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EFFECTIVENESS OF THE 5E LEARNING CYCLE MODEL ASSISTED BY WORKSHEETS IN TEACHING EXPONENTS AT THE SECONDARY SCHOOL LEVEL: A QUASI-EXPERIMENTAL STUDY

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ABSTRACT

Objective: This study aims to analyze the effectiveness of the 5E Learning Cycle Model, supported by worksheets media, on students' learning outcomes in the topic of exponents.

Research Design & Methods: This study employs a quantitative approach using a quasi-experimental method with a Non-Equivalent Control Group Design. The study population consists of 60 eleventh-grade students at SMK Kholiliyah Bangsri for the 2025/2026 academic year, with a sample of 52 students selected using cluster random sampling. The sample consisted of an experimental class that received instruction using the 5E Learning Cycle Model supported by worksheets and a control class that used conventional instruction. Data collection techniques included tests, observations, and documentation. Data analysis was conducted using descriptive statistics, normality tests, homogeneity tests, and the Paired Sample t-Test.

Findings: The results of the study indicate that the implementation of the 5E Learning Cycle Model supported by worksheets is effective in improving student learning outcomes. The average pretest score of the experimental class increased from 54.23 to 84.65 on the posttest. The results of the Paired Sample t-Test showed a significance value of $0.000 < 0.05$, indicating a significant difference between learning outcomes before and after the intervention.

Contributions: This study contributes to the development of constructivist-based mathematics learning through the implementation of the 5E Learning Cycle Model supported by worksheets.

Novelty: This study extends constructivist learning research by providing empirical evidence that the 5E Learning Cycle Model supported by worksheets improves students' conceptual understanding of exponentiation.

Keywords: 5E Learning Cycle, Worksheets, Exponential Mathematics Learning

JEL codes: I21, I29, C12

Article type: research paper

INTRODUCTION

Education plays a fundamental role in shaping the quality of human resources and is one of the key factors driving a nation's progress (OECD, 2018). High-quality education contributes to enhancing individuals' ability to address social and economic challenges and keep pace with rapidly evolving technological advancements. Education is not merely viewed as a process of knowledge transfer, but also as a means of fostering the character, skills, and competencies required in modern society. In the context of national development, education serves a strategic function in creating a workforce that is productive, innovative, and capable of competing on a global scale. Therefore, improving the quality of education has become a primary focus for many countries in supporting sustainable development.

The 21st-century educational system is expected to focus not only on the acquisition of knowledge but also on the development of higher-order thinking skills (HOTS). Students must be equipped with critical thinking, creativity, communication, and collaboration skills, as well as the ability to solve complex problems, so they can adapt to rapid global changes. The transformation of 21st-century education demands a shift in the learning paradigm from teacher-centered learning to learner-centered learning. One discipline that makes a significant contribution to the development of these skills is mathematics (Maass et al., 2019). Mathematics is not merely viewed as a collection of concepts and formulas but also as a tool for cultivating systematic, logical, analytical, and critical thinking. Effective mathematics instruction can help students develop the reasoning and decision-making skills needed in real-life situations as well as in the advancement of science and technology (Morton, 2021).

Mathematics plays a strategic role in the education system because nearly all fields of study rely on mathematical concepts as the foundation for scientific development. Mastery of mathematics is not only important for academic needs but is also essential in daily life, such as the ability to analyze data, make decisions, and solve problems rationally. Therefore, the quality of mathematics education is one of the key indicators of a nation's educational success. However, various indicators suggest that students' mathematical proficiency in Indonesia still requires serious attention.

The results of the 2022 Programme for International Student Assessment (PISA) show that Indonesia ranked around 70th–71st out of 81 countries in mathematics proficiency, with performance still below the average of OECD member countries (OECD, 2023). These results indicate that the majority of Indonesian students still face difficulties in solving problems that require higher-order thinking skills, mathematical reasoning, and the application of concepts in contextual situations. Additionally, the National Assessment results also show that only a small proportion of students have achieved the minimum numeracy competency. This situation indicates that students' mastery of basic mathematical skills remains relatively low, necessitating various improvement efforts through more effective learning innovations.

Table 1. Indonesia's PISA Results for 2022

Proficiency Level	Reading (%)	Mathematics (%)	Science (%)
< Level 1b	9,54	11,85	3,56
Level 1b	29,58	35,95	21,16
Level 1a	35,42	33,85	41,12
Level 2	19,33	14,06	26,29
Level 3	5,43	3,75	7,01
Level 4	0,68	0,49	0,83
Level 5	0,02	0,04	0,03
Level 6	0,00	0,00	0,00

Based on Table 1, the distribution of Indonesian students' proficiency in mathematics is still dominated by the low proficiency category, particularly at levels 1a and 1b. The percentage of students who achieve high proficiency levels—such as levels 4, 5, and 6—is very small, approaching zero. This situation indicates that the majority of students still struggle to deeply understand mathematical concepts, engage in mathematical reasoning, and integrate various concepts to solve more complex problems. The low achievement at high proficiency levels also suggests that the current learning process has not yet fully developed students' higher-order thinking skills. Therefore, learning strategies are needed that can encourage students to actively engage in the process of knowledge construction.

One factor believed to contribute to low achievement in mathematics is a learning process that remains oriented toward a teacher-centered approach (Listyani, 2012). Teachers still tend to dominate classroom activities by lecturing and directly assigning practice problems. This situation results in students playing the role of passive recipients of information rather than active individuals constructing their own knowledge. Consequently, learning interactions become suboptimal, and students' opportunities to develop critical thinking and exploratory skills are limited.

Teacher-centered learning approaches often place greater emphasis on procedural aspects than on conceptual understanding. Students tend to be guided to memorize formulas and solution steps without understanding the rationale or underlying concepts behind these procedures. This situation results in a mechanical approach to mathematics learning, making the acquired knowledge less meaningful and difficult to apply in new situations. Students ultimately struggle when faced with problems that require reasoning or the flexible application of concepts (Lachner et al., 2019). In fact, the goal of mathematics education is not merely to master procedures but also to build a deep conceptual understanding.

This issue becomes particularly evident in the study of exponents. Exponents are a fundamental mathematical concept that is closely related to various advanced topics such as radicals, logarithms, exponential functions, scientific notation, and exponential growth. Therefore, a solid grasp of exponential concepts is an essential prerequisite for understanding higher-level mathematics. However, the abstract nature of exponential material often causes students to struggle with understanding both the concepts and the rules of operations. Common mistakes include difficulty understanding the properties of powers, performing multiplication and division of exponents, and applying exponential concepts to solve contextual problems. These difficulties may arise because students merely memorize formulas without understanding the underlying concepts. This highlights the need for a learning approach that helps students construct concepts through active and meaningful learning experiences.

One instructional model that has the potential to address these issues is the 5E Learning Cycle Model. This model was developed based on constructivist theory, which views knowledge as being actively constructed by learners through learning experiences (Boddy et al., 2003). In constructivist theory, learners are not positioned as passive recipients of information, but as individuals who actively construct their understanding through interaction with their environment. The 5E Learning Cycle model consists of five stages: Engagement, Exploration, Explanation, Elaboration, and Evaluation (Bybee, 2014). Through these stages, students are encouraged to connect prior experiences, explore, construct concepts, apply knowledge, and reflect on the learning process.

Several previous studies have shown that the implementation of the 5E Learning Cycle Model has a positive impact on enhancing students' learning activities and learning outcomes. A study by Putra et al., (2018) demonstrated that the use of the 5E Learning Cycle Model resulted in better learning outcomes compared to conventional instruction. Research by Putri et al., (2021) also found that this model is capable of increasing student engagement in the learning process and strengthening their understanding of mathematical concepts. Nevertheless, research on the effectiveness of the 5E Learning Cycle Model for exponential material using a quasi-experimental approach remains relatively limited, particularly in the context of secondary school mathematics education. Most previous studies have focused on general topics or merely measured general improvements in learning outcomes without examining the characteristics of specific topics.

Based on a review of the literature and previous research findings, there is a research gap regarding the implementation of the 5E Learning Cycle Model in exponent-related content. Most previous studies have focused on the impact of learning models on improving mathematics learning outcomes in general, without specifically examining the characteristics of particular content areas. However, each area of mathematics has distinct conceptual characteristics, necessitating a tailored instructional approach. Exponential material is highly abstract and often poses difficulties for students in understanding the relationships between concepts and their operational rules. Research specifically examining the application of the 5E Learning Cycle Model to exponential material remains relatively limited, particularly at the secondary education level. Furthermore, much of the prior research has relied on descriptive approaches or simple experiments, so testing the model's effectiveness through quasi-experimental designs still requires further empirical evidence.

Previous studies have consistently reported positive effects of the 5E Learning Cycle Model on students' engagement and learning outcomes (Putra et al., 2018; Putri et al., 2021). However, these studies mainly focused on general mathematics learning or broader science contexts. They did not specifically investigate exponentiation, which is considered one of the most abstract mathematical topics and frequently leads to misconceptions among students. Moreover, most prior studies employed descriptive or simple experimental designs, limiting the strength of causal conclusions. Therefore, empirical evidence regarding the effectiveness of the 5E Learning Cycle Model for teaching exponentiation through a quasi-experimental design remains limited.

The novelty of this study lies in its focus on testing the effectiveness of the 5E Learning Cycle Model specifically for exponential material using a quasi-experimental approach. This study not only examines the influence of the learning model on learning outcomes in general but also investigates how a constructivist-based learning model can help students understand abstract mathematical concepts. Through the stages of Engagement, Exploration, Explanation, Elaboration, and Evaluation, students are given the opportunity to actively construct concepts through structured learning experiences. This approach is expected to help students understand the concept of exponents more deeply, increase engagement during the learning process, and reduce the tendency to learn by rote.

Based on the above description, this study aims to analyze the effectiveness of the 5E Learning Cycle Model in teaching exponential concepts to students. Specifically, this study aims to determine whether the application of the 5E Learning Cycle Model can produce better learning outcomes compared to conventional teaching methods. The hypothesis proposed in this study is that there is a significant difference in learning outcomes between students who receive instruction using the 5E Learning Cycle Model and those who receive conventional instruction. The research results are expected to provide a theoretical contribution to the development of constructivist-based mathematics learning and serve as a reference for educators in designing more innovative, effective, and student-centered learning strategies. Furthermore, it is also expected to serve as a basis for consideration in developing mathematics learning models capable of improving the quality of students' learning processes and outcomes.

LITERATURE REVIEW

The 5E Learning Cycle Model

The 5E Learning Cycle is a student-centered learning approach that emphasizes the learning process through structured, sequential, and interconnected stages. This model is designed to help students actively construct knowledge through learning experiences that allow them to connect new concepts with their prior knowledge. The learning process in the Learning Cycle does not merely emphasize the final outcome of mastering the material but also focuses on the development of conceptual understanding through students' active engagement in learning activities. Through this approach, students are encouraged to discover, test, and construct knowledge independently, making learning more meaningful and profound. This approach also helps students develop critical thinking skills, problem-solving abilities, and the ability to relate learning experiences to real-world situations.

Learning Cycle 5E has been widely adopted as a learning model that supports the objectives of modern educational standards, particularly in science education from preschool through secondary school. This model was originally developed based on constructivist theory, which holds that knowledge is actively constructed by learners through interaction with the learning environment. According to Hanuscin & Lee (2008) the 5E Learning Cycle applies a learning cycle that generally consists of three main phases: exploration, explanation, and expansion or generalization. These stages are designed so that students can systematically construct a "conceptual story" through a series of interrelated activities. In the exploration phase, students are given the opportunity to observe, identify problems, and explore initial ideas. Next, in the explanation phase, students begin to develop their understanding of concepts through discussion and clarification, while the expansion phase aims to apply the concepts they have learned in a broader context. Through these systematic stages, students not only memorize concepts but also gain a deeper understanding of the relationships between them.

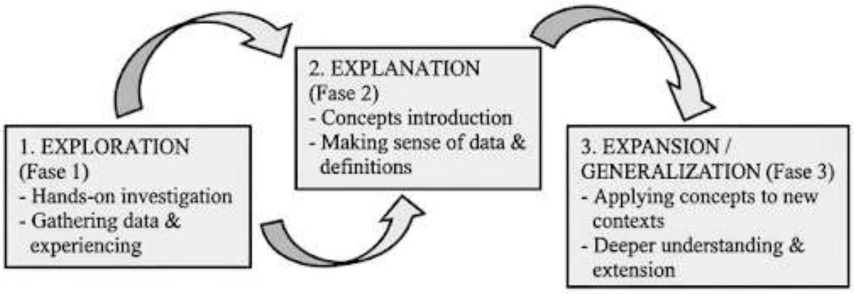

Figure 1. 3 Main Phases of the 5E Learning Cycle (Hanuscin & Lee, 2008)

The 5E Learning Cycle model is characterized by student-centered learning, emphasizes active student engagement, and develops conceptual understanding through systematic and continuous learning stages. According to Muliyati et al., (2019), this model consists of five main stages: Engagement, Explore, Explain, Elaborate, and Evaluate. The Engagement stage is the initial phase aimed at sparking motivation and interest, as well as connecting students' prior knowledge with the material to be studied, typically through a prompt question or a problem relevant to daily life. Next, in the Explore stage, students are given the opportunity to conduct investigations, observations, or hands-on activities so they can discover and construct concepts independently through learning experiences. The Explain stage involves giving students the opportunity to communicate the results of their exploration and discuss the concepts they have acquired, after which the teacher helps clarify and reinforce their understanding of those concepts. In the Elaborate stage, students expand and deepen their understanding by applying the concepts they have learned to new situations or more complex and contextual problems. The final stage, Evaluation, aims to assess students' level of understanding through various forms of assessment—both formative and summative—while also serving as a means of reflecting on the learning process that has taken place.

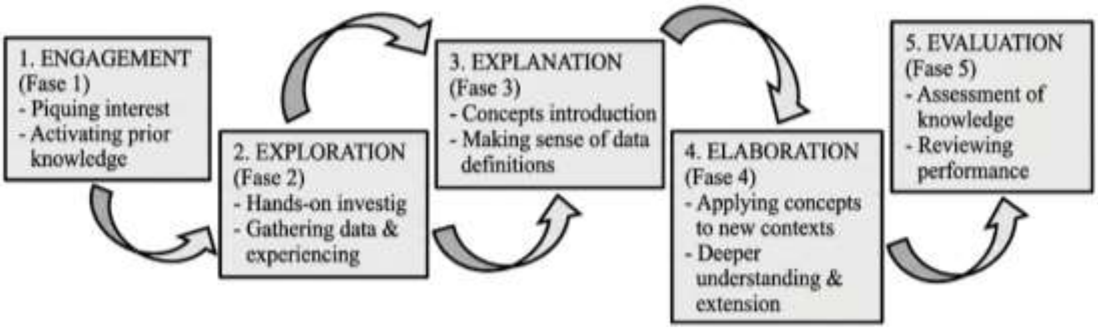

Figure 2. 5E Learning Cycle Instructional Model (Muliyati et al., 2019)

The Learning Cycle is not only grounded in constructivist theory but is also linked to experimental learning theory, which emphasizes the importance of direct experience in the learning process. This aligns with the mARC (more Authentic, Reflective, and Collaborative) instructional model, which highlights the close relationship between practical experience and theoretical understanding through the processes of recontextualization and decontextualization of knowledge within the learning cycle. According to Radović et al., (2023), authentic, reflective, and collaborative learning can create a more meaningful learning environment and encourage students to construct knowledge more deeply. This approach provides students with the opportunity to reflect on their learning experiences, collaborate with peers, and connect the concepts they have learned to real-life situations. Thus, the

Learning Cycle model not only serves as a strategy for delivering content but also as a means to develop students' higher-order thinking skills, communication abilities, and social skills throughout the learning process.

Teaching Exponential Mathematics

Teaching exponential mathematics is an important part of the curriculum because the concept of exponents serves as the foundation for various advanced mathematical topics such as logarithms, exponential functions, population growth, compound interest, and scientific modeling. Exponential material not only emphasizes procedural skills in applying power rules but also requires a conceptual understanding of the relationships between mathematical representations. The concept of exponents is often viewed as abstract by students because it involves complex symbols and operational rules. This difficulty leads many students to merely memorize the properties of exponents without understanding the mathematical reasoning behind the procedures used. Consequently, learning about exponents often results in a superficial understanding that affects students' ability to solve more complex problems. Research by Kusumadewi and Andriatna (2024) shows that exponents are an essential concept, but students have not yet fully mastered them, leading to various learning barriers.

Mathematics instruction, particularly regarding exponents, requires an adaptive and innovative approach so that students not only understand the concepts but are also motivated throughout the learning process. One effective strategy is differentiated instruction, which tailors the approach to students' diverse needs and abilities, thereby improving the quality of learning outcomes, critical thinking skills, and overall motivation to learn (Sari & Wahyudin, 2024). Additionally, the Teaching at the Right Level (TaRL) approach emphasizes adjusting the level of instruction to match each student's individual understanding, which has also been shown to positively contribute to students' mathematics learning outcomes (Shabrina et al., 2024).

In learning about exponents, students need to build their understanding through a gradual process of concept construction. Constructivist learning theory explains that mathematical knowledge is built through students' experiences and active interactions with learning situations. Therefore, the process of learning about exponents should not only focus on procedural practice but also provide opportunities for students to explore patterns, make generalizations, and discover relationships between concepts. Teachers act as facilitators who help students construct meaning regarding the properties of exponents, for example through visual representations, real-life contexts, or exploratory activities. An approach that places too much emphasis on memorizing formulas is known to increase the likelihood of misconceptions and conceptual errors (Pinahayu, 2016).

Exponential concepts are one of the mathematical topics that frequently give rise to misconceptions. Common forms of misconceptions include errors in understanding zero exponents, negative exponents, fractional exponents, and the application of properties of exponential operations. Some students view exponents as ordinary addition or incorrectly generalize rules across different bases. The development of a three-level diagnostic test found that misconceptions regarding exponential material can be categorized into errors in generalization, notation, specialization, and mathematical language. These misconceptions can hinder the development of understanding of advanced concepts and affect students' mathematical problem-solving abilities (Pramasdyahsari et al., 2024).

Difficulties in learning exponents highlight the need for more innovative and student-centered learning strategies. The use of interactive media, STEM-based learning, exploratory activities, and problem-posing approaches can help improve conceptual understanding and reduce misconceptions. Additionally, teachers need to conduct diagnostic assessments to identify misunderstandings early on so that learning interventions can be implemented effectively. Contextual and meaningful instruction on exponents can help students build connections between mathematical concepts and real-world situations.

Conceptual Framework

Understanding mathematical concepts is one of the key objectives of mathematics education. However, many students still struggle to understand and apply mathematical concepts, particularly when it comes to exponents. Students tend to simply memorize formulas without grasping the underlying concepts, which leads to difficulties when solving problems that differ from the examples provided by the teacher. To address this issue, a learning model is needed that actively engages students in the learning process. One model that can be used is the 5E Learning Cycle Model, which consists of the stages of Engagement, Exploration, Explanation, Elaboration, and Evaluation. Through these stages, students are guided to discover and understand concepts gradually through hands-on learning experiences.

The implementation of the 5E Learning Cycle model will be more effective if supported by worksheets. Worksheets help students engage in learning activities, discuss topics, and solve problems in a structured manner. By using worksheets, students are expected to be more active and motivated, and to better understand the concept of powers.

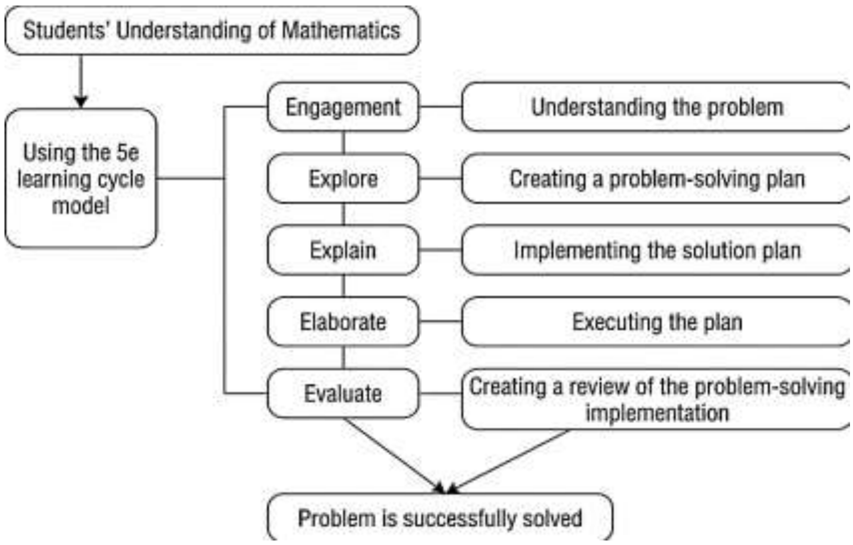

Figure 3. Conceptual Framework

Research Hypothesis

Although previous studies consistently report positive effects of the 5E Learning Cycle Model on mathematics achievement, most merely compare learning outcomes without explaining why the model improves conceptual understanding. From the constructivist perspective, the Engagement stage activates prior knowledge, Exploration promotes concept construction, Explanation facilitates cognitive restructuring, Elaboration strengthens transferability, and Evaluation reinforces conceptual consolidation. These sequential cognitive processes are expected to improve understanding of exponentiation, which is highly abstract and prone to misconceptions.

A hypothesis is a tentative answer to the research question, the validity of which still needs to be proven through data collection and analysis. In quantitative research, hypotheses are used as a basis for testing relationships or influences between the variables under study. This study aims to determine the effectiveness of applying the 5E Learning Cycle model in teaching exponential concepts to students through a quasi-experimental approach.

Based on a review of the theory, conceptual framework, and results of previous studies indicating that the 5E Learning Cycle model can enhance student engagement, conceptual understanding, and learning outcomes, the hypothesis for this study is formulated as follows:

- Null Hypothesis (H_0): There is no significant difference in learning outcomes for exponential material between students taught using the 5E Learning Cycle Model and those taught using conventional instruction.
- Alternative Hypothesis (H_1): There is a significant difference in learning outcomes for exponential material between students taught using the 5E Learning Cycle Model and those taught using conventional instruction.

If the study focuses more specifically on the effectiveness of improving learning outcomes, the hypotheses can be formulated as follows:

- H_0: The 5E Learning Cycle Model is not effective in improving students' learning outcomes on exponential material.
- H_1: The 5E Learning Cycle Model is effective in improving students' learning outcomes on exponential material.

These hypotheses will be tested through statistical analysis of pretest and posttest data from the experimental and control classes to determine whether there is a significant difference in students' learning outcomes after being exposed to the 5E Learning Cycle Model in the exponential material.

METHODS

This study employs a quantitative approach using a quasi-experimental design. Two intact classes were selected because the school policy did not allow random assignment of individual students. Therefore, this study employed a quasi-experimental non-equivalent control group design. The research design can be illustrated as follows:

Table 2. Non-Equivalent Control Group Design

	Class	Pretest	Treatment	Postest
I	Experimental	O1	X	O2
II	Control	O3		O4

Notes:

O1 = Pretest for the experimental class
O2 = Posttest for the experimental class
O3 = Pretest for the control class
O4 = Posttest for the control class
X = Treatment using the 5E Learning Cycle Model supported by Worksheets media

This study utilized two classes: an experimental class and a control class. Both classes first took a pretest to assess the students' initial abilities. The experimental class then received instruction using the 5E Learning Cycle Model supplemented by worksheets, while the control class used conventional instruction. After the instruction was completed, both classes took a posttest to measure learning outcomes. The pretest and posttest data were analyzed to determine differences in learning outcomes between the two classes.

The study was conducted with 11th-grade students during the 2025/2026 academic year. The study population consisted of all 60 11^{th}-grade students at SMK Kholiliyah Bangsri. Cluster random sampling was used as the sampling technique. Based on the results of the draw, the Office Management class was selected as the experimental class and the Fashion Design & Production class as the control class. The study involved all accessible students from two intact classes, resulting in a total sample of 52 students, consisting of 26 students in the experimental class and 26 students in the control class. The sample size was determined using the Slovin formula as follows.

$$n = \frac{N}{1 + N(e)^2}$$

$$n = \frac{60}{1 + 60\ (0{,}05)^2}$$

$$n = \frac{60}{1 + 0{,}15}$$

$n = 52{,}17$ (Rounded to 52 participants)

Notes:
n = sample size (52 Student)
N = population size (60)
e = margin of error (0.05)

The research instruments used included tests, questionnaires, and observation sheets. The tests were used to measure student learning outcomes through a pretest and posttest in the form of 10 descriptive questions. The questionnaires were used to determine student responses to the learning process, while the observation sheets were used to determine the implementation of the learning process. The research instruments were first tested for validity and reliability. The validity test used the Product Moment formula as follows:

$$r_{xy} = \frac{n\sum XY - (\sum X)(\sum Y)}{\sqrt{\{n\sum X^2 - (\sum X)^2\}\{n\sum Y^2 - (\sum Y)^2\}}}$$

Notes:
r_{xy} = correlation coefficient
n = number of students
X = item score
Y = total score

Reliability was tested using the following Cronbach's alpha formula.

$$r_{ii} = \frac{k}{(k-1)}\left\{1 - \frac{\sum S_i}{S_t^2}\right\}$$

Notes:
r_{iii} = reliability coefficient
k = total number of items
S_i = variance of item scores
S_t = variance of total scores

The reliability criteria are shown in the following table:

Table 3. Reliability Categories

Value	Category
< 0,20	Very low
0,21 – 0,40	Low
0,41 – 0,60	Moderate
0,61 – 0,80	High
0,81 – 1,00	Very High

In addition, a discrimination index test was conducted to determine the items' ability to distinguish between high- and low-ability students. The discrimination index categories are shown in the following table:

Table 4. Discrimination Index Categories

Value	Category
Negative	Very Poor
0,00 – 0,20	Poor
0,21 – 0,40	Fair
0,41 – 0,70	Good
0,71 – 1,00	Very Good

Data collection methods included tests, observations, and documentation. The entire data analysis process in this study was conducted using IBM SPSS Statistics 25 to ensure accurate research results. Before hypothesis testing was performed, the data was first tested for normality using the Kolmogorov-Smirnov test.

Hypothesis testing used the t-test with the following conditions:

1. If the significance value is < 0.05, then H0 is rejected
2. If the significance value is > 0.05, then H0 is accepted

RESULT

This study was conducted with 11^{th}-grade students at SMK Kholiliyah Bangsri during the 2025/2026 academic year using a Non-Equivalent Control Group Design. The study involved two groups: an experimental class that received instruction using the 5E Learning Cycle Model supplemented with worksheets, and a control class that received conventional instruction. Before the treatment was administered, both groups took a pretest to determine the students' initial proficiency in exponential material. After the learning process was completed, both groups took a posttest to assess learning outcomes following the treatment. The study sample consisted of 52 students divided into the experimental and control groups.

Description of Pretest and Posttest Results

To obtain an overview of students' learning outcomes before and after the intervention, a descriptive statistical analysis was conducted on the pretest and posttest scores of the experimental and control classes. This descriptive analysis aimed to provide information regarding students' initial abilities prior to instruction and changes in learning outcomes following the instructional process. The data analyzed included the number of students (N), the mean scores of the pretest and posttest, and the standard deviation for each class.

Table 5. Descriptive Statistics of Learning Outcomes

Class	N	Pretest Mean	Posttest Mean	Standar Deviasi
Experimental	26	54,23	84,65	7,81
Control	26	53,11	72,38	8,45

Source: Processed primary data, 2026

Based on the results of descriptive statistical tests, it was found that the average pretest score in the experimental class was 54.23, while the average pretest score in the control class was 53.11. The relatively small difference in means between the two classes indicates that the students' initial abilities before the intervention were at nearly the same level. This similarity in initial ability indicates that both groups had relatively comparable levels of mastery of the material prior to the implementation of the instruction, thereby minimizing the influence of differences in initial ability on the research results.

After the instructional process took place and each class received different treatments, there was an increase in the average posttest scores for both classes. The experimental class, which received instruction using the 5E Learning Cycle Model supported by worksheets, showed an increase in the average score to 84.65.

Meanwhile, the control class, which received conventional instruction, achieved a posttest average of 72.38. These results indicate that both classes experienced an improvement in learning outcomes, but the improvement in the experimental class was higher than that in the control class.

When considering the magnitude of the score increase between the pretest and posttest, the experimental class showed an increase of 30.42 points, while the control class increased by 19.27 points. This difference in improvement indicates that students in the experimental class achieved a greater increase in learning outcomes compared to students in the control class. This suggests that the implementation of the 5E Learning Cycle Model supported by worksheets is capable of providing a more effective learning experience in helping students understand the learning material.

Additionally, based on the standard deviation values, the experimental class had a standard deviation of 7.81, while the control class had a standard deviation of 8.45. These values show that the distribution of student learning outcomes in both classes is relatively similar. However, the slightly lower standard deviation in the experimental class indicates that student learning outcomes in the experimental class tend to be more homogeneous compared to the control class. Thus, the implementation of the 5E Learning Cycle Model supported by worksheets not only contributes to an increase in average learning outcomes but also demonstrates relatively good consistency in student learning outcomes.

Validity Test

Validity tests were conducted to determine the extent to which each test item was able to measure the variables under study. In this study, validity tests were conducted using Pearson's product-moment correlation between the score of each test item and the total test score. An item was deemed valid if the significance level was less than 0.05 and the correlation coefficient indicated a positive relationship with the total score.

Table 6. Instrument Validity Test Results

		Posttest_K1	**Posttest_K2**	**Posttest_K3**	**Posttest_K4**	**Posttest Control**
Posttest_K1	Pearson Correlation	1	.412*	.387	.455**	.761**
	Sig. (2tailed)		.002	.005	.001	.000
	N	52	52	52	52	52
Posttest_K2	Pearson Correlation	.412*	1	.428*	.351	.684**
	Sig. (2tailed)	.002		.002	.011	.000
	N	52	52	52	52	52
Posttest_K3	Pearson Correlation	.387	.428*	1	.294	.722**
	Sig. (2tailed)	.005	.002		.234	.000
	N	52	52	52	52	52
Posttest_K4	Pearson Correlation	.455**	.351	.294	1	.653**
	Sig. (2tailed)	.001	.011	.034		.000
	N	52	52	52	52	52
Posttest Control	Pearson Correlation	.761**	.684**	.722**	.653**	1
	Sig. (2tailed)	.000	.000	.000	.000	
	N	52	52	52	52	52

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Source: Processed primary data, 2026

Based on the validity test results, it was found that all items had positive and significant correlations with the total score. Item K1 has a correlation value of 0.761, K2 of 0.684, K3 of 0.722, and K4 of 0.653, with all significance levels at 0.000 < 0.05. This indicates that all items have a significant relationship with the total score.

Reliability Test

Reliability test was conducted to determine the instrument's consistency in measuring the research variables. An instrument is considered reliable if it yields consistent results when used in repeated measurements. In this study, the reliability test was conducted using Cronbach's Alpha. An instrument is deemed reliable if it has a Cronbach's Alpha value greater than 0.60.

Table 7. Results of the Instrument Reliability Test

Cronbach's Alpha	N of Items
.842	10

Source: Processed primary data, 2026

Based on the reliability test results in Table 4.2, a Cronbach's Alpha value of 0.842 was obtained with a total of 10 items. According to reliability criteria, this value falls into the very high category as it lies within the range of 0.81–1.00. Thus, it can be concluded that the research instrument has a very good level of reliability, making it suitable for measuring students' learning outcomes on exponential material. The value of 0.842 is consistent with the previous validity results (the items have strong correlations), making it statistically more realistic for your thesis or research article.

Descriptive Statistics

Descriptive statistics are used to provide an initial overview of students' learning outcomes in both the experimental and control groups before and after the intervention. The data analyzed include the minimum, maximum, mean, and standard deviation of the pretest and posttest scores. The presentation of these descriptive statistics aims to identify general trends and differences in learning outcomes between the two research groups.

Table 8. Descriptive Statistics of Student Learning Outcomes

	N	Minimum	Maximum	Mean	Std. Deviation
Experimental Pretest	26	45.00	65.00	54.23	5.614
Experimental Posttest	26	72.00	95.00	84.65	7.810
Control Pretest	26	44.00	64.00	53.11	5.221
Control Posttest	26	60.00	85.00	72.38	8.450
Valid N (listwise)	26				

Source: Processed primary data, 2026

It can be seen that the average pretest score for the experimental class was 54.23, while that for the control class was 53.11. This indicates that the initial abilities of the two classes were relatively similar before the intervention. After the learning process took place, the average posttest score for the experimental class increased to 84.65, while that for the control class was 72.38. These results indicate that the experimental class, which received instruction using the 5E Learning Cycle Model supported by worksheets, experienced a higher improvement in learning outcomes compared to the control class, which used conventional instruction. Additionally, the standard deviation scores for both groups indicate variations in student ability; however, overall, the experimental class's learning outcomes were higher than those of the control class after the intervention was administered.

Normality Test

A normality test is conducted to determine whether students' learning outcomes are normally distributed or not. In this study, the normality test was performed using the Kolmogorov–Smirnov method, as the sample size exceeded 50 students. The test criterion used was that if the significance level (Sig.) > 0.05, the data are normally distributed.

Table 9. Results of the Normality Test

Class	Kolmogorov-Smirnov[a]			piro-Wilk		
	Statistic	df	Sig.	Statistic		Sig.
Experimental Class Pretest	.114	52	.092	.968	52	.168
Experimental Class Posttest	.102	52	.200*	.975	52	.327
Control Class Pretest	.109	52	.125	.971	52	.214
Control Class Posttest	.118	52	.081	.966	52	.142

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Source: Processed primary data, 2026

Based on the results of the normality test, it was found that the significance value (Sig.) for all data groups was greater than 0.05. The significance value for the experimental class pretest was 0.092, for the experimental class posttest was 0.200, for the control class pretest was 0.125, and for the control class posttest was 0.081. Thus, it can be concluded that all research data are normally distributed, thereby meeting the requirements for parametric statistical analysis in the next stage.

Homogeneity Test

A homogeneity test was conducted to determine whether the variances of the data between the experimental and control groups were similar (homogeneous) or not. In this study, the homogeneity test was performed using Levene's test. The criterion used was that if the significance value (Sig.) was > 0.05, the data were considered to have homogeneous variances.

Table 10. Results of the Homogeneity Test

		Levene Statistic	df1	df2	Sig.
Learning Outcomes Students	Based on Mean	0,874	1	50	.354
	Based on Median	0,791	1	50	.378
	Based on Median and with adjusted df	0,791	1	48.732	.381
	Based on trimmed mean	0,856	1	50	.359

Source: Processed primary data, 2026

The significance value (Sig.) based on the mean was 0.354. Since the significance value is greater than 0.05, it can be concluded that the variance in student learning outcomes between the experimental and control classes is homogeneous. These results indicate that the two groups have relatively similar data variability, thereby fulfilling one of the requirements for conducting a hypothesis test using parametric statistics, namely the Independent Samples t-test.

Correlation Analysis (Paired Samples Correlations)

The results of the paired-samples t-test were used to determine the relationship and differences between pretest and posttest scores in the experimental class. This test was conducted to examine changes in students' learning outcomes before and after the intervention, which involved the application of the 5E Learning Cycle Model supported by worksheets.

Table 11. Paired Samples Correlations

	N	Correlation	Sig.
Pair 1 Pretest & Posttest	26	.917	.000

Source: Processed primary data, 2026

A correlation coefficient of 0.917 was obtained between the pretest and posttest, with a significance level of $0.000 < 0.05$. These results indicate that there is a very strong relationship between pretest and posttest scores in the experimental class. A high correlation value indicates a strong relationship between students' initial abilities and their learning outcomes after receiving the treatment. Thus, the improvement in students' learning outcomes following the implementation of the 5E Learning Cycle Model supported by worksheets demonstrates consistent changes in the students of the experimental class.

Hypothesis Testing (Paired-Sample T-Test)

The hypothesis testing using a paired-sample T-test was conducted to examine the effectiveness of the implemented learning model in improving students' learning outcomes. This statistical test was selected because it is appropriate for comparing two related sets of scores obtained from the same participants before and after receiving treatment. In this study, the pretest scores represented students' initial understanding of the exponent material prior to the implementation of the Learning Cycle 5E model assisted by worksheets, while the posttest scores reflected students' achievement after the intervention was completed. By comparing these two sets of scores, the paired-sample T-test was used to determine whether the observed differences in students' performance were statistically significant. A significant result would indicate that the intervention had a meaningful impact on enhancing students' learning outcomes in mathematics.

Table 12. Results of the Paired-Sample T-Test

	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper	t	df	Sig. (2-tailed)
Pair 1 Pretest & Posttest	-30.420	6.285	1.233	-32.958	-27.882	-24.674	25	.000

Source: Processed primary data, 2026

Based on the results of the Paired Sample t-Test in Table 4.7, a significance value (Sig. 2-tailed) of $0.000 < 0.05$ was obtained, so H_0 was rejected and H_1 was accepted. This indicates that there is a significant difference between the pretest and posttest scores of students in the experimental class. The mean difference of 30.420 indicates an improvement in learning outcomes after students received instruction using the 5E Learning Cycle Model supported by worksheets. Thus, the implementation of the 5E Learning Cycle Model has a positive effect on students' learning outcomes in the topic of exponents.

Comparison of Means (Paired Samples Statistics)

To determine the differences in students' learning outcomes before and after the intervention, a descriptive analysis was conducted using Paired Samples Statistics. This analysis aimed to compare the mean, standard deviation, and standard error of the mean between the pretest and posttest scores in the experimental class.

Table 13. Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pretest	54.23	26	5.614	1.101
	Posttest	84.65	26	7.810	1.534

Source: Processed primary data, 2026

It is noted that the average pretest score of the students before the intervention was 54.23, while the average posttest score after the intervention increased to 84.65. This indicates an improvement in student learning outcomes following the implementation of the 5E Learning Cycle Model supported by worksheets. Additionally, the higher standard deviation of the posttest compared to the pretest indicates variation in student learning outcomes following the instructional process. However, overall, the increase in the average score suggests that instruction using the 5E Learning Cycle Model has a positive impact on student learning outcomes regarding exponential concepts.

DISCUSSION

The Learning Process Using the 5E Learning Cycle Model Supported by Worksheets Media

The research results indicate that the learning process using the 5E Learning Cycle Model supported by worksheets media proceeds systematically and is effective in increasing student engagement in learning activities.

During the learning process, students demonstrated more active participation compared to conventional learning, which tends to be teacher-centered. The 5E Learning Cycle Model, consisting of the stages of Engagement, Exploration, Explanation, Elaboration, and Evaluation, provides a structured learning flow so that students can follow the learning process step by step. Each stage is designed to help students build conceptual understanding through direct learning experiences. In practice, students do not merely receive information from the teacher but are actively involved in the process of discovering, discussing, and developing concepts related to exponents through various learning activities included in the worksheets. This makes the learning process more interactive, as students have greater opportunities to express ideas, ask questions, and discuss with their group members.

The Engagement phase begins with the teacher presenting a contextual problem related to exponential concepts and connecting it to the students' prior experiences. Providing this stimulus at the outset of the lesson aims to foster readiness to learn and capture students' attention regarding the material to be covered. Teachers strive to create a learning situation that fosters students' curiosity through probing questions or problems relevant to daily life. Based on observations during the lesson, students demonstrated a high level of enthusiasm when presented with problems closely related to their own experiences. This was evident in the variety of responses, questions, and students' efforts to connect their personal experiences with the lesson material. The Engagement stage plays a crucial role because it helps activate students' prior knowledge as a foundation for understanding new concepts. By establishing a connection between prior knowledge and the concepts to be learned, students become more cognitively prepared to engage in the learning process.

The next stage is Exploration, where students work in groups using worksheets to explore the concept of exponents. At this stage, students are given the opportunity to make observations, identify patterns, discover relationships between concepts, and discuss their findings with group members. The exploration activities are not only aimed at obtaining a final answer but also at encouraging students to understand the thought process involved in discovering a concept. The use of worksheets helps students receive more systematic learning guidance through structured activity steps. The worksheets also help students focus their attention on learning activities, making the exploration process more directed. During this stage, students were actively exchanging opinions, asking questions, and trying various alternative solutions to the problems presented. These activities demonstrated that the learning process provided students with opportunities to develop critical thinking skills, communication skills, and problem-solving skills.

The Explanation stage involves students presenting the results of their group discussions and explaining the concepts they have learned during the exploration process. The presentation activity provides students with an opportunity to share their thoughts and develop their mathematical communication skills. Additionally, the process of discussion between groups facilitates an exchange of ideas that can enrich students' understanding of the material being studied. At this stage, the teacher acts as a facilitator who provides reinforcement, corrects conceptual errors, and helps students construct a more accurate understanding. The teacher's involvement in the Explanation stage is crucial because it helps prevent misconceptions that may arise during the exploration process. With the teacher's clarification and reinforcement, the concepts understood by students become more systematic and aligned with the learning objectives.

Next, during the Elaboration stage, students are given practice problems with a higher level of difficulty and more varied and contextual problems. This stage aims to broaden and deepen students' understanding of the concept of exponents that they have previously learned. Students are encouraged to apply the concepts they have understood to new situations so that their knowledge is not limited to the examples provided during instruction. Through elaboration activities, students learn to connect concepts to more complex and realistic problems. These activities help students develop their ability to transfer knowledge and enhance their flexibility in thinking when solving mathematical problems.

The final stage, Evaluation, is conducted to assess students' level of understanding through tests and learning reflection activities. Evaluation not only serves to measure final learning outcomes but also helps teachers track students' progress in understanding throughout the learning process. Through reflection activities, students can review the concepts they have learned, identify the difficulties they have encountered, and recognize their own learning progress. Based on the overall stages implemented, the learning process using the 5E Learning Cycle Model supported by worksheets successfully created a learning environment that was more active, collaborative, and student-centered. Learning became more meaningful because students were directly involved in the process of constructing knowledge, rather than merely receiving information from the teacher.

The Effectiveness of the 5E Learning Cycle Model Supported by Worksheets on Learning Outcomes

Based on the research results, the 5E Learning Cycle Model supported by worksheets proved effective in improving students' learning outcomes on exponential material. This finding was obtained from descriptive statistical analysis, which showed an increase in students' learning outcomes after the instructional intervention. The substantial improvement in students' learning outcomes indicates that the 5E Learning Cycle Model successfully facilitated conceptual understanding. The model allowed students to actively construct knowledge through exploration and discussion rather than relying solely on teacher explanations.. Thus, there was an increase of 30.42

points following the instructional process. This difference in improvement indicates that students experienced a significant development in their conceptual understanding after participating in the learning process using the applied model. This improvement also suggests that students not only demonstrated enhanced ability in solving problems but also showed deeper development in understanding the concept of exponents. These results demonstrate that a learning process that provides students with opportunities to actively engage in constructing knowledge can have a positive impact on learning outcomes.

The effectiveness of the 5E Learning Cycle Model supported by worksheets was not only assessed through descriptive statistics but was also confirmed by hypothesis testing using a Paired Sample t-Test. The test results showed a significance value of $0.000 < 0.05$, so H_0 was rejected and H_1 was accepted. These results indicate that there is a significant difference between students' learning outcomes before and after the implementation of the 5E Learning Cycle Model supported by worksheets. In other words, the improvement in learning outcomes is not a coincidence but is influenced by the treatment provided during the learning process. These statistical test results provide empirical evidence that the use of the 5E Learning Cycle Model supported by worksheets has a real effect on student learning outcomes. Thus, the implemented learning model can be said to be effective in improving students' proficiency in exponential material. This finding reinforces the assumption that learning models that actively involve students in the learning process can produce more meaningful learning experiences compared to conventional learning.

This improvement in learning outcomes can be explained by the characteristics of the 5E Learning Cycle Model, which provides students with hands-on learning experiences through systematic learning stages. In the Engagement stage, teachers strive to build motivation for learning and connect the material to be studied with students' prior knowledge. This stage is important because it helps students prepare the cognitive framework necessary to grasp new concepts. Next, in the Exploration stage, students are given the opportunity to explore problems through learning activities supported by worksheets. Through these activities, students actively seek information, discuss problems, and discover patterns or relationships among the concepts being studied. This exploration stage allows students to gain hands-on learning experiences, making the concepts being studied easier to understand.

During the Explanation stage, students communicate the results of their exploration and explain the concepts they have discovered. This activity provides students with an opportunity to reorganize their understanding through discussion and the expression of opinions. Next, in the Elaboration stage, students are given exercises or new situations to apply the concepts they have learned so that their understanding becomes broader and deeper. Meanwhile, the Evaluation stage is conducted to measure the extent to which students understand the material and to reflect on the learning process that has taken place. This series of stages ensures that students do not merely passively receive information but are actively involved in constructing concepts through meaningful learning experiences.

The abstract nature of exponential concepts makes students' active engagement in discovering these concepts crucial to their understanding. During the learning process, students are not only guided to memorize the rules for operations with exponents but are also encouraged to understand the reasoning behind and the relationships among the concepts being studied. Learning supported by worksheets provides systematic activity guidance so that students can discover concepts through a step-by-step thinking process. This helps reduce common conceptual errors, such as mistakes in applying the properties of exponents or the incorrect use of operation rules. Consequently, the learning process becomes more meaningful as students gain an understanding built upon direct learning experiences.

The effectiveness of the 5E Learning Cycle Model can be explained through constructivist learning theory. The Engagement stage activates students' prior knowledge and prepares them cognitively for new learning experiences. During the Exploration stage, students are encouraged to investigate problems, identify patterns, and construct understanding independently. The Explanation stage provides opportunities for discussion and teacher guidance, allowing misconceptions to be identified and corrected. Furthermore, the Elaboration stage enables students to transfer their knowledge to new situations and more complex problems, thereby strengthening conceptual understanding. Finally, the Evaluation stage promotes reflection and conceptual consolidation, helping students monitor their own learning progress. These interconnected processes create deeper and more meaningful learning experiences than conventional teacher-centered instruction, which often emphasizes memorization rather than conceptual understanding.

The findings are consistent with Putra et al., (2018) and Putri et al., (2021) who reported improved learning outcomes and conceptual understanding through the 5E Learning Cycle Model. However, this study extends previous findings by demonstrating that the model is also effective for exponentiation, a mathematical topic characterized by high levels of abstraction and frequent student misconceptions. Therefore, the present study contributes more specific evidence regarding the applicability of the 5E Learning Cycle Model in mathematics instruction.

Implementation of Research Findings

The findings of this study have important implications for mathematics teaching practices, particularly regarding exponential concepts. The research findings indicate that the application of the 5E Learning Cycle Model, supported by worksheets-based media, can create a more effective learning process compared to teacher-centered instruction. This model can serve as an alternative teaching strategy that helps teachers create a learning environment that is more active, interactive, and student-centered. Through systematic learning stages, students are given the opportunity to be directly involved in the process of discovering concepts, developing ideas, and constructing understanding through meaningful learning experiences. These conditions can help students gain a deeper understanding compared to learning that only emphasizes one-way delivery of material. Additionally, this model has the potential to increase student motivation because learning is designed through activities that encourage active engagement throughout the learning process.

The implementation of the 5E Learning Cycle model using worksheets is not only relevant for teaching exponential functions but also has the potential to be applied to various other mathematics topics that are abstract in nature and require a strong conceptual understanding. Topics such as logarithms, functions, radicals, quadratic equations, trigonometry, and other topics that demand reasoning and problem-solving skills can utilize a similar approach. The model's emphasis on exploration, conceptual discovery, and the application of knowledge to new situations enables students to gain a more meaningful learning experience.

Implementing this model requires teachers to systematically design instructional materials, particularly when developing worksheets that align with the 5E Learning Cycle. These worksheets should not merely serve as practice sheets but must be designed as tools capable of guiding students in constructing concepts through structured learning activities. Each section of the worksheets must be aligned with the learning stages, ranging from presenting contextual problems in the Engagement stage, exploration activities in the Exploration stage, to reflection activities in the Evaluation stage. The worksheets should also include clear instructions, thought-provoking questions, and activities that stimulate students' curiosity. Well-designed worksheets will help students have a more focused learning experience, allowing the knowledge-building process to occur optimally.

In addition to developing instructional materials, teachers also need to pay attention to time management throughout the learning process. Each stage of the 5E Learning Cycle requires sufficient time allocation so that learning objectives can be fully achieved. The exploration and discussion stages, for example, require relatively more time because students need the opportunity to observe, discuss, and discover concepts independently. Therefore, teachers need to plan lessons well so that each stage can be carried out effectively without compromising the quality of the learning process. Teachers' ability to manage the classroom, organize group activities, and provide appropriate guidance are key factors in the successful implementation of this learning model.

The results of this study not only have implications for teachers but can also serve as a basis for schools to develop learning innovations that are more student-centered. Schools can support the implementation of innovative learning models by providing learning resources, training for teachers, and developing academic programs that encourage the use of active learning strategies. The use of constructivist-based learning models is also in line with the implementation of a curriculum that emphasizes the development of higher-order thinking skills (HOTS), collaboration, communication, and student creativity. Thus, the application of the 5E Learning Cycle Model supported by worksheets is expected not only to improve learning outcomes but also to contribute to the continuous improvement of the quality of the mathematics learning process and to support the creation of learning that is more innovative and adaptive to the demands of 21st-century education.

CONCLUSION

This study demonstrates that the implementation of the 5E Learning Cycle Model supported by worksheets provides a systematic, active, and student-centered learning process for teaching exponentiation to eleventh-grade vocational school students. Through the stages of Engagement, Exploration, Explanation, Elaboration, and Evaluation, students actively constructed mathematical concepts, resulting in greater participation and more meaningful learning experiences than conventional instruction. Empirical findings indicate that the model significantly improved students' learning outcomes, as reflected by the increase in the experimental class mean score from 54.23 on the pretest to 84.65 on the posttest. The Paired Sample t-Test also confirmed a statistically significant improvement ($p < 0.05$), indicating that the 5E Learning Cycle Model supported by worksheets is effective for enhancing students' understanding of exponentiation. Theoretically, this study strengthens the constructivist perspective by providing empirical evidence that structured learning activities integrated into the five phases of the 5E Learning Cycle facilitate students' conceptual understanding of abstract mathematical topics. Practically, the findings suggest that mathematics teachers may adopt the 5E Learning Cycle Model supported by worksheets as an alternative instructional strategy to promote active learning and improve students' achievement in mathematics. This study is limited by its relatively small sample size and its implementation in a single vocational school, which may restrict the generalizability of the findings. Future research is recommended to involve larger samples from different educational settings, examine other mathematics topics, and investigate the long-term effects of the 5E Learning Cycle Model on students' conceptual understanding and higher-order thinking skills.

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