Effectiveness of the CORE Learning Model: A Case Study of Learning the Method of Coordinates in a Plane in Vietnam

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Abstract: Coordinate geometry is an important part of mathematics. It helps students develop thinking, logic, and problem-solving skills. This study was conducted to test the effectiveness of the CORE learning model in promoting students' mathematical problem-solving skills when they learn the method of coordinates in a plane. Consequently, this study used mixed methods as a quasi-experiment with a non-equivalent control group design, with assessment tools including pre-test, post-test, classroom observation, and attitude survey. The data collected were quantitatively analyzed with JASP and qualitatively analyzed. The analysis findings demonstrate that the students in the experimental group performed better academically in terms of knowledge and problem-solving skills and had more optimistic learning attitudes. In particular, a correlation test was performed on the pre-and post-test scores of the experimental group. It showed that with a correlation level of 0.810, according to the Hopkins reference table, the scores of the students in the experimental group were higher than those of the control group due to the effectiveness of the CORE learning model in promoting students' problem-solving abilities. In addition, the study identified certain limitations and proposed new research directions for the future.

Keywords: CORE learning model, Mathematical problem-solving skills, Mathematics learning outcome, Method of coordinates in a plane

INTRODUCTION

CORE stands for four words with unifying functions in the learning process, including connecting, organizing, reflecting, and extending. These phases connect old and new information, organize diverse material, reflect on everything students learn, and develop a learning environment. Yaniawati et al. (2019) argue that CORE is one of the learning models based on constructivist theory, which states that students can construct their knowledge by interacting with their environment.

According to Calfee (2010), the CORE learning model involves discussion techniques that can impact students' knowledge acquisition and ability to think critically by keeping them interested. The CORE model expects students to be able to construct their knowledge by connecting and organizing new knowledge with old knowledge, then rethinking the concept being learned, and students are expected to expand knowledge in the learning process. Many studies show the diverse application of this model in many domains of mathematical knowledge, such as conics (Salinas & Pulido, 2016), computational methods course (Khor et al., 2020), and trigonometric material (Yaniawati et al., 2019). From this, this learning model contributes to increasing aspects such as problem-solving (Arizal et al., 2018; Irawan & Iasha, 2021; Son et al., 2020), mathematical communication and connection (Yaniawati et al., 2019), mathematical reasoning ability (Atiyah & Priatna, 2023), and creative thinking (Ardiyanto et al., 2022; Saregar et al., 2021).
The ability to solve mathematical problems plays an important role in mathematics education and is studied by many educators (Alabdulaziz, 2022; Arizal et al., 2018; Gunawan et al., 2023; Jacinto & Carreira, 2023; Putri et al., 2022; Rocha et al., 2024). At the same time, students' mathematical problem-solving skills could be enhanced by applying instructional approaches. Still, little research has been done on applying the CORE learning model in math instruction to improve students' problem-solving skills in Vietnam. For these reasons, the study investigated the effectiveness of the CORE learning model in teaching the method of coordinates in a plane to promote students' problem-solving skills.

LITERATURE REVIEW

CORE learning model

Many researchers use the CORE learning model as an instructional approach in mathematics education. Irawan and Iasha (2021) aimed to improve the mathematical problem-solving abilities of elementary school students using this model. Wiharso and Susilawati's (2020) study as a quasi-experiment aimed to compare the results of students taught with the CORE model and students taught in a traditional learning style. Meanwhile, Saregar et al. (2021) conducted a study on 60 eighth-grade students in a high school using a purpose-sampling technique. The results of this study have proven that the CORE learning model effectively enriches students' creative thinking skills. So, what phases does this model include? What role does each phase play?

The CORE model includes four cyclical phases: connecting, organizing, reflecting, and extending. At each phase, students are directly involved in thinking and acting and are trained in listening, speaking, reading, writing, teamwork, and skills such as purposive observation, thinking, comparison, analysis, synthesis, practical skills, evaluation, and self-assessment.

During the "Connecting" phase, teachers can introduce issues related to the new lesson to attract students' attention to the content, making students realize the need and desire to research and explore new content. Teachers can ask questions or have students discuss in groups to help students recall or activate knowledge that students previously knew related to new content. When asking students to discuss what they already know, teachers can find out how much each student knows and identify any misconceptions they may have about mathematics that need to be cleared up. In the "Organizing" phase, students arrange and organize the ideas they had in the previous phase in their way, such as mind maps, charts, and tables. Therefore, learners must be active, proactive, and creative. If the learners are not active, proactive, and creative, no teacher can help them master the lesson content. The above activities will help students appropriately use the available knowledge to create discovery ideas based on guiding questions and adjusting teacher actions for students instead of answers. With this activity, students will synthesize the knowledge they have learned through problem-solving and critical thinking. In addition, in this phase, students are in the center, and teachers play a consulting role, guiding students in arranging and organizing their ideas to solve problems.

In the "Reflecting" phase, the students contemplate and reflect on the products they made in Phase 2. The teacher has the role of concluding and correcting scientific knowledge. The aim is to improve knowledge about possible misunderstandings and consolidate knowledge. In the "Extending" phase, students apply the knowledge they have just acquired with the existing knowledge base to expand and condense their understanding through new experiences to deepen their knowledge, become more skillful, and know how to apply it to different situations and circumstances, especially practical situations. Teachers act as advisors to help students summarize key content, deepen lessons, and create opportunities for students to expand their knowledge.

Regarding the advantages of the CORE model, the "Connecting" phase helps students focus and pay more attention to the lesson because they feel interested and excited compared to approaching the lesson with traditional teaching methods. The "Organizing" phase helps students have many opportunities to exchange and discuss with each other so that they can express their thoughts and approach the problem through many different perspectives from the opinions of other students. In the group, students summarize the whole problem. Mastering all the activities during this phase helps keep the classroom atmosphere exciting and not boring and increases the student's ability to acquire knowledge. Teachers' lesson preparation becomes simpler and more systematic, helping to create diverse activities for students to experience. This process helps teachers reduce the time spent teaching theory and instead create discovery and practice activities to form new knowledge. This is in line with the current educational trend, which is student-centered.

Regarding the limitations when applying the CORE model in teaching, the "Organizing" and "Reflecting" phases require students to have certain learning abilities and efforts. Arranging and organizing their ideas in the "Connecting" phase or giving feedback on the products they made in Phase 2 is difficult for all students. If the student does not pass that, the results of these phases are limited, or the student does not complete the learning task. Many students can use group activities to work individually and influence their environment. When teachers spend too much time on each phase, it will more or less cause boredom for students, and the CORE model will no longer be effective.

Problem-solving skills

Problem-solving skills are essential in mathematics and everyday life. One can easily solve any problem by having various problem-solving skills. When studying mathematics, students learn abstract concepts and make real-world connections between those concepts and their applications in everyday life. Through this learning, students can understand how to apply mathematics in real-life contexts and develop problem-solving skills. These skills are one of the aspects taught in mathematics.

Polya explains the four main phases of problem-solving: understanding the problem, planning the solution, executing the plan, and checking the results (as cited in Daulay & Ruhaimah, 2019). On the other hand, Polya's approach describes general problem-solving steps and is not limited to mathematical problems. Students' ability to solve mathematical problems includes readiness, creativity, knowledge, skills, and application in everyday life. These skills also have a close relationship with other factors such as written feedback (Santos & Barbosa, 2023), creative thinking (Saregar et al., 2021), ability to mathematical connections (Sari & Karyati, 2020), students' problem-solving beliefs in mathematics (Sintema & Jita, 2022), and student cognitive styles (Son et al., 2020). Many educational approaches have been used to enhance students' mathematical problem-solving skills, such as learning devices with CORE models (Arizal et al., 2018) and digital subtraction games (Erbilgin & Macur, 2022), the use of effective learning media (Gunawan et al., 2023), the CORE learning model (Irawan & Iasha, 2021; Son et al., 2020), technology (Jacinto & Carreira, 2023), realistic mathematics education (Putri et al. al. 2022), and GeoGebra (Suratno & Waliyanti, 2023).

Teaching the method of coordinates in a plane

In the research work "Teaching math solutions on the topic of the method of coordinates in a plane for high school students", the author Hoa (2017) provided a theoretical basis for the history of the formation of the method of coordinates, mathematical ability, factors affecting students' math solving skills, and pedagogical measures to foster math-solving ability in teaching math problem-solving on the method of coordinates in a plane for high school students. The illustrative examples refer only to two objects: a straight line and a circle. In the research work "Teaching the topic of three conic sections in the high school program towards competency development", the author Bang (2019) has provided a theoretical basis for mathematical competencies; the competencies are formed through specialized teaching about three conics, historical development of three conics in mathematics, teaching theorems, properties, solving exercises about three conics in the direction of capacity development; Develop specific lesson plans on teaching three conics.

In the research "Developing problem-solving skills for students in teaching the content of the method of coordinates in a plane", the author Cuong (2018) has provided a theoretical basis and discusses the relationship between problem-solving skills in mathematics and the mathematical competencies of high school students and some pedagogical measures to develop problem-solving competencies for students in teaching math subjects, such as straight lines, circles, and ellipses. In his research, the author applied information technology to teaching three conics. The authors have created a digital environment to help students interact and understand each quadratic curve's nature, shape, and equation, such as circle, ellipse, hyperbola, and parabola (Salinas, 2017).

However, there is no research on applying the CORE learning model to teaching the method of coordinates in a plane to promote mathematical problem-solving skills for 10th-grade students.

Research Objectives and Questions

The purpose of the study was to evaluate the effectiveness of employing the CORE learning model in the context of teaching the method of coordinates in a plane. Therefore, this research was conducted to answer the following questions:

(1) Is there a significant difference in learning outcomes between students instructed by the CORE learning model (experimental group) and students taught using conventional methods (control group)?

(2) Are the students' learning outcomes in the experimental group significantly different before and after the intervention?

(3) Is there any improvement in students' math problem-solving skills with the CORE learning model?

(4) What is the attitude of the students in the experimental group toward learning with the CORE learning model?

The Study's Context

The method of coordinates in a plane was the research subject for grade 10 students in the Vietnam General Education Program. The requirements and course content for studying this subject are described in detail in the General Education Program in Mathematics (2018). In terms of instructional content, the textbook's 10-th-grade program's method of coordinates in a plane topic covers the following topics: (1) Vector coordinates; (2) Straight lines in the coordinate plane and applications; (3) circle in the coordinate plane and applications; and (4) three conics in the coordinate plane and applications (MoET, 2018). In terms of the prerequisites that must be fulfilled, students must: (1) Recognize the coordinates of vectors with respect to a coordinate system; find the coordinates of a vector, the length of a vector when knowing the coordinates of its two endpoints; Use coordinate expressions of vector operations in calculations; Apply knowledge of vector coordinates to solve a number of practical problems; (2) Describe the general equation and parametric equation of a straight line in the coordinate plane; explain the relationship between the graph of a first-order function and a straight line in the coordinate plane; Identify two lines that intersect, are parallel, coincident, or perpendicular to each other using the coordinate method; Establish the formula for calculating the angle formed by two straight lines; Calculate the distance from a point to a straight line using coordinates; Apply knowledge of straight line equations to solve a number of practical problems; (3) Establish the equation of a circle when knowing the coordinates of the center and radius; know the coordinates of the three points that the circle passes through; Determine the center and radius of the circle when knowing the equation of the circle; Establish the equation of the tangent to the circle when knowing the coordinates of the point of contact; Apply knowledge of circle equations to solve a number of practical problems; (4) Recognize three conics using geometry; recognize the canonical equations of three conics in the coordinate plane; solves some practical problems associated with three conics (MoET, 2018).

METHOD

The experiment aimed to determine whether using the CORE learning model to teach the method of coordinates in a plane in math textbooks for the 10th grade would help students become more proficient in solving mathematical problems. In a Vietnamese high school in Ho Chi Minh City, 96 students participated in the experiment. Of these, 47 students in class 10A1 were taught using the CORE learning model in the experimental group, and 49 students in class 10A12 used conventional methods in the control group. Subsequently, various data analysis techniques were employed to thoroughly examine the data gathered from the pre-test, post-test, classroom observation, and student surveys. The Ethics Council of Can Tho University, the Board of Directors of the High School and the parents and students of the High School in Ho Chi Minh City, Vietnam, all consented to the study.

Research design

A quasi-experimental study was conducted with a control group to answer the research objectives and questions. In the experimental design, a pre-test was given to the experimental and control groups to ascertain the participants' entry scores before the intervention and validate the equivalency between the two groups. The lessons were taught using the CORE learning model to the experimental group and conventional instruction to the control group. Specifically, participants in the control group received traditional lectures. Defining differently, they had no advantages over the experimental group from instructing through the CORE learning model. In addition, the students in this group were unaware of the subject that would be studied. The lectures had no subtopic division, and the participants were not encouraged to ask questions during the course. Also, the evaluation was conducted without the use of an inquiry-based methodology.

Each group received a post-test to see how well the students applied their new knowledge. Numerous previous studies (Arizal et al., 2018; Ardiyanto et al., 2022) on the effectiveness of the CORE model in mathematics education employed this experimental design, and there are parallels with certain studies on mathematics education. The experimental procedure took place in the following order using the above design.

A scale was created to assess students based on their proficiency in math problem-solving at each level, considering the requirements of the Mathematics General Education Program (MoET, 2018). This scale is shown in Table 1.

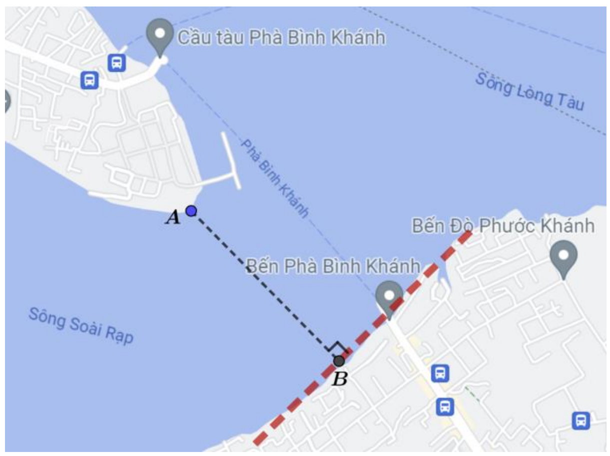
Component capacity	Student expression	Levels of expression			
		0	1	2	3
Detect the problem	1. State the problem that needs to be solved in the assigned task.	Unable to raise the problem.	The problem is stated, but not fully.	Able to state the problem more fully but slowly, thanks to the teacher's guidance	Ability to raise issues fully and quickly.
Proposed Solutions	2. State relevant information.	Relevant information cannot be mentioned.	Incomplete related information.	State all relevant information.	Define all relevant information accurately and scientifically.
	3. Propose solutions to solve the problem.	No solution was proposed to solve the problem.	Propose solutions to solve the problem, but are less feasible and ineffective.	Propose possible solutions	Come up with creative solutions that can solve problems in the fastest and best way possible.
Problem-solving	4. Perform problem solving.	Unable to solve the problem, no product can be created.	Confusion when solving problems leads to creating imperfect products in both form and content.	Solve problems well and create products with good content but poor form.	Implement problem-solving to create excellent products both in content and in form.
Evaluate performance results.	5. Results of self-assess performance.	Inability to self-evaluate.	The exact advantages and limitations of the implementation results have not been stated.	The advantages and limitations of the implementation results are accurately stated, but there is no basis, and no	Clearly state the advantages and limitations of the implementation results, have a valid basis, and learn from experience.

		experience has been learned.

Table 1: Scale to assess students' proficiency in solving mathematical problems.

The research team then designed lesson plans for the experimental group using the CORE learning model and lesson plans using conventional methods for the control group. In CORE model-based lessons, the teacher divided learning activities for each knowledge acquisition process into four stages: connecting, organizing, reflecting, and extending. An example of the activities planned to teach the distance formula from a point to a straight line is provided below.

Stage 1: Connecting.

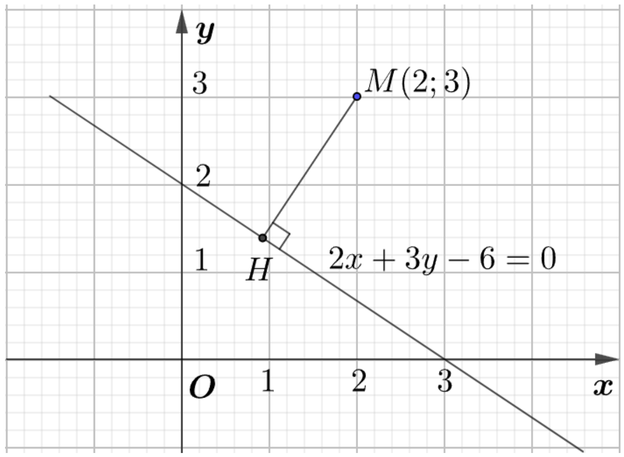


(Source: Image from Google Maps)

Teacher: From the Nha Be district, Ho Chi Minh City, you can visit the Can Gio district, Ho Chi Minh City, through the Binh Khanh ferry terminal. Assuming that the river bank (Can Gio) is a straight line, segment AB is the distance from point A to the river bank (Can Gio). At that time, the segment AB was also the shortest road connecting the two banks of the river. However, due to real conditions, we cannot go directly from A to B, but we have to make a longer journey (the journey of the Binh Khanh ferry). This is also the reason why bridges were born. Then, how is the segment length calculated? This is also the content of the next lesson.

Pedagogical intention: To create an exciting learning mindset for students through practical connections between the Nha Be and Can Gio districts in Ho Chi Minh City. This helps students feel that mathematics becomes interesting and closer to real life, and they love learning math more.

***Stage 2: Organizing*.**



Teacher: In the coordinate plane *Oxy*, a given straight line $\Delta: 2x+3y-6=0$ and a point $M(2;3)$. *H* is called the projection of point *M* onto the line Δ.

a) Find the direction vector of the line MH.

b) Write the parametric equation of the line MH.

c) Find the coordinates of *H*. From there, calculate the length of the line segment MH.

- Call a group to come up to the board to present their group's products.

Students: Follow and comment.

Teacher: Comment. This leads to the general case of giving the distance formula from a point to a straight line.

Suggested solution:

a) MH has the direction vector $\vec{u}=(2;3)$.

b) The parametric equation of the line *MH* is $\begin{cases} x=2+2t \\ y=3+3t \end{cases}$.

c) Because $H \in MH$, we can call $H(2+2t;\ 3+3t)$. On the other hand, $H \in \Delta$, so we have the following: $2(2+2t)+3(3+3t)-6=0 \Leftrightarrow t=\frac{-7}{13}$. Inferring $H\left(\frac{12}{13};\frac{18}{13}\right)$ and

$$MH=\sqrt{(x_H-x_M)^2+(y_H-y_M)^2}=\sqrt{\left(\frac{12}{13}-2\right)^2+\left(\frac{18}{13}-3\right)^2}=\frac{7\sqrt{13}}{13}.$$

Pedagogical intention: By fulfilling the requirements and answering the teacher's purposeful questions, students form new knowledge by applying relevant old knowledge. This has shown the manifestations of problem-solving skills in students.

Stage 3: Reflecting.

Teacher: Give an exact formula to calculate the distance from a point to a straight line.

In the coordinate plane *Oxy*, a given straight line Δ with its general equation of a straight line $ax+by+c=0$, satisfying the condition $a^2+b^2>0$ and a point $M_0(x_0;y_0)$. The distance from a point M_0 to a straight line Δ, denoted as $d(M_0;\Delta)$, is calculated by the formula:

$$\boxed{d(M_0;\Delta)=\frac{|ax_0+by_0+c|}{\sqrt{a^2+b^2}}}.$$

Students: Copy the above content to their memo pad.

Another example: Calculate the distance from a point $M(1;2)$ to a straight line $\Delta: 4x+3y+5=0.$

Pedagogical intention: To help students correct and systematize newly discovered knowledge and, at the same time, respond to knowledge with examples. This allows students to use newly discovered knowledge to solve mathematical problems.

Stage 4: Extending.

Problem 1: In the coordinate plane *Oxy*, a triangle *ABC* whose vertex coordinates are $A(1;1), B(5;2), C(4;4)$. Calculate the length of the altitude from vertex *A* of triangle *ABC*.

Problem 2: Calculate the distance between two straight lines $\Delta_1: 3x-4y+2=0$ and $\Delta_2: 3x-4y+12=0.$

Pedagogical intention: performing the above problems will help students practice recognizing and detecting problems through reading, understanding the problem and then choosing ways and solutions to solve the problem, thus using mathematical knowledge and skills to solve problems. This is also one of the goals of developing mathematical problem-solving skills.

Before implementing the planned lessons, researchers worked with the teacher to set up the classroom using the CORE learning model. In particular, the arrangement of the classroom was adaptable. The classroom could easily rearrange chairs and tables to accommodate various learning activities. There was space in the classroom for group projects, debates, speeches, and individual study. Besides, it gave students enough room to walk around the classroom without feeling crowded. The classroom was then decorated to spark students' interest in learning. The teacher used images, pictures, and mind maps about math material to decorate the classroom. Additionally, the teacher promoted student expression and fostered a creative environment by using bulletin boards to showcase learning materials, group projects, and student accomplishments. Lastly, computers, projectors, or screens were installed in classrooms to present information, videos, and educational materials. A reliable internet connection was also available to students to access online resources.

The research team privately observed the experimental and control groups throughout the teaching process. The content of the observations in the classroom was examined based on some criteria, such as the instructional strategies used by the teacher, the student's methods of learning, the skills that the students had attained, the environment of the classroom, and most importantly, the student's ability to solve math problems both in the experimental group and the control group both before and after the intervention. Lastly, a post-test was administered to the experimental and control groups to gauge the effectiveness of enhancing their ability to solve mathematical problems.

Additionally, students from the experimental group were polled using a series of multiple-choice questions on the Likert scale, which has five levels: totally disagree, disagree, neutral, agree, and totally agree (Likert, 1922). Data on student attitudes, motivation, interests and receptivity were collected using lesson plans connected to the CORE learning model.

Experts in mathematical education at Can Tho University reviewed the experimental teaching lesson plans, and teacher colleagues validated the tests to ensure the instrument's validity and reliability. High school staff conducted experiments to ensure that lesson objectives were met. Once the expert recommendations were implemented, the tools were deemed suitable for academic purposes and could evaluate students' skills, making them suitable for experiment use. Furthermore, the reliability of the post-test questionnaires was assessed using Cronbach's Alpha reliability. The correlation between the scores of the experimental group was determined using the student attitude survey and Pearson's correlation coefficient.

Data Collection and Analysis

Data were collected from the pre-test (first-semester final exam), post-test, class observation results, and post-intervention student opinion survey results. Using JASP software, the data were examined both quantitatively and qualitatively. Table 2 shows the experimental procedure as follows:

Groups	Pre-test	Intervention	Post-test	Opinion survey
Experimental group	x	X: CORE learning model	x	x
Control group	x	-	x	-

Table 2: Quasi-experimental Design

This study used qualitative and quantitative analysis methods to evaluate the experimental results. Regarding quantitative analysis, the pre-and post-test score data of both groups were tested for normal distribution through descriptive statistics (Shapiro-Wilk test), normal probability plots (Normal Q-Q Plot), standard curve chart (Normal distribution curve), the Pearson correlation coefficient (r) between the two sets of pre-and post-test scores of the experimental class, and the effect size using the mean deviation of Cohen (1998). Independent t-test (2-tailed) was used to compare the means of the experimental and control classes. Regarding qualitative analysis, the researchers conducted classroom observations in both experimental and control groups, analyzing based on some main criteria: teaching methods, learning methods, skills acquired, learning content, and classroom atmosphere. Based on the 5-level Likert scale, eight survey questions were created to gauge students' opinions of the CORE learning model's instructional strategies used in the experimental classroom and their ability to solve problems independently.

RESULTS

Results of the pre-test

The correlation between the experimental and control groups' math learning levels was examined using the first semester's final exam. The data processing results show a normal distribution of the test scores between the two groups. The results of the Shapiro-Wilk test indicate that both groups' significance levels for the pre-test are greater than 0.05, confirming the normal distribution of the pre-test scores. Table 3 shows the results obtained.

Groups	Statistics	Sig.
Experimental group	0.982	0.689
Control group	0.956	0.065

Table 3: Pre-test results for the Shapiro-Wilk test

The hypothesis that there was no significant difference in the mean pre-test scores between the experimental and control groups was tested due to the independent t-test. The t-test and descriptive statistical results for the mean pre-test scores of the experimental and control groups are calculated in Tables 4 and 5.

Groups	N	Mean	Std Dev	Minimum	Maximum
Experimental group	47	6.809	1.458	4	10
Control group	49	6.736	1.574	3	9.5

Table 4: Descriptive statistics of scores before the intervention

Table 4 shows that the average score for 47 students in the experimental group is 6.809, while the average score for the control group is 6.736 for 49 students. The data dispersion of the experimental group (standard deviation) is 1.458. The mean and median scores for both groups are nearly identical, and the standard deviation of the control group is 1.574. Additionally, the idea that the pre-test mean scores for both groups were equal was tested using an independent t-test. Table 5 reveals the test results.

t-test

df	t Stat	Sig. (2-tailed)	Mean difference
94	0.235	0.815	0.073

Table 5: The independent sample t-test results regarding the pre-test scores

An independent sample t-test was used to test whether there was a significant mean difference between the experimental and control groups. Consequently, the value (Sig.) is 0.815 (greater than 0.05) with a significance level of 0.05 and degrees of freedom df = 94. The mean score for the experimental and control groups did not differ according to this. In other words, the test results indicate that the qualifications of the two groups are equivalent.

Results of the post-test

The study compared the mean post-test scores of the experimental and control groups using twelve multiple-choice items and two essay items. The results of the Shapiro-Wilk test in Table 6 demonstrate that the observed significance levels of both groups are greater than 0.05, confirming the normal distribution of post-test scores for both groups.

Groups	Statistics	Sig.
Experimental group	0.966	0.178
Control group	0.957	0.071

Table 6: Results after the post-test for the Shapiro-Wilk test

The independent t-test was used to test the hypothesis that there was a statistically significant difference in the mean post-test scores between the experimental and control groups. The results of the independent sample t-test and descriptive statistics for the mean post-test scores of the experimental and control groups are shown in Tables 7 and 8.

Groups	N	Mean	Std Dev	Minimum	Maximum
Experimental group	47	7.580	1.237	4.25	10.0
Control group	49	6.776	1.468	3.50	9.50

Table 7: Descriptive statistics of post-intervention scores

The experimental group's mean score is 7.580, while the control group's is 6.776, according to the statistical analysis of post-test results in Table 7. The experimental group's standard deviation of data dispersion is 1.237, while the control group's standard deviation is 1.468. The post-test mean equality of scores for both groups was tested using an independent t-test. Table 8 shows the test results.

t-test			
df	t Stat	Sig. (2-tailed)	Mean Difference
94	2.897	0.002	0.804

Table 8: The independent sample t-test results regarding post-test scores

An independent sample t-test was used to test whether the mean difference between the experimental and control groups was statistically significant. As a result, the value (Sig.) is equal to 0.002 (less than 0.050) with a significance level of 0.050 and degrees of freedom df = 94. From this, it can be deduced that the mean score differences between the experimental and control groups are statistically significant. The experimental group was concluded to have a higher mean score in the post-test results than the control group because the mean score of the experimental group in Table 7 was higher than the control group.

Furthermore, based on the Cohen influence scale (2011), the calculated standard mean difference (SMD) is 0.591, which falls within the mean (0.5 to 0.79). Based on these findings, it can be said that the teaching process of the CORE learning model had a moderate effect on the academic performance of the experimental group's students. In contrast, a paired sample t-test was used to assess whether the intervention had improved the group's learning outcomes. The results were distributed immediately before and after the intervention, allowing for a relatively high correlation. Figure 1 illustrates the positive linear correlation between the scores of the experimental group before and after the intervention. In addition, a correlation test was conducted to validate the reliability of the results.

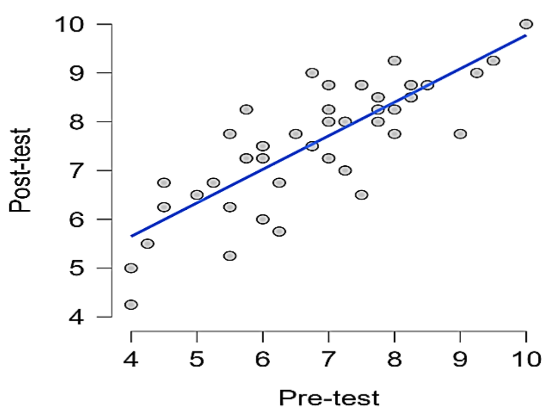


Figure 1: Q-Q plots of the scores of the experimental group before and after the intervention

	N	Correlation	Sig.
Pair of scores before and after the intervention	47	0.810	<0.001

Table 9: Results of the correlation test on the scores of the experimental group before and after the intervention

The results of Table 9 indicate that the calculated Pearson correlation coefficient (0.810) is statistically significant, with an observation value of less than 0.001. In other words, the scores acquired before and after the intervention show a significant correlation. A paired sample t-test was performed, and Table 10 reveals the results. The value obtained is less than 0.05, or < 0.001, suggesting a statistically significant difference in the scores of the experimental group before and after the intervention. In particular, it was determined that there was a difference in mean scores between the pre- and post-intervention periods. The students in the experimental group had higher learning outcomes than before the intervention.

	Mean	Sig.
Pair of scores before and after the intervention	47	<0.001

Table 10: Results of the paired sample t-test using the experimental group's pre- and post-intervention scores

Point range	Frequency	
	Experimental group	Control group
[0;1)	0	0
[1;2)	0	0
[2;3)	0	0
[3;4)	0	2
[4;5)	1	5
[5;6)	4	4
[6;7)	8	9
[7;8)	12	19
[8;9)	17	7
[9;10]	5	3
Sum	47	49

Table 11: Results of the post-test of the experimental and control groups

Table 11 shows that most of the students in the experimental group scored 5.0 points or higher (46/47 students), and no student scored less than 4.0 points. 1/47 students achieved [4;5) points, 4/47 students achieved [5;6) points, 8/47 students achieved [6;7) points, 12/47 students achieved [7;8) points, 17 /46 students achieved [8;9) points, and 5/47 students achieved [9;10] points. Meanwhile, most students in the control group scored from 3.0 points to less than 8.0 points (39/49 students), and only 10/49 students scored more than 8.0 points, of which 3/49 students achieved [9;10] points. Thus, there is a clear difference in the differentiation of scores between the experimental group and the control group. Specifically, the experimental group had an even distribution of scores, concentrated in relatively high score ranges. Meanwhile, the scores in the control group are distributed at many different high and low levels, and there is a difference between the scores, especially since the number of students who achieved scores ranging from 8.0 to higher is relatively small (10/49 students).

Evaluation of math problem-solving abilities

Based on the statistical table of student scores in the experimental and control groups, combined with the problem-solving ability evaluation scale, the ability of the students in the two groups was evaluated according to the level in Table 12:

Capacity component	Expression of students	Experimental group	Control group
1. Detect the problem	1. Identify the problems to solve in the assigned tasks.	Level 3	Level 2
2. Proposed solutions	2. State relevant information.	Level 2	Level 1
	3. Propose solutions to solve the problem.	Level 2	Level 1
3. Problem-solving	4. Perform problem solving.	Level 2	Level 1
4. Evaluate performance results	Results of the self-assess performance.	Level 2	Level 2

Table 12: Evaluation of the problem-solving skills of the students in the experimental and control groups

With the students' performance level in each component's capacity to solve problems, the students in the experimental group were at a higher level than those of the control group. From this, it can be observed that applying the CORE learning model to lesson plans contributed to developing students' problem-solving skills. In general, most of the students in the experimental group did the exercises correctly, presented them closely, discovered the problems, stated the relevant information, and proposed and solved the problems quite well. However, there were still some cases where students discovered problems but provided relevant information and did not solve the problem well. Specifically, some students discovered the problem and could state relevant information, but the conclusion was wrong, and the presentation lacked conditions. Also, most students in both classes had difficulty applying knowledge to solve real-world situations. However, a few students in the experimental group still solved the problems very well through clear and correct presentations and arguments. Furthermore, some students in the control group did not complete this item but had good ideas.

Results of classroom observations

After teaching the lessons on the method of coordinates in a plane, the results of the experimental group and the control group's observations were analyzed and compared based on the factors of the instructional approaches, learning methods, achieved skills, learning content, and students' Student attitude. The observed results are specified in Table 13.

Factors	Experimental group	Control group
Instructional approaches	Applying the CORE learning model. "Connecting" phase: asking questions, making suggestions, making actual contact. "Connecting" phase: Let students participate in activities to form new knowledge. "Reflecting" phase: The teacher summarized the knowledge and gave students exercises to contemplate and reflect on the knowledge they had just learned. "Extending" phase: Students applied the newly learned knowledge to solve real-life problems.	The teacher gave the main presentation. The teacher introduced concepts and formulas on the blackboard, gave examples, and asked the students to do exercises in the textbook.
Learning methods	Individual and group work. Actively explore new knowledge with the support of teachers. Apply the learned knowledge to solve mathematical and practical problems.	Absorb the knowledge that the teacher imparts, work individually, and give opinions. Listen to the lecture and copy the content.
Achieved skills	Teamwork, presentation, and questioning skills. Skills to apply existing knowledge and experience to discover and learn new knowledge. Skills to analyze and generalize learned knowledge. Calculation skills, problem-solving skills.	Skills for personal work, comments, questions and answers, and adjusting math solutions. Interpretation-based memory and problem-solving skills.
Learning Content	Lesson 1: Vector coordinates in the coordinate plane. Lesson 2: Straight lines in the coordinate plane. Lesson 3. Circle in the coordinate plane. Lesson 4: Three conics in the coordinate plane (exercise).	Lesson 1: Vector coordinates in the coordinate plane. Lesson 2: Straight lines in the coordinate plane. Lesson 3. Circle in the coordinate plane. Lesson 4: Three conics in the coordinate plane (exercise).
Student attitude	The classroom atmosphere was cheerful; students actively participated in activities and actively thought about solving the problems that appeared during the lessons.	The class was quiet: The students listened attentively to the lecture and took notes. When the teacher asked questions, only a few students raised their hands to speak.

Table 13: Classroom observation results between the experimental and control groups

The classroom observation results above show that the teaching method according to the CORE learning model in the chapter on the method of coordinates in a plane had achieved some positive results. In terms of content, both classes ensured completeness. However, in the experimental group, students could practice more mathematical skills and abilities than in the control group.

Results of a survey of student opinions

Following the conclusion of the lesson plans in the experimental group, the research team used a Likert scale to administer multiple-choice items to the experimental group's students for their opinions. The purpose of the survey was to find out how students felt about learning using the CORE model, how they felt about the effectiveness of the instruction, and how it helped them develop their problem-solving skills after the intervention. The statistical findings of the responses are as follows.

Items	Totally disagree	Disagree	Neutral	Agree	Totally agree
1. I enjoyed the lessons on the method of coordinates in a plane.	0 0%	0 0%	7 15%	17 36%	23 49%
2. I find that the "organizing" activities in these lessons help me learn more effectively.	0 0%	0 0%	17 36%	14 30%	16 34%
3. I find that the "connecting" activities help me access and visualize new content from the lesson more easily.	1 2%	2 4%	10 21%	12 26%	22 47%
4. I find that "organizing" activities help me to be more interested, actively participate, and contribute to building lessons.	2 2%	1 2%	11 23%	16 34%	17 37%
5. I find that the "reflecting" activities help me to remember new knowledge better.	0 0%	0 0%	7 15%	10 21%	30 64%
6. The "Extending" activities help me practice analyzing and synthesizing related knowledge and better perceiving it.	4 9%	6 13%	7 15%	14 30%	16 33%
7. I am making progress in solving problems related to mathematics.	0 0%	0 0%	18 38%	13 28%	16 34%
8. I want to take similar classes on other topics.	2 4%	2 4%	4 9%	16 34%	23 49%

Table 14: Student feedback on items of the survey

Table 14 indicates that most of the students in the experimental group liked the lessons in the method of coordinates in a plane (85%). This result is consistent with the learning attitudes of the students analyzed above. Some students did not have an opinion on this (15%). Furthermore, most students expressed satisfaction with this learning process (approximately 64%). However, 17 students (36%) still felt that the learning content was vague and unclear. Through classroom observation, it can be determined that the initial cause was the group discussion process that took place quickly during class time, and the tasks were not divided among the group members. However, this can still be seen as a meaningful response to research that shows the effectiveness and feasibility of the CORE learning model.

Table 14 reveals that most of the students in the experimental group thought that the "connecting" activities in the lessons helped them become more interested (73%). Furthermore, there were still three students (6%) who disagreed, and ten students (21%) felt normal with the design of the "connecting" activities; this was also a suggestion for the design of the activities to be more intuitive and fun. Furthermore, the percentage of students in the experimental group who chose the option of totally agreeing was 37% and agreeing was 34%, showing that the students felt interested and comfortable participating in the "organizing" activities. The data in Table 14 confirm that the percentage of students who agreed was very high (85%) in the "reflecting" activities that helped them better understand concepts and the relationships between concepts, and only seven students (15%) felt normal. This shows that the designed "reflecting" activities were appropriate, a prerequisite for promoting problem-solving skills.

Table 14 reveals that 30 students (63%) agreed and totally agreed on training the ability to analyze and synthesize related knowledge and better perceive the relationship between learned knowledge and real-world problems. Furthermore, seven students (15%) felt neutral, and 10 (22%) disagreed or totally disagreed; this suggested designing, engaging, connecting and extending activities with the knowledge learned more closely and closer to practice. This particular item allowed the students to evaluate themselves. According to Table 14, most students (62%) made progress in solving the problems associated with the method of coordinates in a plane. According to Table 14, 39 students, or 83%, wanted to enroll in comparable courses on different subjects. Four students (8%) continued to dislike taking classes like this. Nevertheless, the initial cause of this issue was a fairly challenging topic; some students in the experimental group still did not understand the lesson, as evidenced by the analysis of the experimental group's post-test results, which were better than those of the control group.

DISCUSSIONS

The results of a mixed-method experiment with a control group included group observations, student opinion surveys, results of the pre-and post-test, and qualitative and quantitative analysis of the collected data. The experimental group provided a basis for determining the effectiveness and feasibility of applying the CORE learning model to enhance students' problem-solving skills in teaching the method of coordinates in a plane. The post-test results indicated a significant difference in the students' average scores in the experimental and control groups. Specifically, the t-test between the two scores shows that with sig. (2-tailed) < 0.0001, the experimental group outperformed the control group regarding average score. A correlation test was used to ensure that the students' higher scores in the experimental group were due to the effectiveness of the CORE learning model (and not due to other random factors). The results reveal that the level of correlation was very high between the two scores of the experimental group before and after the intervention, with Pearson's correlation coefficient of the scores before and after the intervention of the experimental group equal to 0.810 and the significance level of 0.810. The significance level of the test is <0.001; this level of correlation is statistically significant. In addition, the Q-Q plots also show that the students' learning outcomes in the experimental group improved when learning the method of coordinates in a plane. The results of the study are consistent with the conclusions of studies on applying the CORE learning model to promote students' problem-solving skills by the authors Arizal et al. (2018), Son et al. (2020) and Irawan and Iasha (2021).

Furthermore, the results of the observation of the experimental lessons show that the students in the experimental group were more positive and proactive in the learning process and received many opportunities to develop real-world problem-solving skills in the lessons learned. The learning activities designed according to the CORE learning model aroused curiosity and desire to learn from most students in the experimental group, and the problems that appeared in the "connecting" activities continued to be presented to the students. Group discussion aimed to generalize and summarize it into a new mathematical object. As a result, students were inspired to be enthusiastic and involved in the learning process. Furthermore, the results of the survey of students in the experimental group showed that the learning efficiency of the students in the experimental group in the lessons was designed according to the four phases of the CORE model (accounting for 64%). In particular, survey questions designed to create conditions for students to self-evaluate the effectiveness of intervention solutions show that learning with the CORE model helped students to learn actively. More extreme (agreement rate is 71%). According to the model designed to learn other topics, 83% of the students still wanted to continue their education. This result is similar to the research results of Ningsih et al. (2019), Khor et al. (2020), Ramadhani (2020), Ardiyanto et al. (2022), Farhan et al. (2022), Atiyah and Priatna (2023) and Suardani et al. (2023).

With the results achieved, this study has some implications. The research results indicate the necessity of organizing and teaching the method of coordinates in a plane based on the level of development of students' problem-solving skills. Also, researchers and educators must focus on providing students with sustainable access to this content to create long-term impact and help them learn the method of coordinates in a space more easily. Therefore, it is necessary to design a consistent and progressive mathematics education program. However, teachers' understanding of mathematical problem-solving skills is important in promoting these skills in students. Hence, mathematics teacher educators should organize training for pre-service and in-service mathematics teachers on the nature of mathematical problem-solving skills and measures to increase these skills for students. These are issues that can be considered in future studies. In addition, the research results show the effectiveness of learning activities designed according to the four important phases of the CORE learning model in enhancing students' mathematical problem-solving skills.

In addition to the results obtained, the study identified some limitations. First, the data collected by the study were not based on long-term experiments. The experimental time was not long (4 weeks), so the experiment could not observe full manifestations of the promotion of students' mathematical problem-solving skills. Therefore, research can have positive and rich results if the experiment is carried out over a long enough period so that the learning activities designed according to the CORE learning model can have a lasting enough impact and consistently improve students' mathematical problem-solving skills. From this, the research team can examine students' progress more clearly. The second limitation is that the scope of the research is restricted to instructing the method of coordinates in a plane instead of implementing it on a wider variety of mathematical topics to clarify the effectiveness of this learning model on the student's learning process. Third, with a relatively small number of students participating in the experiment, 96 students, the research results are local and limited to a narrow research scope. Additionally, because the time for group discussion activities is limited, the knowledge content is too large compared to the class distribution, and not all students can achieve the desired results. Promoting mathematical problem-solving skills requires a long-term process from which the effectiveness of the intervention solution applied is recorded. Through this, teachers must take appropriate measures based on the level of students' mathematical problem-solving skills for mathematical content and teach more effectively.

CONCLUSIONS

The study's conclusions demonstrate how the CORE learning model improves student learning outcomes, problem-solving skills, and attitudes. After analyzing the post-test results, it was discovered that the experimental group outperformed the control group by a significant level (Sig. 2-tailed < 0.001 with $\alpha = 0.05$ and degrees of freedom df = 94). Furthermore, the mean score of the experimental group increased after the intervention (the paired sample t-test revealed a significance level of < 0.001). The lesson plans were designed based on the CORE learning model, which positively impacted their learning outcomes and mathematical problem-solving skills, with an effect size (ES) of 0.591.

Some related research directions are suggested for future studies, including (1) using the CORE learning model to teach different math topics and help students improve other math skills; (2) researching the application of the CORE learning model and GeoGebra in mathematics instruction; (3) researching the influence of certain factors on the development of students' math problem-solving skills; and (4) looking into the long-term effects of using the CORE learning model. However, the research team suggests conducting new studies with sizable sample sizes and extended observation periods to assess the strengths and shortcomings of the CORE learning model in mathematics instruction.

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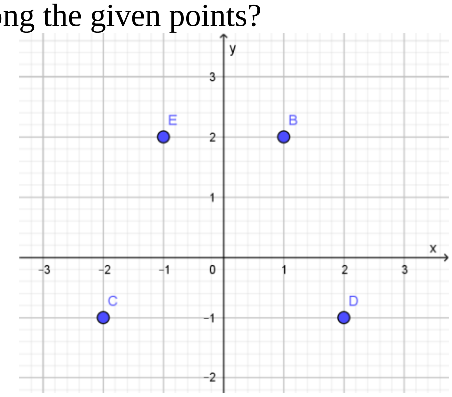
APPENDIX

POST-TEST

Allotted time: 60 minutes

A. MULTIPLE CHOICE SECTION

Item 1. In the coordinate plane Oxy, for points B, C, D, E as shown. How many points have negative coordinates among the given points?



A. 1. B. 3. C. 2. D. 4.

Item 2. Given $\vec{a} = (2;-3); \vec{b} = (-3;4)$. Then:

A. $\vec{a}+\vec{b}=(-1;1)$. B. $\vec{a}+\vec{b}=(5;-7)$.

C. $\vec{a}+\vec{b}=(1;-1)$. D. $\vec{a}+\vec{b}=(1;1)$.

Item 3. A straight line Δ has the following parametric equation: $\begin{cases} x = 2-3t \\ y = 4+2t \end{cases}$. The straight line Δ has a direction vector:

A. $\vec{u} = (2;4)$. B. $\vec{u} = (-3;2)$. C. $\vec{u} = (-3;-2)$. D. $\vec{u} = (2;-3)$.

Item 4. Which of the following points is on a straight line $x - y + 3 = 0$?

A. $(6;12)$. B. $(4;-7)$. C. $(4;2)$. D. $(4;7)$.

Item 5. The center coordinates I , and radius of the circle $(C):(x+1)^2+(y+3)^2=36$ are:

A. $I(-1;3)$, $R=6$. B. $I(-1;-3)$, $R=6$.

C. $I(1;-3)$, $R=36$. D. $I(-1;3)$, $R=36$.

Item 6. Which of the following equations is the equation of a circle?

A. $x^2+y^2-x=0$. B. $x^2+y^2+9=0$.

C. $x^2+y^2-2xy-1=0$. D. $x^2-y^2-2x+3y-1=0$.

Item 7. An ellipse $\frac{x^2}{16}+\frac{y^2}{4}=1$ has an axis length equal to:

A. 16. B. 8. C. 2. D. 4.

Item 8. Which of the following equations is the canonical equation of the hyperbola?

A. $\frac{x^2}{16}-\frac{y^2}{9}=1$. B. $y^2=2x$.

C. $\frac{x^2}{16}+\frac{y^2}{9}=1$. D. $\frac{y^2}{16}-\frac{x^2}{9}=1$.

Item 9. A parabola (P) has a focal point $F(3;0)$. The canonical equation of a parabola (P) is:

A. $y^2=3x$. B. $y^2=-12x$. C. $y^2=12x$. D. $y^2=6x$.

Item 10. In the coordinate plane Oxy, the general equation of the straight line Δ passing through two points $A(3;-1)$ and $B(1;5)$ has the form:

A. $3x+y-8=0$. B. $3x-y+10=0$.

C. $3x-y+6=0$. D. $-x+3y+6=0$.

Item 11. A given circle $(C):(x-2)^2+(y+2)^2=25$. The equation of the tangent to *(C)* at the point $B(-1;2)$ is:

A. $-3x+4y-5=0$. B. $-x+2y-6=0$.

C. $3x-4y+11=0$. D. $-x+2y+6=0$.

Item 12. In the coordinate plane Oxy, given points $A(1;3)$; $B(-2;1)$; $C(4;2)$. Find the coordinates of point *D* so that quadrilateral *ABCD* is a parallelogram.

A. $D(7;4)$. B. $M(-7;-4)$. C. $D(7;-4)$. D. $D(4;7)$.

Item 13. In the coordinate plane Oxy, write the equation of a circle passing through three points $A(0;4)$, $B(2;4)$, $C(2;0)$.

A. $x^2+y^2+2x-4y=0$ B. $x^2+y^2-2x+4y=0$

C. $x^2+y^2+2x+4y=0$ D. $x^2+y^2-2x-4y=0$

Item 14. Determine the coordinates of the focus of the ellipse $4x^2+9y^2=36$?

A. $F_1\left(-\sqrt{5};0\right), F_2\left(\sqrt{5};0\right)$. C. $F_1\left(-\sqrt{5};\sqrt{5}\right), F_2\left(0;\sqrt{5}\right)$.

B. $F_1\left(\sqrt{5};0\right), F_2\left(0;\sqrt{5}\right)$. D. $F_1\left(\sqrt{5};\sqrt{5}\right), F_2\left(-\sqrt{5};-\sqrt{5}\right)$.

B. ESSAY TEST SECTION

Item 15. Write the general equation of the line Δ, knowing that the line passes through a point $M(0;1)$ and is parallel to a straight line $d: x-2y+3=0$.

Item 16. Write the equation of a circle (C) with center $I(2;-1)$ and tangent to a straight line $\Delta': 3x+4y-12=0$.

Item 17. A semicircular gate is *8m* wide and *4m* high. The road under the gate is divided into two lanes for vehicles entering and exiting.

a) Write an equation to simulate the gate.

b) Can a truck *2.5m* wide and *2.9m* high traveling in the correct lane pass through the gate without damaging the gate?