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Using the pentagram method to enhance critical thinking skills in ninth-grade physics students in Jordan

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ABSTRACT

The purpose of this study was to find out the effectiveness of the Pentagram technique to improve the ability of critical thinking among students in the ninth year of studying basic physics. To achieve this goal, we used a semi-experimental design and developed an experimental curriculum. The research sample included 46 ninth-grade students from the Mafraq Kasbah school, who were randomly assigned to either the experimental group (n = 23) or the control group (n = 23). Instructors taught an experimental group using the Pentagram methodology, while the control group received conventional instruction. Research revealed significant differences in critical thinking scores between the two groups. The experimental group has shown a remarkable improvement in critical thinking capabilities, with an average score before the test of 8.17 (SD = 4.01) and after the test of 18.43 (SD = 2.71). The control group had a pre-test score of 8.48 (SD = 4.57) and a post-test score of 13.52 (SD = 3.20). According to the independent test, the Pentagram method significantly improves critical thinking ability in physics learning. This clearly supports the effectiveness of the Pentagram technique in aiding learners' critical thinking.

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Introduction

Critical thinking is a rule-governed mental activity that produces predictable outcomes. It also requires a search for clear explanations. It emphasizes the process of making informed decisions, rather than falsely believing that one is making those choices based on sound internal biases (Siegfried & Colander, 2022). Critical thinking is defined as self-directed thinking, which includes the evaluation of information (Scheffer & Rubenfeld, 2000), and can be described as analytical reasoning to assess the validity of what has been read or heard, leading to the ability to identify evidence that enables more efficacious problem-solving. Knowledge related to critical thinking may vary and would underpin health professional education to become more reflective practitioners (Dwyer et al., 2014). Thinking ability is an essential part of current educational programs. Critical: Critical thinking. A critical-thinking or thinking-critically handler not only has an evaluative component, empirical evaluation, but also the dissection of causes and precursors, along with a deeper review of issues that are highly disputed and generate crises (Cheng & Wan, 2017). What counts in learners' experiences is that they are valuable and have real effects. Enhancing the development of thinking skills is a current focus of global education policy planning in response to intellectual growth, especially among students (Vieira & Tenreiro-Vieira, 2016; Zhu et al., 2016). Therefore, it is a goal that should receive significant emphasis in the processes of learning and teaching. Consequently, educators regard the instruction of critical thinking skills as a top priority within schools today (Huda & Hashim, 2022).

Emphasis in science education has evolved from learning information to including the development of a variety of abilities in learners. Therefore, this transition needs a greater emphasis on critical thinking skills as well as different scientific processes such as observation, categorization, measurement, prediction, drawing conclusions, generating hypotheses, performing experiments, interpreting data, designing procedures, and so on (Turiman et al., 2012; Saido et al., 2018). These processes allow students to distinguish between facts and conclusions, detect causal links, draw inferences, and make sound judgments. Furthermore, the skills learned in scientific education have practical implications for tackling real-life challenges students face outside the classroom (Gualtieri & Finn, 2022).

One of the key goals of the physics curriculum is to encourage students to actively engage with the information they read or hear. Additionally, encourage children to talk and voice their ideas about age-appropriate issues and at their developmental stages (Gawlicz & Millei, 2022). Educators must move beyond traditional forms of pedagogy to cultivate a culture of inquiry among students and to develop their intellectual autonomy and freedom. Educators should also use contemporary teaching and learning techniques to encourage higher-order cognitive skills, i.e., analyzing, synthesizing, and evaluating (Hamzah et al., 2022). The Arab educational system has improved and developed physics instruction to increase students' cognitive potential (Abdelrahman, 2020). It forces people to think differently , which is especially important given the constant changes in our cultures. Critical thinking skills for children also prepare them to make decisions and meet the challenges of the twenty-first century (Bean & Melzer, 2021). Based on their observations of student teachers at Al-Bayt University and Al-Balqa Applied University, the authors found that the predominant teaching method in most schools is for teachers to stand at the front of the classroom and deliver lessons through lectures and explanations, with limited use of teaching aids to introduce new ideas or concepts. The instructor has a major responsibility for the educational process in this traditional method. The teacher may occasionally raise issues for class discussion, followed by summative exercises that students can complete independently or in groups. However, this conventional teaching style in basic physics education often makes the subject feel rigid and challenging for students. Consequently, students are unable to practice critical thinking skills, leading to a loss of motivation and a lack of desire to further engage with the subject (Fung & Liang, 2019; Ugwuozor, 2021; Banda & Nzabahimana, 2023).

There is a growing emphasis on selecting the most efficient teaching and learning methodologies due to the importance of physics education and the challenges it presents. While providing opportunities to develop cognitive, behavioral, and emotional skills in kids, these tactics aim to support improved learning outcomes for those students. This acknowledgment is consistent with the ongoing revolution in knowledge and information in the physics education sector. To address this problem, which is the underdevelopment of critical thinking abilities among students at the upper basic stage, the research was initiated. Previous research, such as Ghahremani et al. (2017), Drosos et al. (2018), and Adel (2021), has supported this claim.

Therefore, there is a need to use modern pedagogical techniques to address the problems faced by ninth-grade Jordanian students when using a new physics textbook. It is also important to make continuous efforts to use diverse methods, approaches, and processes that engage learners' attention and highlight their creative potential in scientific work, thereby developing learners' critical thinking. This allows them to have their problem-solving abilities reinforced in their setting. The purpose of this study is to evaluate the pentagram method, a new model for teaching inquiry and investigation. The aim is to assess its effectiveness in developing physics-reflective critical thinking among grade nine students in Jordan.

This study has been undertaken to meet the needs of twenty-first-century teachers who are willing to align their instructional practices with today's fast-paced, globalized world. The overarching goal of this effort is to improve physics instruction within science education more broadly. The study focuses on using the pentagram technique, which can develop critical thinking abilities, in physics lectures. This tactic helps teachers develop their students' critical-thinking abilities, thereby improving academic performance and motivating physics teachers to refine their teaching strategies, models, and methodologies. The study also offers a critical-thinking exam that industry specialists may use to their advantage. Its conclusions support the practical use of critical thinking skills for problem-solving and understanding cosmic events, benefiting ninth-grade students' fundamental education. The findings of this study will be useful to the Ministry of Education as they revise the physics curriculum's educational activities. The ministry's mistakes in revising physics textbooks may be reduced by using this scientific justification for change.

The importance of developing critical thinking skills in pupils across general education cannot be overstated, underscoring the need for modern strategies such as the pentagram strategy. As a result, the purpose of this study is to investigate the effectiveness of the pentagram technique in improving critical thinking abilities among female students at the higher basic stage. The next sections of the essay follow this structure: a survey of relevant literature on the study's keywords is offered. Section 3 outlines our study technique and data. Section 4 summarizes the main findings and gives a full commentary. Finally, section 5 underlines the study's conclusions.

Background

One of the main objectives of the physics curriculum is to encourage students to actively engage with the knowledge they learn from reading or listening. Students should be able to discuss and argue a range of topics while keeping in mind their age and developmental stage. Promotion of a classroom atmosphere that invites students to develop capacities for critical and intellectual freedom also requires a sense of comfort with challenging conversations with the instructor and their classmates (Beavers et al., 2017). Traditional pedagogical methods must be relinquished in order for educators to foster higher-order thinking processes such as analysis, synthesis, and evaluation (Russell, 2018).

In the past few years, the Arab region has made great strides in physics education by expanding students' access to more advanced educational opportunities. The intent of these programs is the improvement of student cognition and creativity by focusing on a wide range of types and levels of cognitive understanding. Power of Cognition: Strong, high-level cognitive skills endow students with the information they need to make critical decisions, change, and grow to meet the demands of the twenty-first century, especially in our rapidly changing culture.

The purpose of this research is to explore the nature and characteristics of the Pentagram Project, an approach to teaching that aims to develop critical thinking skills through five central learning domains: analysis, synthesis, evaluation, creativity, and reflection. This is not some abstract policy - this is a modus operandi that requires students to think critically as part of schooling. This research is significant because it used the Pentagram method to teach ninth-grade physics, an area with limited published work on such an integrated, multi-level approach.

Leicht et al. (2018) state that this UNESCO report is scholarly and aligns with the recognition of critical thinking as a core educational goal. The strategy highlights the need for education to keep pace with an ever-changing world. The research emphasizes the importance of cultivating cognitive skills that align with social and economic development. Teaching students to think critically will equip them to navigate and participate intelligently in that dynamic environment.

According to Bean and Melzer (2021), the ability of critical thinking involves the cognitive processes necessary for obtaining, maintaining, and using information, including analysis, planning, and evaluation, that are vital to sound judgments and conclusions. The distinction between "thinking" and "thinking" is essential to avoid misconceptions. In its broadest sense, it involves the pupil's ability to understand instructions, formulate unique concepts, and critically assess them. This technique builds on the pupil's prior knowledge and valuable experience. On the contrary, cognitive abilities involve deliberate, focused mental processes used to process information, evaluate situations, and solve problems. Each of these talents increases the overall efficacy of critical thinking.

Pentagram Method

The survey and learning based on the event are central to Pentagram's teaching method. This method is based on the concept of knowledge organization, where students construct meaning and develop their own understanding. The theory of "trees," a new concept aligned with the principles of active learning, forms the basis of the Pentagram method (de la Torre Dece et al., 2019). The method emphasizes the research process to effectively acquire knowledge with the primary goal of supporting higher-order cognitive capabilities. According to Al-Assadi and Rahi Hadi al-Fatlawi (2023), this method includes management of students through five phases: acquiring knowledge, planning, decision-making, application, and evaluation.

The Pentagram method is an effective strategy for increasing students' motivation, capturing their attention, and improving their analytical skills. Introducing students to relevant real-world problems that require active involvement is an achievement (Saber & Salah Anwar, 2020). In addition, this method provides students with the tools and resources needed to address these challenges effectively. The Pentagram method relies heavily on technology because it facilitates the delivery of learning tasks and supports collaboration. The Pentagram method encourages students to work in teams or groups and to use technology to strengthen their critical-thinking skills. The Pentagram method, through technology, supports participants' learning and the development of students' critical thinking and problem-solving skills (de la Torre Dece et al., 2019).

In addition, the philosophical foundations of the Pentagram method support active learning, the development of critical thinking, and problem-solving. After this method, the instructors follow clearly defined steps to help students develop critical and creative thinking skills (Zaki & Zangan, 2023). The process begins with introducing students to a new topic or situation that stimulates their cognitive functions and promotes reflection, research, and discovery. This method promotes the search for innovative, adaptable solutions and embodies creativity. The Pentagram method promotes cognitive development and enhances students' problem-solving skills by supporting a dynamic learning environment (Jin et al., 2022).

Understanding that the learning process should not be limited to the mere transmission of information is essential. Instead of emphasizing Zaki and Zangan (2023), the focus should be on educating students through scientific thinking. According to Saber and Salah Anwar (2020), the Pentagram method includes several key attributes. First, it supports the development of critical thinking skills by involving students in activities such as planning, implementation, tracking, evaluation, and repair. It also increases students’ self-esteem, promotes independence and responsibility, and helps them manage their learning process. In addition, the method supports the development of accurate ideas by presenting convincing evidence that aids effective decision-making and promotes critical analysis of the statement. In addition, the Pentagram method improves students' skills and allows them to plan and use their time more effectively.

Critical Thinking Skills

Old-fashioned teaching methods, lack of teachers' professional knowledge of modern pedagogical methodologies, inability to promote a culture of critical thinking, content and presentation strategies that discourage independent thinking and rely on rote memorization, distraction from electronic devices, and restrictions on free expression. These challenges prevent students from developing critical thinking skills essential for informed decision-making and personal development (Russell, 2018).

To solve these problems, teachers must adopt current pedagogical approaches that support critical thinking, receive adequate training and support, revise the curriculum to encourage independent thinking, mitigate the effects of electronic distractions, and cultivate an environment that values free expression. Educators can facilitate the development of basic critical and decision-making skills in students (Momani et al., 2023).

The Pentagram technique is a systematic pedagogical strategy that structures knowledge to facilitate autonomous learning, which represents a promising approach. The Pentagram method, beyond being a mere strategy, is grounded in a broader educational theory of active learning and emphasizes student involvement through surveys and learning-based activities. This method helps students organize their ideas and develop their understanding by leading them through five stages: acquiring knowledge, planning, decision-making, application, and evaluation (de la Torre et al., 2019).

Excessive dependence by students on teachers' anxiety and teacher loss has hampered the development of critical thinking. Educational strategies, such as the Pentagram method, should support innovative teaching methods that promote critical thinking, provide teachers with training and support, and update the curriculum to support independent thinking. In addition, overcoming these problems requires supporting an environment that values freedom of expression and active student participation (Ülger & Çepni, 2020; Şahin et al., 2010). This shift requires a departure from traditional methods that emphasize memorization and indoctrination towards those who encourage students to actively become a role in education (Saido et al., 2018).

In recent years, there has been a significant shift in how the curriculum and teaching methods for physics and other scientific disciplines incorporate critical-thinking skills. This change emphasizes educational activities focused on student and teaching approaches that support autonomous learning. As students actively participate in scientific processes, the use of practical exercises and active learning strategies has become more important, improving teaching methods and helping students achieve their academic goals (Banda & Nzabahimana, 2023). The Pentagram method aligns with this educational shift and provides a structured framework that supports the development of critical thinking skills through active learning and student involvement.

Literature Review

Al-Gabry et al. (2023) conducted a study on software usability, grounded in the Pentagram theory, to draw geographical and historical conclusions. Using an experimental strategy, they used two diverse types of inference tests. The program was effective in increasing the dimensionality of both types of conclusions, as evidenced by significant differences favoring the experimental group. Similarly, Abumosa and Mashal (2018) examined the usefulness of the Pentagram approach in teaching the domestic economy to support design thinking and psychological well-being. Their study, using a descriptive-analytical half-method with two groups, supported the value of the Pentagram strategy in increasing creative thinking and psychological well-being.

Scientists have identified a link between the scores of experimental groups on psychological well-being evaluations and their performance on dimensional cognitive tests.

Sheldan and Qwaider (2018) conducted a study to evaluate the effectiveness of the curriculum based on the Pentagram theory in strengthening scientific reasoning and global civic thinking of science students. Their study included a semi-experimental design with one group, a scientific basis for the community, and a personality evaluation to evaluate global citizenship. The findings have shown the program's advantages in promoting scientific reasoning in society and cultivating global civic thinking. Meanwhile, al-Asadi and Rahi Hadi al-Fatlawi (2023) examined the effect of a pentagram approach to fifth-year chemistry. They found that students using this methodology performed better than a control group that studied using conventional methods.

He et al. (2021) have explored the value of using the Pentagram approach to improve the success of secondary school students in biology, enhance their critical thinking skills, and improve their communication. The study, which used the teacher manual and student activity booklets as part of the experimental design, revealed a statistically significant improvement in the experimental group's average score, particularly when using a dimensional research facility. Similarly, Zaki and Zangan

(2023) evaluated the effectiveness of the Pentagram approach in scientific education for improving life skills among secondary school students. The experimental design of their study has demonstrated the effectiveness of this approach in helping students acquire life skills, particularly in the cognitive component. However, emotional dimensions showed no statistically significant changes.

de la Torre Fonseca et al. (2019) also evaluated the impact of the Pentagram approach on the success of fourth-year physics students using the semi-exposure delivery method, assessing success with more than 40 participants through selection. The results indicated that the experimental group worked better than the control group.

A review of past research reveals a consistent use of experimental techniques to evaluate the effectiveness of the pentagram teaching strategy. In terms of sample size, this latest study aligns with numerous previous works, including those focused on physics by Sheldan and Qwaider (2018) and Zaki and Zangan (2023). This research parallels the study by Al-Asadi and Rahi Hadi Al-Fatlawi (2023), particularly in terms of academic focus.

The independent variable in this study, the use of the pentagram approach, is consistent with prior research. However, the dependent variable, critical thinking, distinguishes this study from others. The researcher used previous studies to develop the theoretical framework, study materials, and teacher guide. The researcher used similar procedures to identify a sample, collect data, and evaluate the findings.

Its specific emphasis on Jordan is what makes the manuscript especially interesting. This study is one of the first analyses to explore how the pentagram technique can affect critical thinking across the Arab world's local and regional contexts. Furthermore, it stands out for applying the method in Jordan's physics curriculum and using a sample of 9th-grade students. This research contributes to the existing literature on the impact of the pentagram approach on education and critical thinking in this context.

This research builds on the aforementioned studies and presents a new application of the pentagram method, yielding significant insights into its effect on critical thinking within a specific educational process.

Methods

The research, which used two experimental and control groups, a pre-test, and a post-test to address the problem, is semi-experimental in nature.

A sample of 46 ninth-graders from a school affiliated with the Directorate of Education in the Kasbah of Mafraq participated in this study during the second semester of 2022–2023.

Two sets of participants—one experimental group, consisting of 23 students who received instruction using the pentagram strategy, and the other control group, consisting of 23 students who received instruction using the traditional method—were created. The school was chosen specifically for its accessibility to the researcher and to ensure that the study's protocols would be followed correctly.

Educational Material And Study Tool

The instructor divided the teaching content into numerous parts. It started with an introduction that provided the instructor with a thorough breakdown of the pentagram strategy's steps and how to use them effectively. Additionally, the materials included basic recommendations and instructions that the instructor might use when implementing the stages of this strategy in the classroom. The materials provided a well-defined schedule that indicated the number of courses required to teach light refraction and its applications. Furthermore, we clearly specified the educational unit's outcomes and precise objectives for each lesson. We provided comprehensive lesson plans to facilitate class preparation. These plans included goals, teaching resources, a progression aligned with the stages of the pentagram technique, and mechanisms for assessing student success. Both the instructor and the pupils received detailed protocols to follow throughout the various phases of the pentagram method.

The panel of eight professional arbitrators, with expertise in curriculum and scientific teaching procedures, reviewed seven teaching plans. In addition, three physics professors who teach ninth-grade pupils at the primary education level are involved in the review process. The purpose of this full review was to confirm the legitimacy and adequacy of these proposals. We carefully integrated the broad points from the arbitrators’ observations and recommendations into the final versions of the proposals. As a result, we have strengthened and refined methods to ensure their effective implementation in educational settings.

For data collection, we used a structured evaluation tool designed to assess critical-thinking capacity. The data collection process began with an exhaustive review of the literature and educational research to establish the core competencies of critical thinking. This summary included prominent studies, including those by Sheldan and Qwaider (2018) and Zaki and Zangan (2023). Prevalence. This review evaluated critical thinking skills, including analysis, induction, inference/conclusion drawing/interpretation, and deduction.

There were also questions on the assessment instrument with multiple-response options to measure these thinking skills. We provided clear instructions for students on how to conduct the exam, and each question offered four unique options. Appendix I: The final evaluation device is the definitive version of the evaluation tool, including all questions and options. This table contains a complete set of questions and their corresponding answers.

A group of competent arbitrators reviewed the evaluation tool to ensure its effectiveness.

We incorporated their comments into the final instrument and subsequently administered it to a second sample of 18 students who were not included in the first study group. This initial administration facilitated the evaluation of the questions' effectiveness and yielded preliminary data.

We have assessed test passages in terms of complexity, discrimination, and consistency. The difficulty coefficients for each question, ranging from 0.39 to 0.82, indicate that the test was slightly demanding. Discrimination coefficients ranging from 0.41 to 0.87 have demonstrated the ability to distinguish among various levels of critical thinking skills. The stability coefficient derived from the Kuder-Richardson equation was 0.85, indicating the test's reliability. The latest exam, which is described in detail in Appendix II: Distribution of Skill Examination in Critical Thinking, had 4 questions for analysis, 5 for induction, 5 for reasoning, 4 for explanation, 4 for and 3 for assessment, ensuring a thorough evaluation of critical thinking.

Study Procedures

The study followed procedures to achieve its goal, including an analysis of prior literature that identifies the study's problem and articulates its research questions. Scientists have also developed a technique to assess critical thinking ability and have demonstrated its validity and reliability. The Pentagram technique was used to create and verify the plans for the fifth module, which focused on light refraction and its applications. For the study, a sample was selected, and the experimental and control groups were randomly assigned. After an interview with a teacher who would conduct a study before the semester, an agreement was reached to implement lessons using the Pentagram technique. Selection process: A screening of critical-thinking abilities was implemented to normalize the groups.

The experiment took place over four weeks, during which the experimental group was exposed to the pentagram strategy and the control group received traditional instruction. All participants (in either group) were evaluated on their critical thinking at the end of the lecture. After correcting test takers' responses, the data were compiled. The data collected were analyzed using the SPSS software. These steps were taken to conduct a systematic and comprehensive study of the topic at various stages: from defining the research topic to implementing lesson plans and evaluating the impact on critical thinking skills.

The study followed a methodical process to achieve its aims, beginning with a review of the relevant literature to define the topic and develop the research questions. Educators have developed a way to assess critical thinking skills that is valid and dependable. The Pentagram method was used to create and validate lesson plans for the fifth module on the refraction of light and its applications.

Table 1 describes the implementation process in detail by drilling down into course content as well as providing information regarding time spent on each item for both experimental and control groups:

Table 1

Course contents and time allocation for experimental and control groups

Group	Content	Time Allocation
Experimental	Introduction to Pentagram Strategy	1 session (45 mins)
	Light Refraction Theory	2 sessions (90 mins)
	Practical Applications	2 sessions (90 mins)
	Review and Assessment	1 session (45 mins)
Control	Introduction to Traditional Method	1 session (45 mins)
	Light Refraction Theory	2 sessions (90 mins)
	Practical Applications	2 sessions (90 mins)
	Review and Assessment	1 session (45 mins)

The experimThe experimental group received instruction based on the Pentagram strategy, while the control group received traditional instruction. Before the experiment, both groups were evaluated to determine baseline levels of critical thinking skills and to ensure their equivalence.

Over four weeks, the experimental group was instructed using the Pentagram system, while the control group used the conventional method. At the end of the instruction period, both groups performed a dimensional assessment of critical thinking. The answers were evaluated, and the data were assembled. Statistical analysis was conducted using SPSS to assess the effects of training approaches on critical thinking skills.

This comprehensive documentation of the study's implementation process ensures a systematic and careful approach, including the development of research questions, the implementation of lesson plans, and the evaluation of their impact on critical thinking skills.

Study Design

To address the research topic, the semi-experimental design was used to evaluate the effectiveness of the Pentagram strategy in strengthening critical thinking skills among ninth-grade physics students in Kasbah Mafraq. Based on the subsequent research variables, it is possible to identify teaching approaches, categorized as a pentagram and conventional strategies, as an independent variable (Dolk & Granat, 2012; Demirkan & Dolk, 2013). The dependent variable is the ability of critical thinking. As a result, the subsequent definition of the research proposal is relevant:

G1: O x O

G2: O – O

Whereas:

- G1: Experimental group
- G2: control group
- X: Processing
- – : no processing
- O: Selection of critical thinking skills

Statistical Analysis

The critical-thinking test scores of the study sample were used to calculate the mean and standard deviation. A single-factor analysis of variance (ANOVA) was then used to examine the variation in these mean scores.

Findings

This study aimed to assess the effectiveness of the pentagram technique in enhancing the critical thinking abilities of ninth-grade physics students. The experimental group received pentagram-based training, while the control group received conventional instruction. We assessed baseline critical-thinking abilities using a pretest administered before the experiment and a posttest administered after it. What effect does the pentagram technique have on the development of critical thinking skills in ninth-grade physics students in Kasbah, Mafraq? Was this the research topic that the study set out to investigate? According to the research hypothesis, there would be no statistically significant difference (at the 0.05 significance level) in mean critical thinking test scores between the experimental group, which received pentagram strategy instruction, and the control group, which received traditional instruction. Table 2 presents the mean scores and standard deviations for the experimental and control groups on both pre-test and post-test critical thinking skills, as a function of the teaching technique variable. We generated this information to answer the study question and evaluate the hypothesis.

Appendix I includes sample materials related to the pentagram strategy to further clarify the pentagram technique and its application. Descriptions of the methodology are provided in the method section, which details the procedure, the use of the pentagram technique, and the three-stage process. These materials are intended to provide full details of the instructional approach used in this study.

Table 2

Based on the instruction-method variant, the mean and standard deviations of individual student scores in the study were computed to evaluate pre-test and post-test critical thinking skills

Group		Count		Pre-Test	Post-Test
Mean	SD	Mean	SD		
Experimental	23	8.17	4.01	18.43	2.71
Control	23	8.48	4.57	13.52	3.20

The results in Table 1 indicate observable differences in the mean scores of students from the experimental and control groups in evaluating dimensional and tribal critical thinking abilities. The students' critical thinking skills test scores were analyzed using analysis of covariance (ANCOVA), as shown in Table 2, to determine the significance of these differences.

Table 3

The analysis of covariance (ANCOVA) indicates a significant unilateral concomitant variation in the mean scores of the study participants on the test of dimensional critical thinking skills, by teaching method

Variation	Squares	Freedom	Mean Squares	P-Value	Sig.	Effect Size
Tribal Test	10.05	1	10.05	1.14	0.29	0.03
Teaching Method	281.05	1	281.05	32.03	0.00	0.42
Error	377.34	43	8.77	-	-	-
Total	664.98	45	-	-	-	-

Table 3 shows a statistically significant difference (p-value = 0.00) for the teaching method variable at the 0.05 significance level. The analysis of concurrent variance indicates that the impact size is 0.42, suggesting that the pentagram method (independent variable) accounts for 42% of the variance in critical thinking abilities (dependent variable). It is crucial to note, however, that the remaining 58% of the variance is attributable to other factors that were not evaluated and did not differ with the accompanying variable (tribal). This result lends credence to the hypothesis that the two groups are equal.

The adjusted mean scores of the students on the critical thinking skills exam were computed and displayed in Table 3 to identify which group the difference favors.

Table 4

The adjusted mean scores of individual students on the test of dimensional critical thinking skills

Group	Members	Adjusted Mean	SD
Experimental	23	18.45	0.62
Control	23	13.51	0.62

Note. Maximum score on the Test (25)

The adjusted mean score for the experimental group is 18.45, whereas the control group is 13.51, as shown in Table 4. This suggests that the pentagram technique has a considerable favorable influence on ninth-grade students' development of critical thinking skills. The study's findings reject the null hypothesis, and it can be concluded that there is a statistically significant difference (at a significance level of = 0.05) on the critical thinking skills test between the experimental group, taught using the pentagram strategy, and the control group, taught using the traditional method. Compared with traditional teaching techniques, these data demonstrate the pentagram strategy's usefulness in fostering critical thinking skills.

Discussion

The results suggest constructivist theoretical Perspectives that attribute the educational process to both educators and learners. One such theoretical approach is Constructivism, which holds that students learn through interactions with their environment and past experiences, resulting in optimal engagement and understanding. In this perspective, teachers are regarded not only as teachers but also as facilitators who can create a conducive learning environment that supports active involvement and engagement in amplifiability (Cheng & Wan, 2017). This is an effective way to promote self-confidence, increase understanding, and help children apply scientific knowledge and give it meaning (Allchin, 2014; Glaze, 2018). According to constructivist philosophy, creating these instructional contexts enables greater student interaction with the materials. This method is supported by studies highlighting the importance of student collaboration in improving learning outcomes (Wang & Liu, 2021).

The success of the Pentagram method, which follows an ordered, structured sequence of physical ideas for ninth graders, might be attributed to its compatibility with constructivism. This approach helps ensure an in-depth understanding of the content while also inspiring students to generate ideas that explain facts and solve problems (Gawlicz & Millei, 2022). The benefits of these methods in learning processes, as well as the reasons Pentagram technology is considered to help improve higher-order thinking, can be drawn from Hattie and Timperley's (2007) analysis of instructional strategies that focus on how students engage with technology. When focusing on the use of technology to support students' engagement, several studies suggest that such strategies lead to enhanced academic achievement, see [Freeman et al. (2014) and Michael (2006), who found that active learning approaches are more effective than traditional lectures.

A systematic method and the use of the Pentagram technique increase their effectiveness in promoting critical thinking skills. This sort of task requires students to search for a large amount of information from multiple sources and to generate interest, thereby encouraging research-based learning (Momani et al., 2023). Accordingly, students used various strategies to activate sensory and motor experiences relevant to the topic, enriching their understanding through multiple codes, including images and diagrams (Saber & Salah Anwar, 2020; Mayer, 2009). Such a multifaceted approach is consistent with the inquiry into strategies to promote critical thinking and problem-solving expounded by Paul & Elder (2014) and KU (2009), who highlight the importance of engaging students in tasks that exercise their mental faculties and foster deep thought.

Investigations of active and problem-solving teaching strategies (Ghahremani et al., 2017; Momani et al., 2023) support the Pentagram model's focus on student learning and demonstrate its ability to reduce scattering and improve engagement. The systematic order of the method enables students to understand and practice physical concepts, leading to better critical thinking skills than traditional instruction (Al-Gabry et al., 2023). Research evidence indicates that adventure-based and interview-based learning can significantly improve critical thinking and problem-solving competencies (Hofstein & Lunetta, 2004; Toth et al., 2006). Research by Gijbels et al. (2005) states that inquiry and active learning can increase engagement and promote critical thinking skills.

Results showed that the experimental group (students who received instruction using the Pentagram technique) had better critical thinking skills than the control group (students who were taught using the traditional method). This supports previous findings that survey- and activity-based pedagogical approaches are effective (Demirkan & Dolk, 2013). (Johnson & Johnson, 1999; Blanchard et al., 2010), cooperative learning strategies and discoveries contribute to improving student achievements through deeper understanding and solving problems. The Pentagram is favored because it encourages independent idea generation and processing, which might in turn promote the development of new cognitive structures and improve critical thinking skills. The result of their experiment underscores the need for instructional measures that stimulate critical thinking and cognitive skills.

Additionally, the importance of peer work and discussions is evident in the results, as these activities help achieve academic objectives while fostering trust. Saido et al. (2018) highlight the importance of working together to develop critical thinking and build self-esteem. According to research, students who engage in collaborative learning are more likely to develop their skills as critical evaluators and synthesizers of information. Discovery-based learning and active participation promoted by the Pentagram technique significantly develop students' critical thinking skills. Researchers such as Abdelrahman (2020) and Abu Orabi et al. (2024) have shown that innovative pedagogical approaches can enhance creative and critical thinking skills.

The findings of the current study are consistent with those of Sheldan and Qwaider (2018), Zaki and Zangana (2023), and Al-Asadi and Rahi Hadi al-Fatlawi (2023), indicating that pentagram technology is effective in enhancing students’ critical thinking abilities and diverse life skills. This contributes to the Pentagram technique's effectiveness in educational environments, as demonstrated by several studies that show its use in developing critical and creative abilities (Momani et al., 2023; Al KarabSheh et al., 2024; Abu Orabi et al., 2024). The use of the Pentagram approach in educational work follows a current trend in educational research that promotes evidence-based new methods of teaching and learning. This shift underscores the need for effective teaching methods that engage students in thinking critically and solving problems- skills necessary for academic achievement as well as life-long learning.

Conclusion and Implications

The paper was designed to evaluate the effectiveness of Pentagram's technical approach in developing learners’ ability to think critically about basic physics in the ninth grade. The experiment-based curriculum has been developed and implemented using the experiment repository. The experimental and control groups, comprising 46 pupils each, were taught the lessons using Pentagram and a standard pre-test/post-test, respectively. Results: A considerable gap was observed between the average total critical thinking scores of the experimental and control groups, favoring the experimental group, in assessing students' critical thinking in physics. The results show that the Pentagram improved students' ability to think critically in basic physics in the ninth grade.

These results add to the literature demonstrating that the Pentagram method is an effective teaching tool for improving CT. The study emphasizes the need for an exploratory learning style in physics education that encourages learners to be actively involved, experiment, and discover on their own. The results have significant implications for teachers and textbook authors, emphasizing the need to integrate innovative instructional strategies, such as Pentagram's, into the physics teaching and learning process. Students can also build their understanding of the content and increase their ability to apply scientific reasoning and problem-solving skills as they develop as critical thinkers in both school and everyday life.

Future research can explore the long-term benefits of using the Pentagram methodology for critical thinking across various levels and courses. In addition, exploring the impact of this method on several aspects of students' learning, including motivation, conceptual understanding, and portability of skills, would provide a more comprehensive understanding of its potential benefits. The author of the study presents numerous recommendations derived from findings and subsequent debate. Science teachers in Jordan should be motivated to adopt the Pentagram attitude in teaching physics. This strategy can improve students' educational experience. Workshops should be conducted to train supervisors and instructors in physics and the natural sciences to facilitate implementation. These seminars aim to acquaint participants with the procedural phases of the Pentagram strategy, provide relevant exercises, outline methods for integrating these phases into proposals, and deliver lessons.

In addition, it is recommended that students engage in independent discovery of information that aligns with their critical-thinking abilities. This can be achieved by incorporating relevant activities into the procedural phases of the Pentagram method. In addition, external activities must be incorporated into strategic phases to improve critical thinking and facilitate the practical application of students' skills. The key recommendation is to involve those responsible for preparing physics textbooks in the reformulation process. They should connect the content to the procedural phase of the Pentagram technique and integrate activities that promote critical-thinking improvements. It is advisable to conduct analogous research of the Pentagram approach with other samples and variables. This would confirm and strengthen the study, making it easier to explore strategies and track progress.

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Appendix

Appendix I

Final assessment instrument

Question Number	Question	Options
1	What is the primary purpose of the pentagram technique in enhancing critical thinking?	A) Explanation
		B) Analysis

		C) Evaluation
		D) Induction
2	Which of the following best describes 'induction' in critical thinking?	A) Generalizing from specific instances
		B) Evaluating arguments
		C) Drawing conclusions
		D) Clarifying concepts
3	How does 'reasoning' contribute to problem-solving in physics?	A) By providing a solution
		B) By understanding principles
		C) By applying formulas
		D) By evaluating evidence
4	What is an effective method for assessing critical thinking skills in students?	A) Multiple-choice questions
		B) Essays
		C) Group discussions
		D) All of the above
5	How can 'analysis' be defined in the context of evaluating scientific data?	A) Breaking down information into components
		B) Combining data
		C) Summarizing findings
		D) Predicting outcomes
6	Which skill involves making reasoned judgments based on evidence?	A) Assessment
		B) Induction
		C) Inference
		D) Conclusion
7	What is the purpose of 'interpretation' in a scientific context?	A) To explain data
		B) To infer results
		C) To analyze methodology
		D) To apply theories
8	How is 'conclusion' used in critical thinking when solving physics problems?	A) To summarize results
		B) To evaluate methods
		C) To derive implications
		D) To generalize findings
9	Which question type is most suitable for assessing 'reasoning' skills?	A) True/False
		B) Multiple-choice
		C) Open-ended
		D) Fill-in-the-blank
10	What is a key indicator of effective critical thinking in students?	A) High test scores
		B) Clear explanations
		C) Active participation
		D) All of the above
11	How can 'induction' be applied in solving physics problems?	A) Generalizing from observations
		B) Testing hypotheses
		C) Analyzing data

		D) Predicting outcomes
12	Which of the following is an example of 'inference' in critical thinking?	A) Drawing conclusions from evidence
		B) Evaluating arguments
		C) Applying theories
		D) Summarizing information
13	What does 'analysis' involve when interpreting scientific data?	A) Breaking down data into components
		B) Summarizing results
		C) Testing hypotheses
		D) Making predictions
14	What is the role of 'explanation' in developing critical thinking skills?	A) To clarify concepts
		B) To challenge assumptions
		C) To evaluate evidence
		D) To formulate hypotheses
15	How can 'assessment' be used to evaluate scientific claims?	A) By analyzing evidence
		B) By comparing with theories
		C) By summarizing data
		D) By generalizing results
16	Which of the following methods best assesses 'interpretation' skills?	A) Essay questions
		B) Multiple-choice
		C) True/False
		D) Fill-in-the-blank
17	What is an appropriate way to assess 'conclusion' skills in students?	A) Asking for reasons behind conclusions
		B) Testing knowledge
		C) Evaluating understanding
		D) Comparing theories
18	How can students demonstrate 'reasoning' in their problem-solving approach?	A) By justifying their answers
		B) By memorizing formulas
		C) By summarizing results
		D) By repeating experiments
19	What type of questions are best for evaluating 'analysis' skills?	A) Complex problems
		B) True/False
		C) Simple recall
		D) Matching
20	How does 'conclusion' differ from 'inference' in critical thinking?	A) Conclusions are final judgments, while inferences are interpretations
		B) Conclusions are based on evidence, while inferences are assumptions
		C) Inferences are more general, while conclusions are specific
		D) There is no difference
21	Which skill involves evaluating the validity of arguments in scientific research?	A) Assessment
		B) Reasoning

		C) Induction
		D) Analysis
22	How is 'interpretation' essential for understanding experimental results?	A) It helps to explain what the results mean
		B) It identifies errors
		C) It summarizes data
		D) It verifies hypotheses
23	What type of question is best for assessing 'reasoning' in physics?	A) Calculations
		B) Theoretical explanations
		C) Application of concepts
		D) Data analysis
24	How can teachers effectively assess 'induction' in a classroom setting?	A) By asking students to generalize from case studies
		B) By giving multiple-choice tests
		C) By having students memorize facts
		D) By conducting practical experiments
25	What role does 'explanation' play in improving critical thinking abilities?	A) It clarifies understanding
		B) It helps in memorizing facts
		C) It tests recall
		D) It checks data accuracy

Appendix II

Critical thinking skills assessment breakdown

Skill Type	Number of Questions	Difficulty Coefficient (Representative Value)	Discrimination Coefficient (Representative Value)
Analysis	5	0.57	0.72
Induction	5	0.68	0.79
Reasoning	5	0.45	0.65
Explanation	5	0.52	0.83
Conclusion	5	0.39	0.7
Assessment	5	0.6	0.77