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The effect of the enhanced cluster learning strategy on formal thinking in mathematics among middle school female students

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Abstract

The current research aims to investigate the effect of the enhanced cluster learning strategy on formal thinking in mathematics among middle school female students. To achieve this objective, the experimental method was employed, and the study was conducted during the first semester of the 2024/2025 academic year on a stratified random sample. The sample consisted of 80 second-grade female students from Al-Muruj Al-Khadraa Secondary School, affiliated with the Baghdad Al-Rusafa II Directorate of Education. The sample was divided equally into two groups: 40 students in the experimental group and 40 in the control group. The equivalence of the two groups was verified using an intelligence test and a prior knowledge test.

The researcher employed a post-formal thinking test, which included 20 multiple-choice items. The validity and reliability of the test were confirmed. The students' responses were analyzed using an independent samples t-test. The results indicated that the mean score of the experimental group was 12.90 with a standard deviation of 3.801, while the control group had a mean score of 6.93 with a standard deviation of 3.504. The calculated t-value was 7.310, which is higher than the critical t-value of 2 at a significance level of 0.05 and a degree of freedom of 78.

The result indicates that the experimental group significantly outperformed the control group in the post-test of formal thinking skills. The researcher suggested

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using the improved cluster learning strategy for teaching mathematics to students of all ages, helping them learn formal thinking skills and how to use them, emphasizing methods that build formal thinking, and taking into account the number of students when creating math programs.

Keywords: Enhanced Cluster Learning Strategy, Formal Thinking.

Chapter One:

Research Problem:

The researcher's experience of working within a school setting is that there is a general lack of thinking skills and specifically formal-thought skills in mathematics among middle school female students in the Al-Rusafa II Directorate of Education. This observation is further supported by several studies, including those by Al-Janabi (2018) and Al-Gharawi (2016), which confirmed this weakness. One possible reason for this issue may be the teaching methods currently in use, which are often not aligned with the curriculum content and fail to stimulate students' thinking.

The researcher created a questionnaire and randomly assigned it to ten mathematics teachers with varying degrees of experience to further study this issue. After examining the comments quantitatively, it was discovered that the teachers had little awareness of formal thinking and were unsure whether their students had such thinking abilities. Furthermore, they stated that they did not use the increased cluster learning technique in their teaching.

This emphasizes the need for a new teaching technique in mathematics that may stimulate students' active engagement and develop their general thinking abilities, particularly formal thinking skills, among second-grade middle school female students.The research problem can thus be formulated by the following question:

"What is the effect of using the enhanced cluster learning strategy on formal thinking in mathematics among middle school female students?"

Significance of the Research:

Despite their importance, academic curricula are insufficient for attaining educational goals unless accompanied by a real commitment to establish a learning environment that stimulates creativity and innovation. This responsibility falls mostly on teachers, who are regarded as the foundation of the educational process. Their personal characteristics, verbal expressions, emotional responses, and the modern teaching methods they use are all important aspects of the effectiveness of the learning experience. (Al-Mabrouk, 2013. 55).

The teaching method is considered a critical component in providing curriculum knowledge to students because it turns the educational institution's theoretical aims and standards into tangible, observable behaviors (Al-Sayfi, 2013, p. 63). It eliminates monotony and apathy and promotes ongoing contact between teacher and student, making it an important component of the learning process. (Al-Jubaili, 2013. 89).

The cluster umbrella strategy is one such teaching approach that exposes the subject matter from numerous angles by providing a broad question that leads to several sub-questions. These sub-questions help students understand the ultimate answer to the main question. As such, this technique stimulates discussion and dialogue and allows students to seek varied answers, establishing an environment rich in creative thinking. (Al-Ajras, 2013, p. 112).

Formal thinking skills are mental activities inherent to human cognition, enabling individuals to generate solutions, identify successful alternatives, and develop a sensitivity to recognizing gaps and generating fluent ideas (Qatami, 1990. 45). For this reason, formal thinking has gained significant importance in the programs and goals of educational organizations at all academic levels (Al-Atoum, 2013. 60).

And among the various types of thinking that have received significant attention in research and studies is formal thinking, which Piaget considered one of the highest stages of cognitive development. At this stage, the individual reaches the peak of cognitive structure maturity, becoming capable of logical reasoning, solving verbal problems, and deducing possible solutions to problems by employing deductive reasoning (Hormuz & Ibrahim, 1988. 109).

So, it's vital to teach students how to think, learn, remember, and apply knowledge to solve problems. In recent decades, there has been a growing need for standardized tests of formal thinking to be used in both high-level and low-level research, as well as in practical applications for diagnosing individuals' capacity for formal thinking.

The Significance of the Research Lies in the Following Aspects:

1. The enhanced cluster learning strategy may assist mathematics teachers in fostering a spirit of collaboration and leadership, as well as in utilizing the unique abilities of learners—contributing to the development of their formal thinking skills.
2. The importance of the middle school stage lies in its role as a critical educational phase that prepares students psychologically, cognitively, and socially to continue their education. It serves as a foundational stage for future academic progress.
3. The formal thinking test developed by the researcher can be utilized by mathematics teachers as a tool to help students correctly solve hypothetical or verbal problems.
4. The research provides valuable insights for curriculum developers regarding the importance of incorporating this type of thinking into mathematics textbooks.

Research Objective:

The aim of the research is to examine the impact of the improved cluster learning strategy on formal mathematical reasoning in middle school female students.

Research Hypotheses:

To attain the research objective, the investigator postulated a null hypothesis as follows:

- No sufficient difference exists between the mean scores of the experimental group students meant to study mathematics to be learned.
- The improved cluster learning model and control group students studying the same topic in a traditional manner on the post-test of formal thinking prepared for the purpose.

Research Limits:

1. The study involved a sample of second-grade middle school female students from public secondary schools, who were under the supervision of the Baghdad Al-Rusafa II Directorate of Education.
2. The first semester of the 2024–2025 academic year.
3. The first part of the mathematics textbook for second-grade middle school.

Definition of Terms:

- **Enhanced Cluster Learning Strategy:**

This strategy aims to address classrooms with elevated student density by modifying conventional cooperative learning techniques. The technique categorizes pupils into theoretical clusters based on columns, rows, or groups of individuals who possess a conceptual or contextual affiliation, eliminating the need for physical movement from their seats. Students operate under the teacher's direction and the oversight of a selected leader, who is equipped to support and help peers while cultivating the emergence of further leaders within the group. The learning process advances incrementally from basic to complex concepts and skills, according to the principle "success leads to further success." The educational process originates with the instructor, subsequently progresses to the class leaders, and ultimately encompasses all pupils within the classroom. (Mehrazi, 2017).

- **Operational Definition:**

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It is an approach intended for high-density classrooms that consists of cohesive and interconnected questions that cover the topic by introducing a general query, followed by a sequence of sequential questions that lead to an answer. The technique consists of five distinct phases: preparation, first-level learning, second-level learning, third-level learning, and evaluation.

- **Formal Thinking:**

Formal thinking refers to the ability to process abstract elements, such as ideas, symbols, relationships, concepts, and principles, more efficiently than concrete sensory things or physical equipment. (Melhem, 2009. 286).

- **Operational Definition of Formal Thinking (as Defined by the Researcher):**

It is a way of thinking that is based on the meanings of objects and their related words and numbers, rather than their physical forms or mental representations. The study measures students' performance on formal thinking Sub-tests designed expressly for this purpose.

Chapter Two: Theoretical Background and Previous Studies

In classrooms with high student density, Mehrazi (2017) proposed the Cluster Learning Strategy as one of the active learning strategies. This strategy addresses the challenges faced by teachers in such environments, including the increasing number of students, limited instructional time, and dense curriculum content. It is presented as an alternative to the traditional lecture-based approach, which becomes difficult to implement effectively in overcrowded classrooms.

The strategy aims to achieve effective learning outcomes, particularly in mathematics instruction, within such contexts—surpassing those typically associated with lecture-based teaching, which often yields poor results in general and especially in high-density classrooms. Moreover, this strategy is adaptable to various educational environments and may even be more flexible, beneficial, and engaging in ideal classroom settings (Mehrazi, 2017. 15).

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Pathways Implemented by the Cluster Learning Strategy:

This strategy is built upon integrated pathways designed to overcome the challenges posed by high student density and to ensure the optimal use of space and time. These pathways include the following:

1. Gradual progression in lesson content.
2. Developing and utilizing student leaders, with a gradual increase in their number.
3. Striving to reach all students within a high-density classroom to achieve broader and more effective learning outcomes. (Mehrazi, 2017)

Foundations of the Enhanced Cluster Learning Strategy:

1. The learning process is primarily the responsibility of the student, with the support of the teacher.
2. Success leads to further success.
3. Integration of self-directed learning and cooperative learning to develop the learner’s abilities to the fullest and to maximize peer support.
4. High student density in classrooms is a real challenge, but it can be overcome.
5. The learning process is gradual: it begins with the teacher, is led by outstanding students, and benefits all learners.
6. A variety of individual and group assessment methods are used, along with timely feedback.
7. Fostering a spirit of cooperation, camaraderie, and enjoyment during lessons.
8. Promoting collaboration and a sense of belonging among students. (Mehrazi, 2017. 16–17)

Rationale for the Enhanced Cluster Learning Strategy:

1. Assisting students in practicing group work despite the challenges of high student density and limited instructional time.
2. Providing an alternative to the traditional lecture-based method commonly used by teachers in overcrowded classrooms.
3. In high-density classrooms, opportunities for supporting low-achieving students are limited; this strategy offers them greater chances to learn and participate.
4. In such classrooms, this strategy also enhances the opportunities to develop the abilities and creativity of high-achieving students.
5. Managing cooperative learning in overcrowded classrooms requires significant skill, effort, and time—resources that many mathematics teachers may lack. This strategy offers a practical solution and a foundation for teachers to improve and develop their classroom practices. (Al-Kahlan & Mehrazi, 2020. 423)

The Significance of the Enhanced Cluster Learning Strategy:

- The strategy relies on activating the role of student leaders in the classroom, which contributes to the development of their academic, leadership, and life skills.
- It provides feedback, assistance, and support to students with low and average academic performance through the guidance of classroom leaders, granting them the opportunity to gradually improve their academic abilities and address accumulated gaps in foundational knowledge.
- The strategy helps motivate average-performing students to become future leaders, thereby increasing the number of high achievers over time.
- It offers a logical sequence for presenting lesson content, progressing from simple to complex concepts, which enhances learners' motivation and engagement.
- The use of a learning and assessment model contributes to continuously engaging students with the content both during and beyond the classroom session.

- It provides high-achieving students with the opportunity to express creativity and demonstrate their academic and leadership skills, preparing them for future leadership roles.
- The strategy adopts the principle of “success leads to more success”—one of its core foundations—allowing students to experience the joy of achievement in the subject, thereby increasing their motivation to learn and enjoy the lessons.
- The strategy facilitates assigning differentiated homework based on students’ levels and abilities, ensuring inclusivity for all learning groups. Moreover, the structured and progressive cooperative work between students and leaders contributes to reducing the time required for grading. (Al-Kahlan & Mehrazi, 2020. 424)

Steps of the Developed Cluster Learning Strategy:

1. Preparation: The teacher begins by preparing for the lesson and presenting the key concepts, as is customary in any class session, while also reviewing previously learned material.
2. First-Level Learning Phase: The teacher then introduces the main idea of the lesson and explains to the students that the cluster learning strategy will be used during the class.
3. The teacher carefully and clearly explains the lesson and demonstrates the main concept on the board, ensuring clarity and focus.
4. Based on the example solved by the teacher, the cluster learning process begins. The teacher provides students with sufficient time to focus on the steps, explains any ambiguities, and ensures that all points are well understood.
5. The self-paced and gradual learning phase begins, during which the teacher checks initial responses and asks students to complete the task individually within a specified time frame.
6. The teacher reinforces and praises students who complete the task within the initial minutes and appoints them as mobile leaders. If no student completes the task, the teacher revisits and re-explains the concept to ensure understanding.

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7. The appointed leaders begin transferring their knowledge to their peers, with each leader responsible for a column of students. To save time and effort, multiple leaders divide the column among themselves.
8. Each leader moves through their assigned column, assisting each student individually by providing clarification without directly solving the task for them. After correcting all answers, the students turn in their work to the teacher within the allotted time.
9. (Second-Level Learning Phase): After completing the first question, the teacher presents another example that is closely related to the concept of the first one, following the same previously outlined steps.
10. **(**Third-Level Learning Phase): At the end of the lesson, the teacher assigns a homework problem related to each concept from the textbook. These problems are of a higher difficulty level than the previous examples and are carefully selected. You can skip this step if time is not available.
11. (Assessment Phase): At the end of the lesson, the teacher assigns an exercise for each concept as homework, in addition to another high-level optional task aimed at assessing higher-order thinking skills. Students first review and correct each other's responses with their leaders' guidance before submitting them to the teacher for evaluation.

Thus, the learning process is structured into three levels—ranging from simple to complex—preceded by preparation and followed by assessment. (Meharzi, 2017. 19–21)

Formal Thinking:

Formal thinking represents the highest stage of cognitive development, according to Piaget. In the formal operational stage, individuals reach the peak of cognitive structure development. At this stage, they can engage in logical reasoning in all its forms, solving hypothetical problems systematically, as well as tackling verbal

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problems. They can deduce all possible solutions to a given problem by employing deductive reasoning. (Hirmiz & Ibrahim, 1988. 109)

Formal thinking is considered one of the most critical types of thought in students' lives. It plays a vital role in knowledge acquisition, problem-solving, and decision-making. (Saeed, 1999. 1)

During this stage, individuals possess the ability to hypothesize, test their assumptions, and choose between alternatives based on symbolic and abstract reasoning rather than concrete materials. They are also capable of organizing, investigating, reasoning, analyzing, inductive thinking, and making careful observations to reach generalizations and fundamental concepts for problem-solving. (Abu Huwaij & Abu Al-Mughli, 2004. 132)

Piaget's Stages of Cognitive Development:

Piaget argued that mental development follows a constant and sequential framework, with each stage culminating in a definite point that serves as the foundation for the next. These stages are interrelated and overlap with one another.

According to Piaget's theory, children go through four stages of cognitive development. The gradual organization of mental functions distinguishes each stage and lays the groundwork for the subsequent stage's development.

The four stages of cognitive development**,** according to Piaget, which can be distinguished from each other, are as follows:

1. **Sensorimotor Stage (0–2 years):**
   In this stage, the child learns about the world primarily through sensory experiences and motor activities. Understanding of object permanence begins to develop by the end of this stage.

2. **Preoperational Stage (2–7 years):**
   This stage is characterized by symbolic thinking, egocentrism, and limited logical reasoning. Children in this stage can use words and images to represent objects but lack the ability to perform operations or reversible mental processes.
3. **Concrete Operational Stage (7–11 years):**
   At this stage, children develop logical thinking about concrete objects and events. They become capable of performing operations like classification, seriation, and conservation, but their reasoning is still tied to tangible and real-world situations.
4. **Formal Operational Stage (11–15 years):**
   This stage marks the emergence of abstract and formal reasoning Adolescents can now think hypothetically, deduce consequences, test hypotheses, and engage in systematic problem-solving. (Abu Zeina, 2010. 143–145)

Characteristics of Formal Thinking:

1. Formal thinking primarily relies on hypothetico-deductive reasoning.
2. It reflects the ability to engage with events through logical and synthetic operations.
3. Individuals exhibit growth in abstract thinking abilities.
4. The individual becomes more independent in thought, no longer constrained by external factors.
5. Thought processes are increasingly based on hypothetical reasoning, particularly following an "if...then..." structure.
6. The individual becomes capable of isolating variables that may influence a situation, a crucial skill in scientific fields.

At the formal operational stage, individuals can solve problems involving ratios and proportions and understand geometrical problems. (Abu Jado, 2000. 112)

Formal Thinking Skills:

Formal thinking skills are closely related to advanced thinking since they are critical in determining an individual's cognitive level in a variety of areas of life, including cognitive, social, emotional, and motor domains. Research and studies reveal a quick rise in intelligence throughout the period of abstract formal thinking. Individuals tend to exhibit general cognitive talents. (Ibrahim, 2005. 352)

According to **Al-Najdi et al. (1999)**, formal thinking skills include the following:

- Conservation.
- Controlling variables.
- Cognitive exchange.
- Measurement.
- Hypothetico-deductive reasoning.
- Thinking through propositions.
- Proportional reasoning.
- Correlation.
- Probability.
- Abstract inference.
- Theoretical reasoning.
- Hierarchical classification.

(Al-Najdi et al., 1999. 254)

Zaytoun (2007) asserts that formal thinking skills encompass making inferences based on evidence, managing diverse variables, employing logical reasoning, comprehending Relationships, engaging with probabilities, identifying connections, and categorizing items by various attributes. (Zaytoun, 2007. 181).

Based on the above, several classifications of formal thinking skills have been proposed. However, the classification adopted in this study is that of (Piaget & Inhelder, 1958. 12), which includes the following:

1. **Hypothetical (Deductive) Reasoning:**

   According to Abu Zayneh (2011), deduction and inference are considered synonymous terms, both referring to the process of moving from a general rule or principle to specific cases. Typically, the premise is a generalization or a mathematical law. (Abu Zayneh, 2011. 30)

2. **Proportional Reasoning:**

   Piaget asserts that mathematical proportionality involves the equality between two quantities; however, this type of reasoning does not emerge until the formal operational stage. It is difficult for people in the concrete operational stage because understanding logical proportionality requires a complete understanding of how different relationships and groups work within a number system. (Piaget & Inhelder, 1958. 314–315)

   It represents a form of mathematical reasoning that involves establishing a relationship between two relations, rather than between two tangible objects. This cannot be accomplished at the concrete level, as it requires second-order operations that characterize formal operational thinking. (Balah, 2007. 40)

3. **Combinatorial Reasoning:**

   It refers to the process of combining various elements to produce new outcomes, whether material, intellectual, or conceptual. (Qatami, 2001. 75)

4. **The Skill of Identifying and Controlling Variables:**

   This process involves isolating the factors that influence a particular phenomenon by fixing all variables except one and observing its effect. Then, other variables are tested one by one to determine the factor responsible for the observed change. This skill is essential for conducting scientific experimentation, as it enables learners to study the effect of the independent variable on the dependent variable. This is achieved through the identification, control, and isolation of variables and the manipulation of one of them to determine its effect and efficiency. As a result, the outcomes of the experiment become more logical, valid, and accurate. (Habib, 1996. 83)

5. **Correlational Reasoning:**
   It refers to the notion that if certain events or variables occur, they will inevitably be followed by the occurrence of other events. In other words, there is a cause-and-effect relationship between two events — one being the cause and the other result. (Al-Jarjari, 2003. 140)
6. **Probabilistic Reasoning:**
   It is the ability to analyze quantitative relationships, determine their respective proportions, compare them, and assign specific probabilities. This type of reasoning is similar to deductive reasoning in that it aims to reach a fundamental rule or principle based on general information. (Al-Khalili, 1996. 133)
7. **Proposing Solutions:**
   It's referring to the effort exerted by students to generate alternatives that may enhance the effectiveness of their thinking, promote the creation of new ideas, and encourage students to freely express and discuss their thoughts. (Al-Jarjari, 2003. 145)
8. **Problem Solving:**
   Problem solving encompasses various levels of cognitive development for students, beginning with the formation of concepts, generalizations, and skills, and culminating in the ability to solve problems. Most mathematics curricula have emphasized problem -solving as a key approach, and mathematics educators have recommended that it be the central focus and core of mathematics instruction. (*Salama, 1995. 282*)

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According to Rabea (2008), problem -solving is defined as a cognitive process in which an individual utilizes all prior and acquired knowledge and skills to respond to an unfamiliar situation. (*Rabea, 2008. 382*)

This study focused on five main skills: hypothetico-deductive reasoning (which includes deductive and inferential reasoning), proportional reasoning, combinatorial reasoning, the ability to identify and control variables, and correlational reasoning.

Previous Studies

First: Studies Addressing the Developed Cluster Learning Strategy:

1. **Al-Husseini (2016):**
   This study aimed to identify the impact of the *Cluster Umbrella Strategy* on students' achievement in geography and their attitudes toward it among second-grade intermediate female students. The sample consisted of 60 students, and the researcher employed an achievement test and an attitude scale. The results indicated statistically significant differences in favor of the experimental group in both the achievement test and the post-attitude scale.
2. **Al-Kaabi and Al-Haidari (2018):**
   This study aimed to examine the effectiveness of the *Cluster Umbrella Strategy* in developing creative thinking among first-grade intermediate female students in science. The sample included 60 students, and a creative thinking test was utilized. The findings showed statistically significant differences in favor of the experimental group in the post-test of creative thinking.
3. **Kahlan and Mehrazi (2020)**:
   The study sought to investigate the effect of using the Developed Cluster Learning Strategy in teaching mathematics in overcrowded classrooms on academic achievement and students' attitudes toward mathematics at the intermediate level. The sample included 80 students, and both an academic achievement test and a mathematics attitude scale were administered. Results

showed statistically significant differences in favor of the experimental group in both achievement and attitudes toward mathematics.

Second: Studies Addressing Formal Thinking:

1. **Al-Mawla (2011):**
   This study aimed to examine the effect of a proposed strategy supported by *guided imagery* in solving mathematical problems on the academic achievement and the development of formal thinking among fifth-grade science students. The sample consisted of 70 students, and two tests were used: one for academic achievement and another for formal thinking. The results revealed statistically significant differences in favor of the experimental group in both the achievement test and the overall formal thinking test. Additionally, there were significant differences in most formal thinking skills except for deduction, synthesis, and correlation skills.
2. **Al-Shaibawi (2016):**
   This study aimed to investigate the effect of an instructional design based on *divergent thinking strategies* on the academic achievement and formal thinking of preparatory stage students in physics. The sample consisted of 74 students. Two tests were employed: one for academic achievement and another for formal thinking. The results revealed statistically significant differences in favor of the experimental group in both the achievement and the post-formal thinking tests.
3. **Al-Janabi (2018):**
   The study aimed to explore the impact of the *Cube Strategy* on academic achievement and formal thinking among first-grade intermediate female students in mathematics. The sample included 64 students, and both an achievement test and a formal thinking test were used. The findings indicated statistically significant differences in favor of the experimental group in both the achievement and the post-formal thinking tests.

Chapter Three: Research Methodology and Procedures

This chapter provides a detailed description of the procedures followed by the researcher in conducting this study, including the research methodology, the population and sample, the instruments used, and the statistical treatments applied to analyze the data.

1. Research Methodology: The researcher adopted the experimental method in this study, as it is well-suited to the nature and objectives of the research. The experimental method is considered one of the most accurate in scientific research, as it allows for control over variables and enables the direct examination of the effect of the independent variable on the dependent variable.

2. Experimental Design: The study employed a post-test- only control group design, consisting of two groups (experimental and control). This design was used to measure the effect of the independent variable (the Enhanced cluster learning strategy) on the dependent variable (formal thinking). Table (1) presents the general structure of the experimental design used in this study:

Table (1): Experimental Design

The Group	Equivalence	The independent variable	The dependent variable
Experimental	Intelligence previous knowledge	Enhanced Cluster Learning Strategy	Formal Thinking
Control		The usual method	

3. Research Population: The research population consists of all second-grade intermediate (middle school) female students in public schools under the Directorate of Education of Rusafa Second District during the first semester of the academic year 2024–2025. According to official records from the Directorate, the total number of students was 12,343.

4. Research Sample: This study was applied to a random sample of second-grade intermediate female students from Al-Murouj Al-Khadraa Secondary School for

Girls. The sample consisted of 80 students, distributed equally into two groups: 40 students in the experimental group and 40 students in the control group.

5. Control Procedures: The researcher ensured the equivalence of the two groups in terms of certain extraneous variables that might influence the dependent variable apart from the independent variable. Equivalence was established using the Danleys (1986) IQ test and a prior knowledge test in mathematics related to the instructional material under investigation. The results showed no statistically significant differences between the two groups at a significance level of 0.05 with 78 degrees of freedom, as shown in Table (2)

Table (2): Control Procedures

The group	Experimental		Control		T value	
Equivalence variables	Arithmetic mean	Standard deviation	Arithmetic mean	Standard deviation	Calculated	Table
Intelligence	**15.70**	**4.24**	**14.33**	**6.30**	**0.89**	**2**
previous knowledge	**8.79**	**2.12**	**8.57**	**1.82**	**0.422**	**2**

6. Research Instrument: A test of formal thinking was developed as follows:

- **Purpose of the Test:** The test aims to measure the level of formal thinking skills among middle school female students in both the experimental and control groups through their responses to the items specifically designed for this purpose.
- **Test Item Development:** A total of 20 multiple-choice items were developed, encompassing various formal thinking skills.
- **Test Validity:** The validity of the test was verified by presenting it to a panel of experts from Al-Mustansiriyah University, along with several experienced mathematics teachers. Based on their feedback, the researcher made several modifications to the initial version of the test. Consequently, the test was deemed ready for the pilot study.

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- **Pilot Study of the Test:** The test was administered to a pilot sample of 35 second-grade middle school female students who were not part of the main research sample. The aim was to ensure the clarity of the test instructions, determine their reliability and validity, and estimate the appropriate time required for completion, which was found to be 30 minutes.
- **Test Reliability:** Cronbach's alpha coefficient was used to determine the reliability of the test by administering it to the pilot sample. The reliability coefficient was found to be 0.86 at the 0.05 level of significance.
- **Internal Consistency Validity:** Internal consistency validity refers to calculating the correlation coefficients between each item score and the total score of the spatial visual perception test. Using the point-biserial correlation coefficient, the researcher calculated the correlation values for each item with the total test score, which ranged between 0.30 - 0.41, All items showed statistically significant correlations at the 0.05 level, indicating a high level of test validity.
- **Final Administration of the Test:** The final version of the test was administered on Tuesday, January 7, 2025. The test was completed by the sample participants under the supervision of the researcher. The test was scored based on multiple-choice answers, and the scores were recorded, tabulated, and then statistically analyzed.
- **Statistical Methods Used:** After completing the scoring and recording of test results, the data were statistically analyzed using the Statistical Package for the Social Sciences (SPSS).

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Chapter Four:

1. Presentation and Discussion of Research Findings

Identifying the Impact of Using the Modified Cluster Learning Strategy on Formal Thinking in Mathematics among High School Female Students.

The analysis of the students' responses using the independent samples t-test (Table 3) revealed that the mean score of the experimental group was 12.90 with a standard deviation of 3.801, while the mean score of the control group was 6.93 with a standard deviation of 3.504. The calculated t-value was 7.310, which is greater than the tabulated t-value of 2 at a significance level of 0.05 and a degree of freedom of 78.

This result indicates a statistically significant difference in favor of the experimental group, demonstrating that the students who were taught using the modified cluster learning strategy outperformed their peers in the control group on the post-test measuring formal thinking skills.

Table (3): Results of the Independent Samples T-Test for the Formal Thinking Test

The group	Sample size	Arithmetic mean	Standard deviation	Freedom degree	T value	
					Calculated	Table
Experimental	40	12.90	3.801	78	7.310	2
Control	40	6.93	3.504			

Table (4): Response Rate of the Research Sample to Formal Thinking Skills

No.	Skill	Response rate	Ratio
1	Hypothetico-deductive reasoning (deductive and inferential reasoning)	20	0.2
2	proportional reasoning	30	0.3
3	combinatorial reasoning	15	0.15
4	ability to identify and control variables	25	0.25
5	correlational reasoning	10	0.1

2. Recommendations

In light of the research findings, the researcher recommends the following:

- Utilizing the developed cluster learning strategy in teaching mathematics across different age groups.
- Training students in formal thinking skills, focusing on how to apply them, and emphasizing methods and strategies that foster the development of formal thinking.
- Taking classroom density into account when designing the mathematics curriculum.

3. Suggestions

- Conducting further studies similar to the current research on different samples and then comparing their results with those of the present study.
- Carrying out studies that examine the developed cluster learning strategy in relation to other dependent variables, such as mathematical intuition.
- Integrating the developed cluster learning strategy with artificial intelligence in the teaching of mathematics.

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