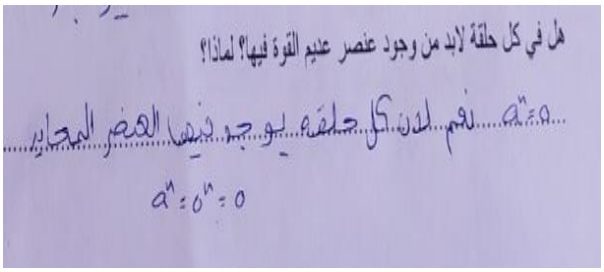


Is it necessary for every ring to contain a nilpotent element? Why?

$a^n = 0$ is not necessarily true, because there are rings that do not contain nilpotent elements, for example $\mathbb{Z}_n$when $n$is prime, since there are no zero divisors.

In contrast, the response of the experimental group demonstrated a clear ability to construct new concepts based on foundational ones. The students were able to reorganize prior knowledge and generate new mathematical conceptions that reflect a deep understanding of the relationships between algebraic structures. The student successfully arrived at the correct generalization by linking the concept of a ring with the concept of a nilpotent element, which reflects her ability to derive a general rule from the properties of individual elements. This indicates an advanced level of generating new mathematical concepts through the integration of fundamental ideas.

Example (2):
Figure (4): Student's response



Is it necessary for every ring to contain a nilpotent element? Why?

Yes, because every ring contains an identity element such that $a^n = 0^n = 0$

Third: The skill of generating new ideas:

During the lecture, the course instructor posed the following question to the students:
If $f: R \to \dot{R}$is a homomorphism, how can we prove that (f) is injective?

A student from the control group responded that this can be proven using the injectivity condition $f(a) = f(b) \to a = b$.

The responses of the control group were characterized by limited diversity, as their ideas were confined to the traditional solution path or explanation, with a clear weakness in proposing alternative solutions or innovative perspectives for the mathematical situation. This reflects reliance on linear and direct thinking, as the student's response showed dependence on conventional methods, difficulty in flexible application of concepts, and limited ability to generate new ideas.

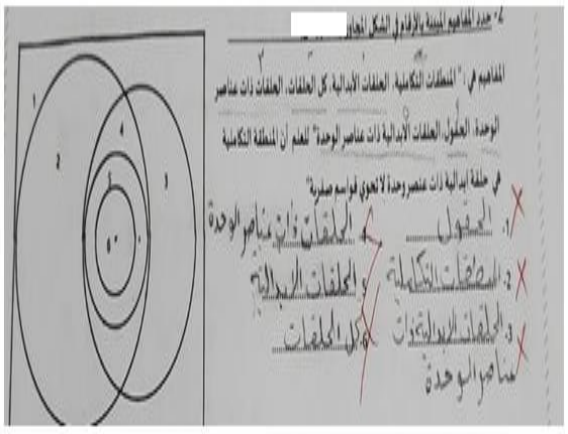
In contrast, a student from the experimental group responded that injectivity can be proven by examining the kernel of the homomorphism, based on the theorem stating that if ($ker\, f = \{e\}$), then (f) is injective. Alternatively, this can also be explained by considering the images, particularly in the case of finite rings.

The responses of the experimental group demonstrated diversity and richness in idea generation, as students were able to propose different solution approaches and present innovative ways of understanding the mathematical situation, with clear flexibility in shifting between multiple cognitive paths. The student's response reflects a clear ability to think differently, utilize acquired knowledge, and generate innovative solutions and new ideas.

Fourth: The skill of generating new alternatives:

The response of the control group was characterized by rigidity and reliance on traditional solutions or direct explanations. Their ability to propose alternative pathways or explore different solutions to the mathematical situation was weak, reflecting limited cognitive flexibility in dealing with abstract concepts. The student was unable to arrange any of the interconnected structures, which indicates difficulty in linking concepts and an inability to generate alternatives or organize ideas in a logical manner.

Example (1):
Figure (5): Student's response

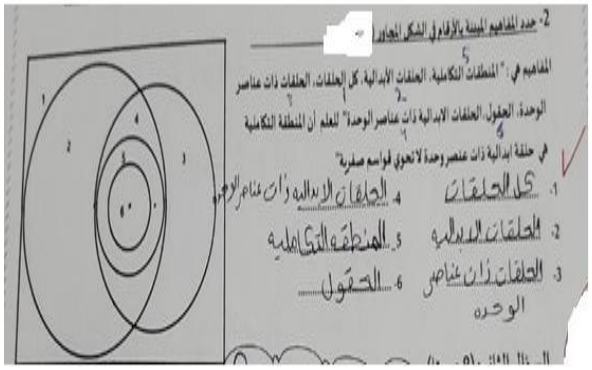


Identify the concepts indicated by the numbers in the adjacent figure.
The concepts are: "integral domains, commutative rings, all rings, rings with unity, fields, commutative rings with unity." Note that an integral domain is a commutative ring with unity that has no zero divisors.

1- Fields. 2- Integral domains. 3- Commutative rings with unity. 4- Rings with unity. 5- Commutative rings. 6- All rings.

In contrast, the response of the experimental group demonstrated a clear ability to interpret concepts in multiple ways and to explore different possibilities for dealing with the mathematical concept, reflecting diversity and flexibility in thinking. The student was able to provide the correct answer and accurately arrange all concepts, which reflects a comprehensive understanding of the theoretical structures, as well as the ability to organize and integrate concepts. This indicates an advanced level of structural understanding of rings and the interconnection between different elements and concepts, reflecting the student's ability to organize ideas in an innovative manner and generate new alternatives.

Example (2):
Figure (6): Student's response



Identify the concepts indicated by the numbers in the adjacent figure.
The concepts are: "integral domains, commutative rings, all rings, rings with unity, fields, commutative rings with unity." Note that an integral domain is a commutative ring with unity that has no zero divisors.

1- All rings. 2- Commutative rings. 3- Rings with unity. 4- Commutative rings with unity. 5- Integral domains. 6- Fields.

The previous examples illustrate that the use of ChatGPT with the experimental group contributed to enhancing lateral thinking skills compared to the control group, which did not receive the same support. This strengthens the quantitative results and provides a qualitative interpretation of the effectiveness of using ChatGPT in teaching.

Summary of Findings

The quantitative results revealed and supported the presence of statistically significant differences in favor of the experimental group in lateral thinking skills after using ChatGPT in teaching group theory.

In support of these findings, the qualitative results in the context of ring theory provided a deeper interpretation of these differences. Performance observations and analysis of students' responses indicated that students in the experimental group did not merely improve in applying group theory concepts within their direct context; rather, their improvement extended to their ability to reorganize the algebraic structure of rings and to perceive the relationships among their various components.

In contrast, the responses of the control group reflected a more procedural and traditional pattern, focusing on the application of rules without reconstructing the structural relationships among concepts.

Accordingly, the quantitative superiority of the experimental group can be interpreted as a reflection of a qualitative shift in the nature of cognitive processing. The difference was not merely an improvement in test scores, but rather a transformation in the thinking mechanism itself, manifested in the ability to:

- transfer concepts from the context of group theory to the context of ring theory.
- reconstruct mathematical relationships.
- generate alternative solutions within a more complex structure.

Thus, the qualitative findings supported the quantitative results by providing a deep structural explanation for the statistical differences, confirming that the effectiveness of AI-based instruction was not superficial or temporary, but rather reflected a reorganization of students' cognitive structures in a way that aligns with the characteristics of lateral thinking.

RECOMMENDATIONS

1. Employ artificial intelligence applications in teaching mathematics across different educational levels.
2. Enrich mathematics curricula with activities that support teachers in developing students' lateral thinking skills.

Suggestions for Future Research

1. Investigate the effectiveness of using other artificial intelligence applications on different dependent variables, such as critical thinking and others.
2. Conduct a study to identify the challenges of using artificial intelligence in educational stages and explore ways to overcome them.

REFERENCES

Abdul Latif, A, J. (2025). The effect of the Appleton strategy on cognitive achievement and lateral thinking among College of Education students in the curriculum and textbook course. *Lark Journal, 17*(2), 520–539.

Agustyaningrum, N., Hanggara, Y., Husna, A., Abadi, A, M., & Mahmudi, A. (2019). An Analysis of Students' Mathematical Reasoning Ability on Abstract Algebra Course. *International Journal of Scientific & Technology Research*, 8(12), 2800-2805.

Ajlouni, A, O., Wahba, F, A, A., Almahaireh, A, S. (2023). Students' attitudes towards using ChatGPT as a learning tool: The case of the university of Jordan. *International Journal of Interactive Mobile Technologies*, 17 (18), 99- 117.

Al- Jarrah, A, A., & Al- Tarawneh, M, A, F. (2021). The impact of SCAMPER and Baron's techniques on the development of English language critical thinking skills: Applied study on 10th grade students. *Dirasat: Educational Sciences*, 48 (3), 437- 445.

Alam, A., & Mohanty, A. (2024). Unveiling the complexities of "Abstract Algebra" in University Mathematics Education (UME): fostering 'Conceptualization and Understanding' through advanced pedagogical approaches. *Cogent Education*, 11(1).

Al-Hariri, G, Y, A. (2024). The effect of using ChatGPT on academic achievement, motivation, and classroom interaction in learning mathematics among tenth-grade female students in Irbid. [Published master's thesis, Al al-Bayt University, Jordan]. Dar Almandumah Database.

Al-Khazraji, N, T, K. (2021). The effect of generative learning strategy on lateral thinking and cognitive motivation for mathematics among middle school students. *Journal of the College of Basic Education, 27*(113), 463–482.

Al-Luhabi, B, A. (2019). The level of lateral thinking and its relationship with problem-solving style among gifted students in Taif city. *Scientific Journal, 35*(12), 450–480.

Almarashdi, H, S., Jarrah, A, M., Gningue, S, M., &Khurma, O, A. (2024). Unveiling the potential: A systematic review of ChatGPT in transforming mathematics teaching and learning. *Eurasia Journal of Mathematics Science and Technology Education*, 20(12).

Al-Masoudi, Z, A., & Al-Maliki, A, M. (2021). The extent to which teachers of mathematics at the secondary stage in Saudi Arabia use the skill of generating new perceptions, one of the lateral thinking skills. *Arab Journal of Scientific Publishing, (27)*, 274–291.

Al-Rashdan, M, M, H. (2024). The degree of mathematics teachers' utilization of lateral thinking skills in developing problem-solving abilitiesto solve mathematical problems among upper primary stage students in Al-Koura Directorate of education from the perspectives of their teachers. [Published master's thesis, Jerash University, Jordan]. Dar Almandumah Database.

Al-Saadi, E, A. (2024). The challenges facing mathematicsteacherspre-service in the abstract algebra course from their poin of view. *Sana'a University Journal of Human Sciences, 1*(2), 1–13.

Al-Shahrani, A, N. (2025). The role of generative artificial intelligence in mathematics assessment from teachers' perspectives. *Journal of Curricula and Teaching Methodology, 4*(4), 54–70.

Bishay, Z, J, H. (2018). The use of the SCAMPER strategy in teaching geometry to develop lateral thinking skills and creative decision-making among preparatory school students. *Journal of Mathematics Education, 21*(11), 44–94.

Egara, F, O., &Mosimege, M. (2024). Exploring the integration of artificial intelligence- based ChatGPT into mathematics instruction:Perceptions, Challenges, and Implications for educators. *EducationSciences*, 14 (742), 1- 20.

Fardian, D., Suryadi, D., Prabawanto, S., & Al Jupri. (2025). Integrating Chat-GPT in the Classroom: A Study on Linear Algebra Learning in Higher Education. *International Journal of Information and Education Technology*, 15(4), 732-751.

Gabr, N, S, A. (2020). The effectiveness of using lateral thinking strategies in developing some soft skills for field training students at the Faculty of Education for Early Childhood in Matrouh Governorate. [Published master's thesis, Matrouh University, Egypt]. Dar Almandumah Database.

Genelza, G, G. (2024). Unlocking the opportunities and challenges of using ChatGPT tools for educational services: A narrative literature review.*Journal of Emerging Technologies*, 4 (1).

Getenet, S. (2024). Per- service teachers and ChatGPT in multistrategy problem- solving: Implication for mathematics teaching in primary schools. *International Electronic Journal of Mathematics Education*, 19 (1), 1-12.

Hasanbasoglu, B., & Baloglu, M. (2026). The double-edged sword of artificial intelligence: Gifted college students' use of ChatGPT in academicwriting. *Contemporary Educational Technology*, 18(2).

Hassoun, S, K. (2025). The effect of Felder and Silverman's model in the achievement of fifth high school female studentsand their lateral thinking in mathematics. *Maysan Journal for Academic Studies, 24*(53), 314–334.

Heung, Y, M., & Chiu, T, K. (2025). How Chatgpt impacts student engagemrnt from a systematic review and meta- analysis study.*Computers and Education: Artificial Intelligence*.

Ibrahim, F, A., Abdul Ameer, A, N. (2024). The effect of Bransford & Stein's model on lateral thinking of second intermediate grade female students in mathematics. *Journal of the College of Basic Education, 30*(123), 142–156.

Khalaf Allah, M., & Nasr, M, S. (2020). The extent of practicing literal thinking skills by math teachers of the higher primary phase. *IUG Journal of Educational and Psychology Sciences, 28*(3), 748–771.

Mousa, M, S. (2023). The mediating role of lateral thinking in the relationship between strategic intelligence and competitive advantage: An empirical study on employees at telecom companies in the Arab Republic of Egypt. [Published doctoral dissertation, Mansoura University, Egypt]. Dar Almandumah Database.

Nair, T, S., & Mohan, S. (2023). Lateral thinking and scientific creativity in students: A correlation analysis. *International Journal of Development Resrarch*, 13 (10), 63903- 63907.

Nguyen, D, T., & Pham, Q, V. (2025). The evolving landscape of AI integrationin mathematics education: A systematic review of trends (2015- 2025). *EURASIA Journal of Mathematics, Science and Technology Education*, 21 (10), 1-23.

Nur, A, S., Kartono, K., Zaenuri, Z., &Rochmad, R. (2022). The lateral thinking processes in solving mathematical word problems reviewed at adversity quotient and reflective cognitive style. *Journal of Mathematics Education*, 11 (2), 223- 236.

Opesemowo, O, A, G., & Adewuyi, H, O. (2024). A systematic review of artificial intelligence in mathematics education: The emergence of 4IR. *Eurasia Journal of Mathematics Science and Technology Education*, 20 (7), 1-11.

Polakova, P., &Ivenz, P. (2024). The impact of ChatGPT feedback on the development of EFL students' writing skills. *Cogent Education*, 11(1), 1- 12.

Qasem, D, S., & Al-Zoubi, A, M. (2023). Kagan structures' role in improving lateral thinking in mathematics among eleventh-grade. *Educational Sciences, 50*(4), 108–122.

Roisah, S., Widyaningsih, T, L., Purwananti, Y, S. (2024). The impact of ChatGPT use on EFI students' writing ability. *Journal of social humanities and education*, 3 (3), 191- 199.

Romero-Rodriguez, J., Ramirez-Montoya, M., Buenestado-Fernadez, M., & Lara-Lara, F. (2023). Use of ChatGPT at University as a Tool for Complex Thinking: Students' Perceived Usefulness. *Journal of New Approaches in Education Research*, 12(2), 323-339.

Shodiq, L, J., Juniati, D., & Susanah, S. (2025). Teaching creativitythrough mathematical lateral thinking problems: A pilot study. *Eurasia Journal of Mathematics Science and Technology Education*, 21 (2), 1- 14.

Susilawati, W., Maryono, I., Widiastuti, T., & Abdullah Ridha. (2018). Improvement of Mathematical lateral thinking skills and student character through challenge- based learning. *Advances in Social Science, Education and Humanities Research*, 261, 95- 101.

Veith, J., Bitzenbauer, P., &Girnat, B. (2022). Exploring Learning Difficulies in Abstract Algebra: The Case of Group Theory, *Education Sciences*, 12(8), 1-21.

Wang, M., & Guo, W. (2025). The potential impact of ChatGPT on education: Using history as a rearview mirror. *Review of Education*, 8 (1), 41- 48.

Wardat, Y., Tashtoush, M, A., AlAli, R., & Jarrah, A, M. (2023). ChatGpt: A revolutionary tool for teaching and learning mathematics. *Eurasia Journal of Mathematics Science and Technology Education*, 19(7).

Yusmin, E., T Yani, A., Pasaribu, R, L., &Fitriawan, D. (2022). Students' mathematical lateral thinking skills in creative problem- solving. *Al- Jabar: Jurnal Pendidikan Matematika*, 13 (2), 331- 341.