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The Impact of the Six-Dimensional PDEODE Teaching Strategy on the Development of Critical Thinking among Secondary School Students

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Abstract: The present study aimed to investigate the impact of the six-dimensional PDEODE teaching strategy on the development of critical thinking among secondary school students. To achieve this aim, the researcher adopted an experimental research design involving two groups: an experimental group and a control group. The study sample consisted of 60 male and female secondary school students, randomly selected from Dhi Qar Governorate. The researcher administered a critical thinking test developed by Qanoua Mustafa (2019), which comprises five subscales. The results revealed a statistically significant superiority of the experimental group over the control group in the critical thinking test. Accordingly, the researcher recommended the adoption of the six-dimensional PDEODE strategy in teaching secondary school students.

Keywords: Critical thinking; Secondary school students; Six-dimensional strategy (PDEODE).

Chapter One

First: Research Problem

In recent years, there has been a growing expansion of the gap between learners' educational needs and teachers' professional capacities to keep pace with rapid civilizational and societal transformations. This situation has created an urgent need to employ modern educational strategies aimed at developing learners' thinking, inquiry, and discovery skills to the greatest possible extent, to achieve the desired educational objectives (Al-Adwan, 2016, p. 13).

Preparing learners with desirable and appropriate competencies necessitates teaching them how to think. Traditional classroom instruction represents an artificial educational identity that society has been compelled to follow (Dawood, 2014, p. 314). Thinking constitutes an essential component of the educational process and cannot be separated from other human activities (Al-Madhoun, 2012, p. 13).

De Bono argues that thinking represents the process through which intelligence activates itself in response to experience; it involves the ability to employ innate intelligence and translate it into real-life behavior. Thus, thinking is a reflective and deliberate exploration of experience aimed at achieving a desired goal (Noufal & Abu Awad, 2010, p. 26).

Critical thinking refers to an individual's ability to verify the accuracy of information and to evaluate situations. It is considered one of the fundamental and essential skills required in daily life, as it enables students to develop a deep understanding of academic concepts and helps them analyze information effectively (Hashim, 2024, p. 87).

Harold Brewer, Superintendent of the Montgomery School District in Troy, North Carolina, maintains that critical thinking and higher-order skills "must be fully and integrally embedded across all subject areas." The ability to observe, collect information, analyze it, and make data-based decisions will be essential in the

twenty-first century. Similarly, Cornelius Cain, Superintendent of the Camp Hill School District in Camp Hill, Pennsylvania, believes that the ability to employ critical thinking and decision-making skills "may be among the most important outcomes of the educational process." He emphasizes that students should be taught to continue learning beyond the conventional school day, to reflect on what they have learned, and to apply that learning in their lives, whether or not the teacher is present. In the same vein, Thomas Fegley, Superintendent of Schools in Collinsville, Illinois, proposes that "we must help students become resourceful" (Long & Withrow, 2007, p. 70).

John Dewey is regarded as one of the most prominent educational philosophers whose ideas have had a profound influence on the concept of critical thinking in education. He defined it as the suspension of premature judgments, or what he termed "healthy doubt." What characterizes critical thinking, according to Dewey, is the analysis of information after it is received through active reflection, rather than accepting information superficially. Instead, the learner interacts with information, exercises caution toward any assumed form of knowledge in light of the evidence supporting it, and considers ideas within their contexts, which aids in evaluating the validity of knowledge (Al-Tamimi, 2016, p. 70).

Keeping pace with the information and communication revolution and employing digital technology are essential to move from rigid, static learning to flexible learning. This shift enables learners to seek knowledge independently and to acquire thinking and problem-solving skills (Shelby, 2018, p. 28).

The teacher, as a facilitator of learning, must be capable of selecting appropriate learning strategies that can enhance students' academic abilities through approaches that promote critical thinking and communication skills. One effective alternative is the PDEODE learning strategy (Predict–Discuss–Observe–Explain–Discuss–Explain), which was developed from the POE learning strategy (Predict–Observe–Explain) (Kosto, 2008). The POE strategy is grounded in a constructivist approach, and the PDEODE strategy further emphasizes the active role of students in the learning process, enabling them to discover and construct their own knowledge.

Within this instructional strategy, students engage in logical and theoretical thinking based on relationships and hypotheses, and can make decisions grounded in evidence-based conclusions. At the same time, teachers assume the role of motivators and facilitators of learning activities. They guide, direct, and support students, enabling them to interact meaningfully with their environment and everyday life. The problems presented to students are closely related to their surrounding environment, which allows them to think critically and to identify solutions in accordance with their cognitive development (Dipalaya & Corebima, 2016, p. 62).

The six-dimensional strategy is grounded in constructivist theory, one of whose fundamental principles is that new knowledge is built upon prior knowledge. Learners construct connections between what they already know or have previously experienced and the new material they encounter. Jean Piaget emphasizes that knowledge is constructed through a process of adaptation consisting of two complementary components: assimilation and accommodation. Assimilation refers to the creation of new cognitive structures by modifying and building upon existing ones. Accommodation becomes necessary when new perceptions and experiences do not fit within existing cognitive structures, requiring these structures to be reshaped to adapt to new experiences. Accordingly, what is learned is determined by two influences: the schemas already present in individuals' minds and the information embedded in external stimuli to which they respond.

New knowledge is constructed through the interpretation, organization, and integration of selected information. This newly organized knowledge interacts with relevant prior knowledge retrieved from long-term memory and subsequently transforms it. Mental operations and computational processes are carried out in short-term memory, while long-term memory serves as a repository for knowledge structures (Savander-Ranne & Kolar, 2003, p. 189).

The researcher observed that the learning process tends to rely on rote memorization rather than on students' lived experiences. Consequently, students' abilities are often perceived merely as memorization skills. Such learning processes are incapable of developing students' thinking skills, as students are not afforded sufficient opportunities to construct, analyze, evaluate, and infer knowledge, nor to identify solutions as outcomes of their thinking activities. In accordance with the constructivist approach to learning, students should assume responsibility for their own learning.

The research problem is therefore articulated in the following question:

What is the effectiveness of the six-dimensional strategy in developing critical thinking among secondary school students?

Second: Significance of the Study

Psychologists emphasize the importance of critical thinking in enhancing students' levels of creativity and in equipping them with problem-solving skills and other forms of thinking that enable learners to comprehend complex life crises, perceive the world more clearly, and understand issues in a deeper and more precise manner. Critical thinking contributes to the development of questioning ability, which is considered one of the most important higher-order cognitive capacities, as it inherently involves a set of mental skills such as linking, analysis, comparison, and effecting change—all of which constitute the core components of critical thinking. Moreover, this type of thinking contributes to the formation of a balanced and intelligent personality capable of confronting complex life problems, relying on oneself, and seeking truth through scientific and logical approaches (Younis & Jassim, 2020, pp. 119–120).

The ability to think critically helps individuals adapt more effectively than their peers with lower cognitive abilities, as it enables them to select and evaluate alternatives accurately, which represents the essence of critical thinking. Critical thinking requires individuals to weigh matters carefully and compare different advantages. It also enhances students' skills, supporting their success in both academic and professional life by enabling them to identify problems they face with precision and clarity (Al-Hashimi & Riyalat, 2012, p. 670).

In addition, critical thinking is regarded as one of the fundamental educational objectives in contemporary educational systems across most countries worldwide. Educators agree that the ultimate goal of curricula in the current century is to develop students' critical and creative thinking skills, as these skills constitute the primary gateway to preparing a generation capable of adapting to the rapid changes of the modern era and dealing consciously and effectively with various problems and situations (Younis & Jassim, 2020, p. 118).

Critical thinking skills are essential for students, as they enable them to deal effectively with social, scientific, and practical problems. Students who possess strong critical thinking skills are better able to solve problems efficiently. In order to function effectively in both professional and everyday life, possessing knowledge or information alone is insufficient; students must be capable of problem-solving to make sound and effective decisions. Therefore, students need to develop critical thinking abilities. Learners who demonstrate critical thinking skills are also able to construct knowledge that will be useful in the future, thereby enhancing their motivation in daily life (Dipalaya, T., Susilo, H., & Corebima, A. D., 2016).

Interaction and collaboration among peers provide students with opportunities to benefit from multiple perspectives and have been documented as effective tools for enhancing understanding. Encouraging students to engage in discussion and collaboration allows them to approach concepts, processes, and phenomena in diverse ways. Peer interaction enables students to communicate with their partners, discuss viewpoints and conflicts, predict, interpret, explain, and clarify ideas, and collaboratively construct knowledge. When students are required to justify and defend their ideas and perspectives, they are compelled to think more deeply. They must make their intuitive and emerging ideas explicit and open to scrutiny, yet within an environment where no individual stands alone. In this context, it is essential that the classroom and group atmosphere support discussion and value diverse viewpoints. This strategy provides students with opportunities to express their prior knowledge related

to the presented material, collaborate with peers during discussions, exchange viewpoints, and revise their conceptions of the knowledge they possess (Savander-Ranne & Kolar, 2003).

Accordingly, the significance of the present study is manifested in the following points:

Third: Research Objective

• The present study aims to identify the effectiveness of the six-dimensional strategy in developing critical thinking skills among secondary school students.

Fourth: Research Hypothesis

To achieve the objective of the study, the researcher formulated the following hypothesis: There are no statistically significant differences at the significance level (0.05) between the mean scores of the experimental group students who were taught using the six-dimensional strategy and those of the control group students who were taught using traditional instructional methods in the development of critical thinking skills.

Fifth: Delimitations of the Study

The current study is delimited to the following:

- **Temporal boundary:** The first semester of the academic year 2023–2024.
- **Spatial boundary:** Day secondary schools affiliated with the Directorate of Education of Dhi Qar Governorate.
- **Human boundary:** Secondary school students.

Sixth: Definition of Terms

1. **Critical Thinking**: Robert Ennis, one of the leading figures in the critical thinking movement, defines critical thinking as the type of thinking concerned with what should be believed or done in a given situation or event. It is characterized by two fundamental features: it is rational thinking that leads to sound, well-justified conclusions and decisions, and it is reflective thinking that demonstrates full awareness of the steps through which conclusions and decisions are reached. Ennis further argues that critical thinking abilities are more explicit, comprehensive, and broader than higher-order thinking skills, as critical thinking adds the capacities of observation and interpretation to these skills (Razuqi, Mohammed, & Dawood, 2018, p. 47).

Hassan Shehata (2002) defines critical thinking as a set of intellectual skills that actively and skillfully engage in constructing concepts, applying them, analyzing, synthesizing, and evaluating information gathered or generated through observation, experience, reflection, reasoning, or communication, as a basis for forming beliefs and actions. These elements constitute the core components of critical thinking, such as identifying and inferring information relevant to a problem (Madi, 2011, p. 138).

Watson and Glaser (1964) define critical thinking as an individual's ability to verify the accuracy of information and evaluate situations. It is considered one of the essential skills required in daily life, as it helps students achieve a deep understanding of academic concepts and analyze information effectively (Hashim, 2024, p. 87).

Operational Definition:

Procedurally, the researcher defines critical thinking as a comprehensive and progressive process and a fundamental skill that individuals must master. Developing students' critical thinking skills within the learning process is essential for enhancing their cognitive learning outcomes and life skills. These skills include induction, credibility (truthfulness), prediction, experimental planning, fallacy recognition, and deduction. Operationally, critical thinking is represented by the score obtained by the student on the critical thinking test.

2. PDEODE Strategy

Costa defines the six-dimensional strategy as one of the instructional strategies capable of achieving a set of constructivist principles in teaching and learning. It allows learners to actively participate in constructing knowledge and new experiences, and it encourages

interaction and collaboration among learners in the process of knowledge construction. The strategy links educational content to learners' social and cultural contexts and includes a reflective stage that focuses on thinking about the learning process itself. Moreover, it helps integrate diverse knowledge and skills in the construction of new knowledge and encourages learners to organize and manage their own learning processes (Costu, 2008).

Zayan (2020) defines the six-dimensional PDEODE strategy as a modern instructional strategy in which the teacher captures students' attention and stimulates their thinking by presenting a problem or a mathematical question. This strategy consists of six sequential steps aimed at correcting students' misconceptions and developing their critical thinking skills (Zayan, 2020, p. 5).

Operational Definition:

Procedurally, the PDEODE strategy involves providing students with instructional situations that enable them to construct new experiences, pose questions to themselves and others about these experiences, and activate both hemispheres of the brain by establishing logical and interconnected relationships to build knowledge on sound foundations. This is achieved through the sequential steps of the strategy: **Prediction, Discussion, Observation, Explanation, Discussion, Explanation, and Evaluation**.

Chapter Two
Theoretical Background and Previous Studies
First: Theoretical Background

The PDEODE strategy was initially proposed by Kolar(i) in 2003 as an extension of the POE strategy. The POE strategy is based on exploring students' understanding by engaging them in three essential tasks: students are required to predict the outcome of a given event or situation and justify their predictions, then describe what actually occurs, and finally reconcile any discrepancies between their predictions and their observations. This strategy has been widely used in educational contexts. The PDEODE strategy represents a modification of the POE strategy, with the principal difference lying in its additional emphasis on enhancing its value as a learning activity by creating an environment that supports discussion and values the diversity of viewpoints. The PDEODE strategy consists of six sequential steps (Costa, 2012, p. 50).

The PDEODE instructional strategy is derived from the POE strategy. The primary objective of the POE strategy, as employed by White and Gunstone (1992), is to enable students to develop a sound understanding of any event or situation presented to them. One of its most important features is that it provides students with opportunities to become aware of their alternative conceptions related to the topic and to engage in discussion about their ideas. This strategy comprises three main stages:

The first stage is the **Prediction (P)** stage, in which students are asked to make predictions about the events occurring in the activity prepared by the researcher.

The second stage is the **Observation (O)** stage, during which students are enabled to observe the event taking place in the prepared activity.

The third stage is the **Explanation (E)** stage, in which students are guided to provide explanations in order to resolve any conflicting situations that arise between their initial predictions and their subsequent observations.

Discussion plays a crucial role in the POE strategy, as it provides students with opportunities to engage in dialogue, encourages collaboration, and enables them to address concepts, processes, and events from multiple perspectives. Ultimately, constructivist classrooms emphasize discussion and interaction among students as fundamental components of the learning process.

The PDEODE strategy represents an extension of the POE strategy. It adds three additional phases to POE:

1. **Discussion (D) phase:** Students discuss their predictions, observations, and explanations in small groups.
2. **Second Explanation (E) phase:** Students present and explain the outcomes of their group discussions to the entire class.

3. **Evaluation (E) phase:** Students evaluate what they have learned and correct any misconceptions.

These additional phases in PDEODE are intended to promote conceptual change through discussion and social interaction among students (Dimercioglu, H., 2017, p. 79).

Importance of the strategy:

Research findings indicate that PDEODE can facilitate students' understanding of situations or problems encountered in everyday life and help them develop a deeper comprehension of concepts. The consistent implementation of this instructional strategy can provide positive feedback and foster a shift toward student-centered learning. Student-centered learning strategies enable learners to learn more effectively and to develop their ability and confidence in evaluating their own knowledge. Moreover, this instructional strategy can enhance students' motivation. Students become more active in interacting with other study groups and in constructing their own knowledge. Through this learning strategy, students can communicate with peers to discuss their views and conceptual conflicts, engage in prediction, interpretation, and explanation in the process of building or constructing knowledge, and correct their misconceptions through discussion and demonstration. It can also support the development of students' critical thinking skills (Costa, B., 2008, p. 3).

Within this strategy, the teacher guides and directs students so that they are able to interact with their environment and daily life. The strategy provides students with opportunities to express their prior knowledge related to the presented material, collaborate with other students, and modify their existing conceptions of knowledge (Dipalaya, T., & Aloysius, D., 2016, p. 60).

Critical Thinking:

The study of critical thinking began relatively early; however, attempts to develop structured lists of critical thinking skills date back to Smith and Tyler (1942). The difficulty in reaching consensus on a definitive set of critical thinking skills is attributable to the nature of critical thinking itself, which encompasses multiple, diverse, and interrelated dimensions. Some critical thinking skills involve cognitive behaviors such as recognition, interpretation, analysis, justification, and discrimination, while others involve affective behaviors such as appreciation and evaluation. Despite these differences, all such skills share the characteristic of being higher-order thinking skills marked by depth, intensive mental effort, and the pursuit of underlying causes and reasons (Abd al-ʿĀl, 2012, p. 100).

Educators define critical thinking as the ability to evaluate information and examine opinions while taking into account diverse perspectives. It involves distinguishing between hypotheses and generalizations, facts and claims, and between organized and unorganized information. Critical thinking is regarded as a reflective and purposeful mental activity that relies on logical reasoning with the aim of reaching sound and objective judgments according to accepted standards. This type of thinking consists of a set of skills that may be applied individually or in an integrated manner, and these skills are generally classified into three main categories: analysis, synthesis, and evaluation (Zarouqi et al., 2018, p. 291).

Some scholars have distinguished between strong and weak critical thinking. Strong critical thinking applies critical questioning to all ideas and beliefs, including those held by the critical thinker himself or herself (Al-Nashar, 2013, p. 126).

Critical Thinking Skills:

Thinking skills involve providing learners with appropriate opportunities to practice specific processes that are deliberately employed in information processing. Thinking consists of multiple skills, and mastery of each contributes to the overall effectiveness of thinking (Al-Moussawi, 2016, p. 625).

Many researchers have regarded critical thinking as one of the core thinking skills, and, in turn, critical thinking itself comprises a set of distinct skills. Scholars have differed in identifying and classifying these skills, largely due to the multiplicity of definitions and theoretical frameworks used to explain critical thinking. This diversity has resulted in numerous classifications and a

wide range of identified skills, among the most well-known of which is Watson's classification.

Watson's Classification:

Critical thinking is considered a higher-order mental activity that encompasses a set of complex skills aimed at analyzing information, deriving conclusions, and evaluating them logically and objectively. Several researchers have identified these skills, most notably Al-Kubaisi (2007), who highlighted the following:

- **Deduction:** A mental process through which a conclusion is derived from two or more premises that are logically related, leading to a valid result.
- **Inference:** The ability to arrive at specific conclusions based on available facts or data.
- **Interpretation:** The intellectual process through which an individual assesses the logical soundness of proposed explanations based on the accuracy and validity of the information presented.
- **Evaluation of arguments:** The individual's ability to distinguish between strong and weak arguments in terms of their relevance to the topic and their logical significance.
- **Recognition of assumptions or presuppositions:** The ability to identify implicit assumptions or taken-for-granted conclusions in light of given premises or facts, through analyzing the situation and extracting the underlying hypotheses it contains.

Facione's Classification:

Facione identified six core skills of critical thinking, as follows:

1. **Interpretation:** This refers to understanding given information and expressing it in accordance with rules, standards, and procedures. It includes sub-skills such as classification, deriving meaning, and clarifying concepts.
2. **Analysis:** This involves clarifying the logical and inferential relationships among statements and concepts. It includes skills such as distinguishing opinions and identifying and analyzing arguments.
3. **Evaluation:** This entails judging the credibility of opinions or arguments according to logical criteria. It includes skills related to evaluating claims and arguments.
4. **Inference:** This refers to deriving new information from known or presented information. It includes skills such as confirming evidence, hypothesizing possible outcomes, and reaching logical conclusions.
5. **Explanation:** This involves presenting and clarifying the results of thinking based on evidence, concepts, and various contexts. It includes skills such as stating conclusions, explaining procedures, and advancing persuasive arguments.
6. **Self-Regulation:** This is the individual's ability to monitor one's own thinking, assess its credibility, and organize ideas and conclusions. It includes two sub-skills: self-examination and self-correction (Al-Minyawi, 2024, p. 213).

Characteristics of Critical Thinking:

Harndeck (1976) argues that individuals who possess critical thinking exhibit a set of cognitive and behavioral characteristics that reflect their capacity for logical analysis and objective judgment. These characteristics may be summarized as follows:

1. Openness to new ideas, demonstrated by acceptance of diverse viewpoints without prior bias.
2. Refraining from argumentation on matters beyond one's knowledge, indicating awareness of the limits of one's understanding.

3. The ability to recognize the need for additional information when confronted with unclear issues or insufficient data.

4. The ability to distinguish between possible outcomes and confirmed outcomes, recognizing the difference between what may be true and what must be true.

5. Avoidance of logical fallacies in reasoning and a commitment to sound thinking when analyzing issues.

6. Separation of emotional thinking from logical thinking, thereby ensuring objectivity and minimizing personal bias.

7. A continuous search for reasons and evidence before adopting any idea or opinion.

8. An organized approach to dealing with complex situations by analyzing their components and identifying the relationships among them (Ismail, 2009, p. 64).

Critical thinking contributes to the development of the learner from mere acquisition of knowledge to independent thinking, as it encourages learners to engage in personal reasoning rather than merely adopting the ideas of others. It also enhances both the quantity and quality of meanings that learners derive from what they read or comprehend, and improves their ability to express themselves effectively in writing and orally. In addition, critical thinking supports communication skills and scientific literacy, and contributes to improving students' academic achievement across various subject areas. It further strengthens learners' ability to solve problems and to think across different domains of knowledge, equipping them with the essential skills needed to confront the challenges of the technological age (Mustafa & Makdour, 2021, p. 178).

Based on the foregoing, the researcher concludes that critical thinking represents one of the most important goals of contemporary education. Its significance lies in shaping students' personalities, developing their capacity to construct knowledge, and teaching them how to learn rather than what to learn.

Application of the Strategy:

Educational Objectives:

- To enable students to identify assumptions embedded in situations and problems.
- To enable students to interpret available information and data logically.
- To enable students to evaluate arguments and evidence presented in discussions.
- To enable students to infer logical conclusions from given premises.
- To enable students to provide logical justifications for their opinions and judgments.

Materials and Tools:

A variety of instructional situations and problems; an interactive whiteboard; student worksheets.

Steps of the Strategy:

1. **Predict:**
    - The teacher presents a situation or problem to the students.
    - Students are asked to predict possible assumptions and conclusions.
    - Students record their predictions on worksheets.
2. **Discuss:**
    - The teacher divides students into small groups.
    - Each group discusses its predictions and justifies its choices.
    - Groups share their predictions and justifications with the class.
3. **Explain:**

- The teacher asks selected students to explain their predictions and analyze the situation.
- The teacher discusses the proposed explanations with the students and guides them toward accurate analysis.

4. **Observe:**
   - The teacher presents the correct solution or analysis of the situation.
   - Students are asked to observe the steps followed and compare them with their own predictions.
5. **Discuss:**
   - The teacher once again divides the students into small groups.
   - Each group is asked to discuss their observations regarding the correct solution or analysis.
   - The groups share their observations and suggestions with the class.
6. **Explain:**
   - The teacher asks selected students to explain the differences between their predictions and the correct solution.
   - The teacher discusses the explanations presented with the students and clarifies any ambiguous points.

Evaluation:

- The teacher presents new situations and problems to the students.
- Students are asked to analyze the situations and make critical judgments individually.
- The teacher evaluates students' performance in light of the targeted critical thinking skills.

Previous Studies:

Iraqi Studies:

Several recent studies have indicated the effectiveness of the Six-Dimensional Strategy (PDEODE) in developing thinking skills and enhancing concept acquisition among students at different educational stages:

1. **Kahlan (2020)** examined the effect of the Six-Dimensional Strategy on the acquisition of rhetorical concepts and the development of critical thinking among fifth-grade literary stream students in the subject of rhetoric and application. The study adopted an experimental design with a sample of 60 students, divided into two equal groups (30 students each). The researcher prepared 12 instructional lesson plans, six for each group, and administered a critical thinking test consisting of 80 items and a rhetorical concept acquisition test consisting of 51 items. The results showed the superiority of the experimental group over the control group in both tests, which was attributed to the use of the Six-Dimensional Strategy in instruction. The researcher recommended strengthening the use of this strategy in teaching.
2. **Abdul-Radi Ahmed (2021)** investigated the effectiveness of the Six-Dimensional Strategy in teaching social studies to develop historical understanding skills and values of national belonging among primary school pupils. The research sample consisted of 60 sixth-grade pupils, divided into an experimental group (30 pupils) and a control group (30 pupils). The researcher employed both the descriptive and quasi-experimental approaches. The results revealed statistically significant differences between the mean scores of the two groups in the post-application of the historical understanding skills test and the national belonging values scale, in favor of the experimental group. The modified gain ratio (Blake) was acceptable for both variables. The study recommended the use of the Six-Dimensional Strategy in teaching social studies, with an emphasis on developing historical

understanding skills and values of national belonging across different educational stages.

3. **Mheidat and Nawafleh (2020)** examined the effect of using the Six-Dimensional Strategy on the academic achievement of eighth-grade female students in science and their attitudes toward this strategy. The sample consisted of 61 students, divided into an experimental group (31 students taught using the strategy) and a control group (30 students taught using the traditional method). The study employed two instruments: an achievement test administered before and after the intervention, and an attitudes scale administered to the experimental group after the intervention. The results indicated a statistically significant difference in students' achievement in favor of the experimental group at the level of the overall test and across the cognitive domains (recall, comprehension, and analysis), while no significant difference was found at the application level. The findings also showed that students' attitudes toward learning using the strategy were high.

All previous studies indicate that the Six-Dimensional Strategy (PDEODE) has a clear and positive impact on the development of critical thinking, concept acquisition, academic achievement, and the enhancement of cognitive and value-based skills among students at various educational stages. Moreover, the use of this strategy contributes to fostering positive attitudes toward learning.

Foreign Studies:

Demircioglu, H. (2017). *The Effect of Activities Developed According to the PDEODE Teaching Strategy on Students' Understanding of the Particulate Nature of Matter* (pp. 27–38).

This study aimed to determine the effect of activities developed in accordance with the PDEODE teaching strategy on students' understanding of the particulate nature of matter. The study sample consisted of first-year students enrolled in a primary teacher education program. To achieve the study's objective, an eight-item test was administered to the sample as a pre-test, post-test, and delayed post-test. The results revealed statistically significant differences among the measurements ($p < 0.05$), indicating that the instructional intervention enhanced conceptual change and improved students' conceptual understanding. Post hoc analysis using the Tukey HSD test showed statistically significant differences between the pre-test and post-test means, as well as between the pre-test and delayed post-test means ($p < 0.05$), while no statistically significant difference was found between the post-test and delayed post-test means ($p > 0.05$).

Keywords: alternative conceptions, conceptual change, particulate nature of matter, PDEODE teaching strategy (Explain–Observe–Discuss–Explain).

Dipalaya, T., & Corebima, A. D. (2016). *The Effect of the PDEODE Learning Strategy (Predict–Discuss–Explain–Observe–Discuss–Explain) across Different Academic Ability Levels on Senior High School Students' Critical Thinking Skills Compared with Traditional Learning* (pp. 59–78). This quasi-experimental study aimed to determine: (1) differences in students' critical thinking skills between PDEODE-based learning and traditional learning; (2) differences in critical thinking skills between students with higher and lower academic abilities; and (3) the effect of the interaction between learning strategy and academic ability on students' critical thinking skills. The research employed a non-equivalent pre-test–post-test control group design. The sample consisted of 40 students from Makassar State Senior High School and Athirah Islamic Senior High School. The study was conducted during the first semester of the 2015–2016 academic year. Data were collected through pre- and post-tests using an essay-based test and were analyzed using ANCOVA. The results indicated that the learning strategy, academic ability, and the interaction between the learning strategy and academic ability had a statistically significant effect on students' critical thinking skills. Specifically, the PDEODE learning strategy improved students' critical thinking skills by 71.43% compared with traditional learning, while higher academic ability contributed to an improvement of 67.03% in critical thinking skills compared with traditional learning.

Discussion of Previous Studies:

1. Most of the reviewed studies examined the impact of the Six-Dimensional Strategy on students across a range of variables.

2. The majority of studies agreed on the importance of the Six-Dimensional Strategy in developing students' thinking skills.

3. Some studies adopted a descriptive research approach, while others employed an experimental design.

4. The present study adopts an experimental research methodology.

5. The present study differs from previous research in its focus on the effectiveness of the Six-Dimensional Strategy (PDEODE) in developing critical thinking skills among secondary school students, whereas earlier studies addressed other educational stages, such as primary and middle school, and focused on different knowledge domains, including rhetorical concepts, historical understanding, and academic achievement in science.

6. The present study benefited from previous research in several respects, including the selection of an appropriate research design and methodology, the choice of the sample and its division into experimental and control groups, the development of measurement instruments and tests aligned with the study objectives, and the application of appropriate statistical analysis methods to evaluate the impact of the strategy with accuracy and objectivity.

Chapter Three
Research Methodology and Procedures

First: Research Methodology

The researcher adopted the experimental method, which is characterized by its ability to control the variables influencing the phenomenon under investigation. This method begins with the identification of a research problem and the search for solutions through the implementation of controlled experiments.

Second: Research Procedures

The research population may be defined as the set of elements that includes all individuals who possess data related to the phenomenon under study. This population constitutes a fundamental basis for understanding and analyzing the research phenomenon (Mansi, 2003, p. 73).

The research population consisted of female secondary school students in schools affiliated with the Dhi Qar Directorate of Education. The research sample comprised 60 second-grade secondary students, divided into two groups (30 students in each group). The first group was subjected to the experimental treatment using the Six-Dimensional Strategy (PDEODE), while the second group was taught using the traditional method. Both groups were equivalent in terms of age and intelligence level. To ensure equivalence between the two groups, the researcher matched them on intelligence using Raven's Progressive Matrices Test, which is a standardized test appropriate for the Iraqi context. Table (1) presents the results.

Table (1): Arithmetic Means, Standard Deviations, and *t*-Value for the Control and Experimental Groups in Intelligence Scores

Group	Mean	Standard Deviation	*t*-value	Significance
Control group	37.8	3.32	0.579	Not significant
Experimental group	36.3	4.80		Not significant

The results presented in Table (1) indicate that there are no statistically significant differences at the significance level (0.05) in the intelligence test, which suggests that the two groups are equivalent with respect to the intelligence variable.

Third: Research Instrument

After reviewing the theoretical literature and drawing on a number of previous studies, as well as examining various critical thinking measures—such as the Watson–Glaser Critical Thinking Appraisal, the Cornell Critical Thinking Test, and the California Critical Thinking Skills Test—the researcher adopted the Qunaʿa (2019) scale. This scale is based on the critical thinking measure developed by Farouk Abd al-Salam, with certain modifications, which in turn was derived from the Watson–Glaser scale. The instrument was selected for its suitability to the objectives and variables of the present study.

The scale consists of five sets of questions designed to measure the following dimensions:

- **First dimension: Recognition of assumptions**, comprising 7 questions, each followed by three proposed assumptions (applicable / not applicable).
- **Second dimension: Interpretation**, comprising 6 questions, each followed by three proposed assumptions (applicable / not applicable).
- **Third dimension: Argumentation**, comprising 6 questions, each followed by three proposed assumptions (strong / weak).
- **Fourth dimension: Deduction**, comprising 7 questions, each followed by three proposed assumptions (true / false).
- **Fifth dimension: Inference**, comprising 5 questions, each followed by six proposed inferences rated on a five-point scale.

Scoring is conducted by awarding one point for each correct response and zero for each incorrect response in the first four dimensions, with scores ranging from 0 to 3 per item. In the fifth dimension, one point is awarded for each correct response, yielding scores ranging from 0 to 5. Responses across the five dimensions are then summed to obtain the total score on the scale.

Content validity was established through agreement among experts regarding the validity of the test content. The researcher further verified the validity of the instrument as follows:

A. Validity and Reliability

To ensure the validity and reliability of the instrument, the researcher administered the scale to a pilot sample consisting of 25 students drawn from outside the main study sample.

Face Validity:

Face validity refers to the overall appearance of the instrument or its external form in terms of the type of items, their wording, and their clarity (Al-Zuhairi, 2017, p. 226). The test was presented to several experienced faculty members to verify the soundness of the linguistic formulation, the clarity of the statements, and the absence of ambiguity. Their observations and suggested modifications were taken into account before approving the instrument for use in the study.

Construct Validity:

The construct validity of the scale depends on the validity of its individual items, as the total score of the scale represents its internal criterion and indicates whether each item measures the same construct assessed by the total score. To examine this relationship, the scale was applied to the pilot sample, and Pearson's correlation coefficients were calculated between each dimension and the total test score, as shown in Table (2).

Table (2): Correlation Coefficients Between the Scale Dimensions and the Total Scale Score

Scale Dimensions	Correlation Coefficient	Sig.
Recognition of Assumptions	0.822**	Significant
Interpretation	0.713**	Significant
Argumentation	0.842**	Significant
Deduction	0.718**	Significant
Inference	0.678*	Significant

**** Significant at (0.01) * Significant at (0.05)**

Table (2) shows that the correlation coefficients of the scale are statistically significant, indicating that the instrument possesses satisfactory construct validity.

B. Reliability of the Scale:

The reliability coefficient was calculated using Cronbach's alpha. The value obtained was 0.873, which is a high coefficient, indicating strong internal consistency of the test and a high level of reliability of the results derived from it.

Chapter Four: Research Findings

To test the null hypothesis—*There are no statistically significant differences at the 0.05 level between the mean scores of students in the experimental group and those of the control group on the critical thinking test after the use of the six-dimensional teaching strategy*—the differences in means and standard deviations of students' scores in the group taught using the strategy and the group taught using traditional methods were examined. An independent-samples *t*-test was conducted to determine the significance of differences in critical thinking skills in the post-test. Table (3) presents the results.

Table (3): Means and Standard Deviations of the Experimental and Control Groups' Scores on the Critical Thinking Scale After the Experiment

Skill	Group	Mean	Standard Deviation	*t* value	Significance
Recognition of Assumptions	Experimental	19.56	0.626	9.632	Significant
	Control	14.23	2.96		
Interpretation	Experimental	15.40	0.813	9.478	Significant
	Control	11.966	1.80		
Argumentation	Experimental	14.833	0.874	20.796	Significant
	Control	9.80	0.99		
Deduction	Experimental	17.70	1.28	16.363	Significant
	Control	11.90	1.47		
Inference	Experimental	19.56	0.935	11.420	Significant
	Control	14.60	2.19		
Total	Experimental	87.100	3.95	14.324	Significant
	Control	62.50	8.53		

Table (3) shows that the mean scores for all critical thinking skills in the experimental group exceeded those of the control group. The experimental group achieved a mean score of 87.100 with a standard deviation of 3.95, whereas the control group obtained a mean score of 62.50 with a standard deviation of 8.53. This indicates the presence of clear differences between the mean scores of the two groups on the critical thinking scale, in favor of the experimental group taught using the Six-Dimensional Strategy (PDEODE), compared with the control group taught using conventional instructional methods.

To further confirm the significance of the differences between the two groups, an independent-samples *t*-test was conducted. The obtained *t* value was 14.324, which is statistically significant at a level of significance less than 0.05, thereby confirming that the differences between the two groups are statistically significant.

To determine the magnitude of the effect of the instructional strategy on critical thinking, Eta coefficient (η) was calculated, as shown in Table (4).

Table (4): Eta Coefficient Values

Eta Coefficient (η)	Eta Squared ($η^2$)
0.883	0.780

As shown in Table (4), the Eta coefficient reached 0.883, with an Eta squared value of 0.780. This value exceeds the benchmark of 0.14, indicating a large effect size. The findings demonstrate that the use of the instructional strategy significantly contributed to the development of critical thinking among the experimental group. An Eta squared value of approximately 0.75 indicates that about 75% of the improvement in the experimental group's acquisition of critical thinking skills can be attributed to the use of the proposed instructional strategy.

Conclusions

- The results of the hypothesis testing revealed statistically significant differences in the mean scores of the experimental and control groups in critical thinking skills, attributable to the use of the PDEODE strategy.

- The presence of significant differences between the control and experimental groups in favor of the experimental group, which received instruction using the PDEODE strategy, can be explained by the fact that students in the experimental group developed the ability to construct knowledge socially. This, in turn, contributed to the enhancement of students' thinking abilities during the instructional process. The PDEODE strategy provided learners with increased opportunities for discussion and interaction, beginning with the elicitation of their prior knowledge and continuing through the review of ideas within small groups and whole-class discussions. Throughout this process, students attempted to resolve conflicts between their prior beliefs and their observations, highlighting the importance of the PDEODE strategy in fostering critical thinking skills among secondary school students.

- These findings are consistent with the results of previous studies, including Mahidat and Nawafleh (2020), which examined the effect of the six-dimensional PDEODE strategy on the achievement of eighth-grade female students in science; Dipalaya and Corebima (2016), which demonstrated the impact of the PDEODE strategy on various academic abilities and students' critical thinking skills at the upper secondary level; and Kahlan (2020), which investigated the effect of the six-dimensional strategy on the acquisition of rhetorical concepts and the development of critical thinking among fifth-grade literary stream students in rhetoric and application.

- The PDEODE strategy created an interactive learning environment that encouraged students to engage in discussion, reflection, and analysis. Its structured steps—prediction, discussion, explanation, observation, discussion, and explanation—helped students activate prior knowledge and challenge misconceptions. Active engagement in the learning process consequently enhanced students' critical thinking skills.

- The PDEODE strategy also provided opportunities for interaction and discussion among students in small groups, facilitating the exchange of diverse viewpoints, the justification of opinions, and the collaborative construction of knowledge.

- The effect size reached 0.883, indicating that the use of the PDEODE strategy had a strong and substantial impact on the development of critical thinking skills among students in the experimental group. This finding confirms the effectiveness of the strategy in enhancing students' abilities in analysis, interpretation, evaluation, and inference.

Second: Recommendations

- Training secondary school teachers to use the six-dimensional PDEODE strategy in teaching various subjects in order to develop students' critical thinking skills.
- Integrating the six-dimensional PDEODE strategy into pre-service and in-service teacher education and training programs.
- Encouraging students' active participation and positive interaction during the implementation of the six-dimensional PDEODE strategy in the classroom.
- Conducting longitudinal studies to examine the impact of the PDEODE strategy on the development of students' critical thinking skills over extended periods of time.
- Providing an appropriate and supportive learning environment for the effective implementation of the six-dimensional PDEODE strategy.

Third: Suggestions for Future Research

- Investigating the effect of using the six-dimensional PDEODE strategy on the development of creative thinking skills among secondary school students.
- Conducting studies similar to the present one on samples drawn from other educational stages, such as the primary or university level.
- Comparing the effectiveness of the six-dimensional PDEODE strategy with other instructional strategies in developing critical thinking skills among secondary school students.
- Examining the effect of using the six-dimensional PDEODE strategy on other variables, such as academic achievement or students' attitudes toward the subject matter.

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