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Effect of Conceptual Scaffolding in the E-Recitation Program on Students Conceptual Understanding

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Abstract: Conceptual understanding is a fundamental aspect of physics learning because each concept is interrelated and becomes the basis for mastering subsequent materials. However, students often experience misconceptions that lead to low conceptual mastery. This study aims to analyze the effect of conceptual scaffolding in the E-Recitation program on students' conceptual understanding of temperature and heat. This study uses a quantitative, experimental approach with a One-Group Pretest-Posttest Design, which involves a single group without a control group. The research subjects were 29 grade XI Science students. The research procedure consisted of three main stages: administering a pretest to measure students' initial abilities, providing treatment by implementing conceptual scaffolding in the E-Recitation program, and administering a posttest to measure changes in conceptual understanding after treatment. The instrument used was a conceptual understanding test comprising 20 multiple-choice questions, validated by experts. The data were analyzed using the Shapiro-Wilk normality test followed by a paired sample t-test to test the hypothesis, as well as to calculate the effect size. The average pretest score of 55.00 increased to 77.24 in the posttest. The analysis results indicate that the data are normally distributed, and the paired-samples t-test is significant ($p = 0.000 < 0.05$), indicating a significant difference between the pretest and posttest results. In addition, the effect size of 2.07 falls in the very large category. The novelty of this study lies in the direct application of conceptual scaffolding to each answer choice through guiding questions and conceptual feedback videos in the E-Recitation system. Thus, it can be concluded that the application of conceptual scaffolding in the E-Recitation program has a very significant effect on improving students' conceptual understanding of temperature and heat.

Keywords: Conceptual Scaffolding; Conceptual understanding; E-Recitation.

Introduction

Understanding is an important component in the cognitive domain. A person is said to understand a concept if they are able to grasp the meaning and substance contained within it [1]. Conceptual understanding is one of the achievements in the learning process that reflects the ability of students to demonstrate mastery of the material, explain the relationships between concepts, and apply concepts appropriately, effectively, and systematically in solving problems [2]. Thus, conceptual understanding plays a fundamental role in successful learning because it serves as the basis for the development of critical and problem-solving skills, as well as for in-depth, structured mastery of the material.

Conceptual understanding is an important asset in learning Physics. Each topic in physics learning is closely related, so that initial conceptual understanding is an important prerequisite before studying the next material [3]. Understanding of physics concepts reflects the ability of students to internalize the meaning of the material being studied and be able to convey the concept again with a simpler explanation [4]. However, based on observations and information from one of the junior high schools in the odd semester of the 2017/2018 academic year, the average understanding of Physics concepts among students remains relatively low. This problem is evident especially in the material on temperature and heat, which is one of the topics in physics learning [5].

Temperature and heat are difficult topics that students often poorly understand. Phenomena related to temperature and heat are closely related to everyday life, but students often have difficulty explaining them scientifically due to the abstract nature of the topic [6]. This is also supported by research findings showing that students' conceptual understanding of temperature and heat, based on reasoned multiple-choice tests, has an average score of 13.06 [7]. Therefore, it can be concluded that students' understanding of temperature and heat is still in the very low category.

Thus, one strategy is conceptual scaffolding, an effective way to gradually support students in developing conceptual understanding. Scaffolding is a teacher's effort to provide students with assistance so that learning objectives can be achieved optimally [8]. Research indicates that scaffolding in physics instruction is effective in improving students' conceptual understanding of temperature and heat. By providing targeted and gradual assistance, students more easily overcome learning difficulties and develop a more meaningful understanding [9]. Conceptually, scaffolding provides structured, temporary assistance to help students identify misconceptions, connect prior knowledge with correct scientific concepts, and gradually carry out cognitive restructuring. With this mechanism, scaffolding not only helps students find the correct answer but also corrects the structure of erroneous conceptual understanding.

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Conceptual scaffolding is very useful in supporting students who lack adequate prior knowledge, enabling them to construct new knowledge in a more focused and effective manner [10]. However, one of scaffolding's shortcomings is the difficulty teachers face in adapting the scaffolding design to each student's abilities. In addition, limited class time is a real obstacle for teachers in implementing scaffolding optimally [11]. These conditions indicate that providing conceptual assistance, ideally done right when students make mistakes, cannot be fully implemented in conventional learning. Therefore, a system is needed that provides scaffolding in a more flexible and timely manner.

As technology advances, the E-Recitation program can be an effective alternative to overcome time constraints in implementing conceptual scaffolding. The recitation method is also known as the assignment method. Although often equated, assignments are not the same as homework and have a broader scope. Recitation is a method that can increase student activeness when learning, both individually and in groups [12]. Recitation is an activity in which the teacher delivers lesson material and gives certain tasks to students. The assigned tasks can be done both in class and outside of class time [13].

Meanwhile, the Recitation Program is a system that provides multiple-choice practice questions, complete with feedback for each answer, both correct and incorrect, to assist and improve students' problem-solving skills [14]. The Recitation Program is a learning program that uses the recitation method, assigning students specific tasks to complete outside class hours. This method, when implemented, can help improve conceptual understanding and mastery. Recitation programs generally contain conceptual questions supplemented with feedback, where providing feedback on each answer choice plays a crucial role in strengthening students' conceptual mastery[15].

In this study, conceptual reinforcement was integrated directly into the E-Recitation system, specifically for each incorrect answer choice in the form of guiding questions and conceptual explanation videos. This integration forms a learning mechanism involving three stages: identifying misconceptions through student responses to questions, providing direct conceptual assistance when errors occur, and strengthening understanding through repeated practice and digital feedback. This mechanism systematically links conceptual reinforcement, E-Recitation, and improved conceptual understanding. Thus, through the E-Recitation program, the physics learning process can be integrated with conceptual reinforcement in a more flexible and structured manner. This approach is expected to be an innovative solution for effectively and sustainably improving students' conceptual understanding.

Research Methods

This research is a quantitative study with an experimental design using a One-Group Pretest-Posttest Design, with one group of subjects and no control group. The selection of this design is based on the research's focus on observing improvements in students' conceptual understanding of temperature and heat, as well as on the effect of implementing conceptual scaffolding in the e-recitation program. The research was carried out in three main stages: administering a pretest to measure students' initial conceptual understanding, implementing conceptual scaffolding in the E-Recitation program, and administering a posttest to measure changes in students' conceptual understanding after the treatment.

Study implemented during four meetings on the material temperature and heat. The meeting first started with administering a pretest to measure the ability of beginning understanding draft students. Meetings two and three were used to implement integrated learning with the E-Recitation program based on conceptual scaffolding. In meeting four, after all the series of interventions had finished, students were given a posttest to measure the change in understanding.

The research subjects were all 29 grade XI science students. The sampling technique used was saturated sampling, meaning the entire population served as the research sample. Data collection was conducted using a multiple-choice test of conceptual understanding. In this study, the test implementation consisted of two stages, namely a pretest and a posttest. Before the treatment, a pretest was administered to assess students' initial understanding of the material on temperature and heat. As an initial benchmark, the results of this pretest were used before the learning intervention was carried out. Furthermore, a posttest was conducted after the implementation of conceptual scaffolding in the e-recitation program. The research instrument was validated by two experts, namely a physics education lecturer and a physics teacher, and was declared suitable for use. This research focuses on the content validity of the instrument; therefore, interpretation of the results is limited to the context of content validity confirmed by experts.

The conceptual scaffolding in the E-Recitation program is implemented through 20 interactive multiple-choice questions. Each question is designed to identify potential misconceptions regarding temperature and heat. If a student selects an incorrect answer, the system automatically displays conceptual support in the form of a short explanatory video that links the incorrect answer to the correct scientific concept. This support provides immediate feedback before students move on to the next question. This mechanism allows for the gradual process of error identification, conceptual clarification, and reconstruction of understanding.

Data analysis began with a Shapiro-Wilk normality test to assess the data distribution. The criteria for the normality test are that data is considered normally distributed if the p-value is > 0.05 and not normally distributed if the p-value is < 0.05. Next, hypothesis testing was carried out using a paired-samples t-test (or a Wilcoxon test if the data are not normally distributed) at the 0.05 significance level. To determine the magnitude of the treatment effect, an effect size (Cohen's d) was calculated to describe the strength of conceptual scaffolding's influence on students' conceptual understanding.

Table 1. Effect Size Criteria

Effect Size	Interpretation
$ES < 0.2$	Small
$0.2 < ES < 0.8$	Currently
$ES > 0.8$	Tall

Because this study did not include a control group, the resulting causal conclusions are limited to indications of improvement after the intervention and do not completely rule out the influence of external factors.

Results and Discussion

Based on the pretest and posttest results of 29 students, the following descriptive statistical data were obtained. The pretest scores ranged from 35 to 80, with an average of 55.00 and a standard deviation of 11.726. Meanwhile, the posttest scores ranged from 60 to 95 with an average of 77.24 and a standard deviation of 9.69. The difference in score range indicates a shift in the score distribution towards higher levels after implementing the scaffolding concept in the E-Recitation program.

Table 2. Descriptive Statistics of Pretest and Posttest Scores of Students' Concept Understanding

	N	Min.	Max.	Mean	Std. Deviation
PRETEST	29	35.00	80.00	55.0000	11.72604
POSTTEST	29	60.00	95.00	77.2414	9.69040
Valid N (listwise)	29				

There was an average increase of 22.24 points after the implementation of conceptual scaffolding in the E-Recitation program. In addition to the average increase, the minimum score also increased from 35 in the pretest to 60 in the posttest. The decrease in the standard deviation from 11.726 to 9.69 indicates that the variation in student abilities after the treatment was more even than before.

Normality tests were conducted on two types of pretest and posttest data. Because the sample size in this study was less than 30, normality was assessed using the Shapiro-Wilk test. The results of the normality test are as follows:

Table 3. Pretest and Posttest Normality Tests

	Kolmogorov-Smirnov [a]			Shapiro-Wilk		
	Statistics	df	Sig.	Statistics	df	Sig.
Pretest	.086	29	.200 *	.974	29	.672
Posttest	.143	29	.133	.959	29	.308

Based on the results of the statistical analysis of the prerequisite test, the pretest and posttest data were found to be normally distributed. By fulfilling the normality assumption, the hypothesis testing in this study can be conducted using parametric statistical analysis. Therefore, the statistical test used to test the hypothesis is the Paired Sample T-Test. The use of this test is based on the characteristics of the research data, namely, the pretest and posttest data originating from the same sample group and satisfying the normality assumption. This test aims to determine whether there is a statistically significant effect on students' conceptual understanding before and after treatment.

Based on the test results table using the Paired Sample T-Test, the t-statistic was -17.065 with 28 degrees of freedom (df) and a significance value of Sig. (2-tailed) of 0.000. This significance value is below the significance level of $0.000 < 0.05$, so the null hypothesis (H_0) is rejected, and the alternative hypothesis (H_a) is accepted. Thus, it can be concluded that the implementation of conceptual scaffolding in the E-Recitation program significantly improves students' conceptual understanding of temperature and heat.

Table 4. Sample T-Test Test Results

	Mean	Standard Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	Upper			
Pretest - posttest	-22.24138	7.01862	1.30333	-24.91112	-19.57164	-17,065	28	.000

Test analysis results: A Paired Samples T-Test indicated that the implementation of conceptual scaffolding in the E-recitation program significantly improved students' conceptual understanding of temperature and heat. However, to further determine the extent of this influence, an effect size test was conducted. The results of the effect size test are presented in the following table:

Table 5. Effect Size Test Results (Cohen's d)

	Mean	Standard Deviation	Pooled Elementary School	Effect size value
Pretest	55	11.72604	10.759	2.07
Posttest	77.2414	9.69040		

The effect size test in this study used Cohen's d. The calculation yielded a Cohen's d of 2.07, which falls within the very large effect category ($d > 0.8$). A high effect size indicates that the difference in students' conceptual understanding before and after learning is not only statistically significant but also has a real and relevant impact on the learning process. This indicates that the implementation of conceptual scaffolding in the E-Recitation program has a very significant influence on improving students' conceptual understanding.

The implementation of conceptual scaffolding in the E-Recitation program is designed as a form of learning support that emphasizes structured conceptual assistance. Conceptual scaffolding is provided through explanations of key concepts, guiding questions, and reinforcement of main ideas integrated into the E-Recitation digital assignments. Through this mechanism, students are guided to construct their own understanding while still receiving support to help them overcome conceptual difficulties. One application that can support the E-Recitation program is Liveworksheet. The Liveworksheet application is a platform that provides online worksheets with an attractive appearance and is easily accessible to students. Through this application, learning materials can be presented in various formats, such as images, symbols, audio (MP3), and even video [16].

The E-Recitation program functions as a structured digital recitation tool through a series of questions structured around indicators of conceptual understanding, encouraging students to review the material and connect prior concepts to new ones. Each student's answers to the provided questions serve as the basis for conceptual support. This support is not intended to provide direct answers, but rather to help students review concepts they do not yet understand and build their understanding based on sound scientific principles.

Figure 1. Example of the front view of the E-Recitation program

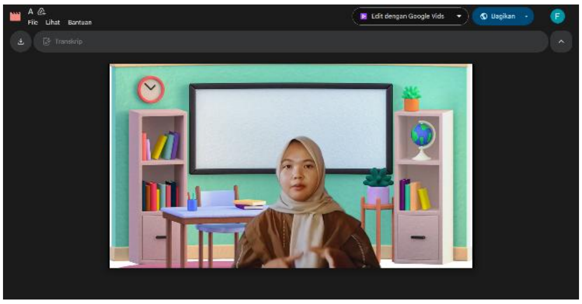

Figure 2. Video view of conceptual scaffolding in the form of an explanation of each incorrect choice.

The increase in the mean score from 55.00 to 77.24 indicates a change in students' conceptual understanding after the implementation of conceptual scaffolding in the E-Recitation program. This improvement is reflected not only in the mean difference but also in the increase in the minimum score and the decrease in the standard deviation. The decrease in the standard deviation indicates that the intervention not only improved the achievement of high-ability students but also helped students with low initial abilities, thus providing a more even distribution of understanding. Thus, the improvement is both quantitative and structural in terms of equitable understanding.

The study found that implementing conceptual scaffolding in the E-Recitation program improved students' understanding of temperature and heat. This effect was evident in students' ability to answer questions, as they demonstrated greater accuracy and consistency in differentiating between the concepts of temperature and heat and in understanding the mechanisms of heat transfer. Then, it can be seen from the effect size value obtained, 2.07, with a very large effect category, compared to that in previous scaffolding research, with an effect size of 1.29 [17]. This indicates that conceptual scaffolding not only improves learning outcomes in terms of grade achievement but also enhances students' conceptual understanding.

This influence can be interpreted as resulting from systematic support that guides students' cognitive processes. Conceptual scaffolding helps students identify errors, correct inaccurate understandings, and gradually reconstruct knowledge that is more in line with the concept [18]. In its implementation, students receive conceptual guidance that encourages analysis of the answers given and adjustments to relevant scientific principles, so that the process of refining understanding takes place in a directed manner. This process has the potential to create cognitive conflict that encourages deeper conceptual reconstruction rather than merely correcting answers. Through this process, the improvements achieved are not only the result of practice, but also of continuous conceptual development reinforced by direct feedback in the E-Recitation program.

Theoretically, the results of this study are consistent with the learning theory, which holds that knowledge is actively constructed by students through the process of linking new information with previously acquired knowledge. One strategy considered relevant is scaffolding in the Zone of Proximal Development (ZPD) developed by Vygotsky. Scaffolding is understood as a form of temporary assistance that allows students to reach a higher level of understanding before being able to learn independently [19]. In the context of this study, conceptual explanation videos provided after students make mistakes function as temporary assistance that gradually reduces student dependence and encourages independence. Thus, conceptual scaffolding in the E-Recitation program acts as a supporting tool for students to build a more meaningful understanding.

The study's results indicate a significant increase in students' conceptual understanding following the implementation of conceptual scaffolding in the E-Recitation program. This is also supported by research results showing that the application of E-scaffolding in guided inquiry learning has a significant influence on students' conceptual understanding [20]. The similarity of these results confirms that providing structured conceptual assistance, both through E-Recitation and E-scaffolding, can build and improve students' conceptual understanding.

This is in line with research that the PBL learning model, combined with scaffolding, has an effect on students' conceptual understanding, as indicated by significant differences in learning outcomes [21]. This alignment of results confirms that scaffolding integration can improve the quality of conceptual understanding through systematic conceptual assistance. Research has shown that computer-assisted recitation programs improve mastery of physics concepts. The program is designed with several main components, one of which is practice questions accompanied by feedback on each answer choice. The similarity with this research is the use of a digital platform that provides reinforcement through direct feedback [22]. The difference is that this research specifically emphasizes the staged structure of conceptual scaffolding, so that it not only provides feedback but also systematically directs students' thinking processes in building conceptual understanding.

The results of this study are also supported by studies related to program-based recitation methods. One method that can improve students' conceptual mastery is program-based recitation, which involves assigning tasks with feedback on each answer. Its application has been shown to significantly improve students' understanding of physics concepts [23]. The similarity with this study lies in the function of feedback as a means of directly clarifying conceptual errors. In line with that, the study stated that the use of a recitation program has been shown to significantly improve conceptual understanding, with a moderate improvement, because this program provides feedback [24].

Although the study's results showed a significant increase with an effect size of 2.07, which is categorized as very large, interpreting the magnitude of this effect requires caution. In research, an effect size above 2 is considered very high and can be influenced by the characteristics of the study design [25]. The One Group Pretest-Posttest Design used has limitations in controlling external variables, such as testing effects, practice effects, and maturation effects. Therefore, the increase in scores cannot be fully attributed to the intervention without considering other contributing factors. Thus, although the conceptual scaffolding in the E-Recitation program shows strong potential in improving conceptual understanding, generalization of the findings must be done proportionally and accompanied by the development of a stronger research design in future studies, for example, by involving a control group to strengthen internal validity.

Based on the overall analysis, the implementation of conceptual scaffolding in the E-Recitation program has a significant impact on students' conceptual understanding of temperature and heat. The difference in comprehension ability before and after implementation indicates that structured conceptual support can help students build a better understanding. Furthermore, the magnitude of the effect shown confirms that conceptual scaffolding not only has a statistical impact but also makes a real contribution. Thus, conceptual scaffolding in the E-Recitation program can be considered an effective learning support strategy for gradually and independently improving students' conceptual understanding.

Conclusion

Based on the results of the data analysis and hypothesis testing, it can be concluded that the implementation of conceptual scaffolding in the E-Resitation program significantly influences students' conceptual understanding of temperature and heat. The results of the paired-samples t-test yielded a significance value of 0.000 (<0.05), indicating a significant difference between the pretest and posttest scores after treatment. In addition, the effect size (Cohen's d) of 2.07 falls in the very large category, indicating that the treatment effect is not only statistically significant but also has a strong practical impact. The results of this study indicate that integrating conceptual scaffolding into the E-Resitation program facilitates students' gradual, systematic, and structured development of conceptual understanding. Therefore, this learning strategy is worthy of recommendation as an innovation in digital-based physics learning, especially for temperature and heat material, and has the potential to be developed for other physics materials to improve the quality of the learning process and outcomes. Despite its strong findings, this study has limitations, including the absence of a control group, a relatively small sample size, and a focus on a single physics topic. Future research is recommended to employ quasi-experimental or randomized controlled designs, involve larger and more diverse samples, and examine long-term retention effects to strengthen the generalizability of the findings.

Author's Contribution

F. Wendra acted as the lead author responsible for the research design, instrument development and validation, data collection, data analysis, and preparation and revision of the article manuscript. Nehru and C. Riantoni served as supervisors who guided the overall course of the research, strengthened the theoretical and methodological foundations, and conducted critical reviews and refinements of the manuscript through the final stage of publication.

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