Vol 12 No 1 2026 DOI : https://doi.org/10.24036/jppf.v12i1.36 Page : 83-95
JURNAL PENELITIAN PEMBELAJARAN FISIKA (JPPF)
Journal of Physics Learning Research
ISSN 2252-3014 (Print) | ISSN 2746-8445 (Electronic)

Effects of a Scaffolding Problem-Solving Model on Students' Problem-Solving Abilities in Work and Energy

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ARTICLE INFORMATION

Received : 2025-12-17
Revised : 2026-03-31
Accepted : 2026-03-31

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KEYWORDS :

Problem-Solving Model, Scaffolding, Problem-Solving, Work and Energy.

ABSTRACT

A preliminary study's findings, which showed that pupils at SMA Negeri 7 Tasikmalaya had poor problem-solving abilities with an average score of only 32% in the low category, served as the impetus for this investigation. Determining the impact of using scaffolding problem-solving model on the material of effort and energy in class X at SMA Negeri 7 Tasikmalaya during the 2024/2025 academic year was the aim of this study. The methodology used was a quasi-experiment with a matching only posttest only control group design. 433 students made up the study population, and two classes X-7 and X-8 were purposefully chosen as a sample. Measurement of problem-solving ability was carried out through a descriptive test. At a 0.05 threshold of significance, the hypothesis findings test using the t-test revealed that the t_{count} *(5.341) was greater than the* t_{table} *(1.669), so* H_a *was accepted. The scaffolding problem solving model has been shown to provide gradual assistance, encourage activeness, systematic thinking, and evaluation of student solutions. Thus, it can be concluded that this model is influential in addressing problem-solving abilities in work and energy materials.*

INTRODUCTION

The education system in Indonesia is regulated by a curriculum, one of which is the independent curriculum. Students are required to develop critical thinking, problem-solving, and creativity skills as part of the independent curriculum. This aligns with the 21st century skills that students must possess, which include creativity, communication, teamwork, critical thinking, and problem solving (Mutmainah et al., 2022). Based on 21st century skills, one of the skills that students must have is problem solving skills. Problem solving skills are the ability to analyze, identify, and find solutions to a problem (J. I. Heller & Reif, 1984). This skill can be developed in the classroom, particularly when studying physics.

Problem-solving skills play an important role in physics learning because they encourage students to deepen their understanding of concepts, foster creativity that is useful in everyday life, and think critically (Kiraga, 2023). Physics learning is learning that develops students' abilities in facing and solving problems (Aripin et al., 2021). Physics learning requires an understanding of science in general and the ability to solve problems (Nurjannah et al., 2021). That's consistent with (Aji & Hudha, 2017), Problem-solving skills help students gain new understanding while accelerating their learning process. Based on the opinions of several previous researchers, problem-solving skills are abilities that need to be developed in physics learning.

The results of a preliminary study at SMA Negeri 7 Tasikmalaya showed that students in the material of work and energy, problem solving skills are relatively weak. Furthermore, the findings of physics teachers' interviews revealed that pupils struggled to comprehend physics problems because instruction was still centered on practice math problems. The interview's findings were supported by the findings of a test that included five indicators from (K. Heller & Heller, 2010), students had difficulty understanding and evaluating physics problems. Student learning outcomes will be influenced by low problem-solving skills. In line with this, according to (Ionita & Simatupang, 2020), a solution is needed in the form of using an appropriate learning model to enhance pupils' ability to solve problems. The scaffolding problem solving model is one learning model that works well for this issue.

The problem-solving model is a framework for improving students' problem-solving skills and cultivating critical thinking habits (Harefa, 2020). The problem solving model is a model that teaches students to think critically by seeking information, finding problems, and analyzing situations (Suardin & Andriani, 2021). The problem-solving learning encourages students to recognize and address challenges in order to meet learning objectives (Febriana & Indariani, 2020). In addition, according to (Kim & Hannafin, 2011b)explains that students are taught to be proactive, research, and solve problems through the problem-solving model's learning process. According to the opinions of some experts, the problem-solving model is a teaching strategy that stresses the development of critical thinking and problem-solving abilities through the processes of information collection, inquiry, analysis, and issue solving. There are five syntaxes of the problem solving model, namely identification, exploration, reconstruction, presentation communication, and reflection negotiation (Kim & Hannafin, 2011a). The problem-solving model concentrates on enhancing students' problem-solving skills, whereas the scaffolding model provides the support children require to overcome obstacles in daily life. This is why the two models are related.

The practice of giving pupils complete support throughout the early phases of learning and then progressively reducing that support to give them the chance to work through challenges on their own is known as scaffolding(Suardipa, 2020). (Mansyur & Nugraha, 2021) stated that scaffolding can build students' systematic and reflective thinking skills. Scaffolding is based on Vygotsky's theory, namely that assistance must be adjusted to the Zone of Proximal Development (ZPD) (Azmi et al., 2020). The gap between students' capacity to solve issues on their own and with the help of adults or more experienced peers is known as the Zone of Proximal Development (ZPD). Problem solving that is done independently is called the actual development level, while problem solving that is done with the guidance of adults or with the guidance of more experts is called the potential development level. Kim & Hannafin classify scaffolding into four types, namely conceptual, procedural, strategic, and metacognitive scaffolding.

Numerous earlier research have demonstrated the beneficial effects of problem-solving and scaffolding models on learning. (Syam, 2024) implemented problem-based learning assisted by conceptual scaffolding, but the assistance provided was limited to only one type of scaffolding. (Dzakiyyah, 2024) showed that the effectiveness of problem solving assisted by PhET simulation was effective in improving learning outcomes, but assistance was given when students experienced difficulties, not in a structured manner. Meanwhile, (Priyani, 2023) implemented a metacognitive-based problem solving model, but the assistance provided was limited to explaining the teaching media and was not applied consistently to each learning syntax. Research by (Hidayati, 2023) used a creative problem solving model supported by only one type of scaffolding. Meanwhile, (Arifin, 2023) showed that the problem solving model was quite effective, but its implementation was only in the form of providing directions and confirmation of answers. Based on the results of previous researchers, there are weaknesses, namely the lack of structured application of scaffolding and the limited types of assistance used.

The low problem-solving abilities of students indicate the need for learning strategies that focus not only on outcomes but also on the thinking process. This study offers a solution in the form of integrating scaffolding problem solving model that is applied systematically at each stage of learning. Four types of scaffolding are applied adaptively according to the learning syntax: conceptual scaffolding in the identification syntax to help understand concepts, procedural scaffolding in the exploration syntax to guide students in finding solutions, strategic scaffolding in the reconstruction and presentation syntax to help connect exploration results with concepts and communicate solutions through discussion, and metacognitive scaffolding in the reflection and negotiation syntax to encourage students to reflect on problem solving. The novelty of this study lies in the application of scaffolding that is tailored to the actual needs of students at each stage of learning.

Based on the description above, the aim of this study is to determine the effect of the student scaffolding problem solving model on students' problem-solving abilities. This research is motivated by students' still low ability to understand and solve physics problems systematically. In this study, scaffolding serves as a step-by-step assistance provided to students to help them understand the problem, design a solution strategy, and evaluate the solutions obtained.The results of this study are expected to strengthen the basis for implementing scaffolding as a supporting strategy in problem solving models. In addition, this study can be used as a reference in designing active, interactive, and contextual physics learning.

METHODS

Research Design

The research method used is a quasi-experiment. Quasi-experiments are a development of true experimental designs, which are difficult to conduct. This research method aims to determine the effect of certain treatments on dependent variables. A control group in the quasi-experimental approach is powerless to influence outside factors that impact the experiment's execution (Sugiyono, 2024).

The study methodology used is the matched only posttest only control group design. The matched only posttest only control group design is one kind of quasi-experimental study design that uses a test after treatment (Fraenkel et al., 2011). This design uses two research samples that are matched based on characteristics. Direct instruction is used to teach the control group, while the scaffolding problem solving model is used to teach the experimental group. The following is the research design used.

Table 1. Design of Research

Group	Treatment	Posttest
Experiment	X	O_1
Control	-	O_2

(Fraenkel et al., 2011)

This study was conducted in the even semester of the 2024/2025 academic year at SMA Negeri 7 Tasikmalaya. The planning, execution, and completion phases are all included in the research process. At the planning stage, the researcher prepared an instrument in the form of descriptive questions on problem-solving abilities and observation sheets for the implementation of learning. Then, during the implementation phase, two classes received distinct treatments: the experimental class learned using the scaffolding problem solving model, whereas the control class learned conventionally. Following the course of treatment, students took a posttest to gauge their ability for problem-solving using five indicators adapted from (K. Heller & Heller, 2010).

Participants

A population of SMA Negeri 7 Tasikmalaya class X students from the 2024–2025 school year was employed in this study. There are 12 classes in Class X at SMA Negeri 7 Tasikmalaya, totalling 433 pupils. Purposive sampling, which is a sampling approach based on certain criteria, was used to pick the sample (Sugiyono, 2024). The criteria used to select the sample for this study were standard deviation and classes taught by the same teacher. For the research samples, class X-7 was selected as the control class and class X-8 as the experimental class.

Instruments

The instruments in this study were tests and non-tests. The tests conducted were descriptive tests to measure problem-solving abilities. Five measures of problem-solving abilities were used to create this test, according to (K. Heller & Heller, 2010), namely understanding problems, explaining problems into physics concepts, planning solutions, implementing solutions, and evaluating solutions. Furthermore, observation sheets were employed as non-tests to evaluate how the learning model’s syntax was being applied. The developed test instruments will be validated by experts, then tested to obtain validity and reliability before being used in data collection.

Data Analyis

The data obtained were analyzed using descriptive statistical methods. Students from each group's problem-solving abilities scores were determined using descriptive analysis. The evaluation of students’ problem-solving abilities was done using Heller’s indicators and an assessment rubric modified from (Pravidya et al., 2022). Utilizing the following formula, the percentage of problem-solving ability was calculated (Mustofa & Rusdiana, 2016).

$$P_x = \frac{R_s}{nS_x} \times 100\%$$

The following table interprets problem-solving abilities used to categorize the results of percentage calculations.

Table 2. Percentage Category of Problem-Solving Ability

Percentage Indicator	Criteria
$80 < P_x < 100$	Very high
$60 < P_x < 80$	High
$40 < P_x < 60$	Enough
$20 < P_x < 40$	Low
$P_x \leq 100$	Very Low

(Mustofa & Rusdiana, 2016)

The collected data were put through precondition checks utilizing the normality and homogeneity tests before to the hypothesis test. Using the following formula, the Chi-Square test was used to perform the normalcy test (Sugiyono, 2023).

$$\chi^2 = \sum_{i=1}^{k} \frac{(f_0 - f_h)^2}{f_h}$$

The Fisher test was then used to perform a homogeneity test using the following formula (Sugiyono, 2023).

$$F_{hitung} = \frac{S_b^2}{S_k^2}$$

After completing the prerequisite tests, a two-tailed (independent) t-test was used to test the hypothesis and determine whether the experimental and control classes differed in problem-solving ability. If $t_{hitung} > t_{tabel}$ at a significance level of 5% ($\alpha = 0,05$), then the scaffolding problem solving model has an impact on students' problem-solving abilities. The t-test is calculated using the following formula (Arikunto, 2013).

$$t_{hitung} = \frac{\overline{X_1} - \overline{X_2}}{SDG\sqrt{\frac{1}{n_1} + \frac{1}{n_1}}}$$

To determine the Combined Standard Deviation (SDG), you can use the following equation (Arikunto, 2013).

$$SDG = \sqrt{\frac{(n_1 - 1)V_1 + (n_2 - 1)V_2}{n_1 + n_2 - 2}}$$

RESULTS AND DISCUSSION

Results

During the one-month study, the experimental class utilized the scaffolding problem solving model to learn, whereas the direct instruction approach was used by the control group. The examination of problem-solving ability was administered once, specifically as a posttest following treatment. Table 3 below displays the findings of the posttest on the experimental and control classes' problem-solving ability.

Table 3. Results of Problem-Solving Ability of Experimental and Control Classes

Statistical Data	Class	
	Experiment	Control
Number of Students (N)	35	34
Ideal Score	75	75
Highest Score	71	62
Lowest Score	30	23
Average	51.8	38.97
Variance	97,341	101.4
Standard Deviation	9,866	10.07

Based on table 3, if all questions are answered correctly, the ideal score for students' problem-solving ability is 75. The results of the analysis show that the experimental class has a higher average score than the control class. This indicates that the experimental class has better problem-solving ability after being treated with the scaffolding problem-solving model. In addition, the variance value of the experimental class is lower than the control class, which indicates that the experimental class data is more varied than the control class data. Then the standard deviation of the experimental class has a smaller value than the control class. This indicates that the distribution of data in the experimental class is closer to the average value compared to the control class.

The distribution of student scores after the posttest in the experimental class is shown in Figure 1. The data is visualized in the form of a histogram and frequency polygon to illustrate the distribution of scores at each class interval and the variation in student learning outcomes after the implementation of the learning model. Through this visualization, the score distribution pattern can be identified as an initial picture that serves as the basis for further analysis in the following discussion.

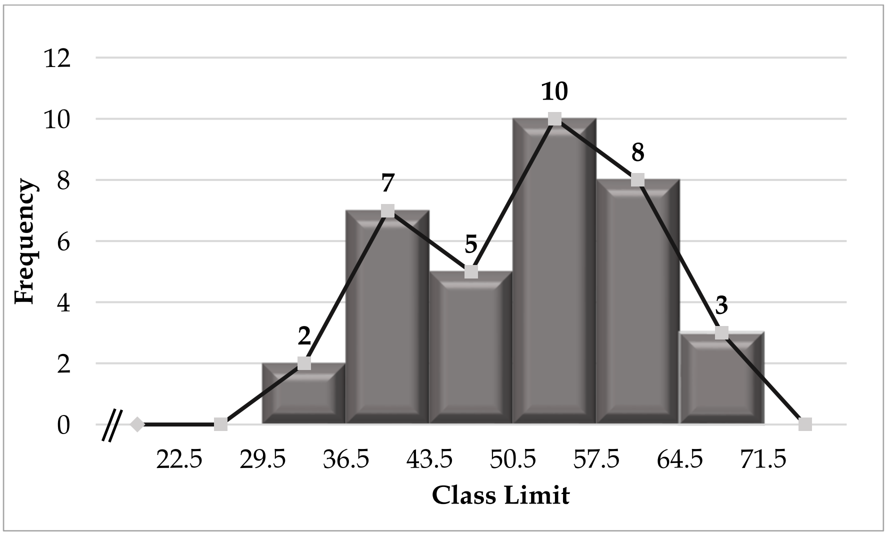

Figure 1. Histogram and Polygon of Posttest Scores for the Experimental Class

Figure 1 shows that two students had the lowest posttest scores between 29.5 and 36.5, and three students had the highest posttest scores between 64.5 and 71.5. Ten students also had the highest posttest scores between 50.5 and 57.5. The figure shows a distribution curve that fluctuates, indicating frequency variation across the class. The shape of this curve appears to be skewed to the left, indicating negative skewness. The statistical results support this: the mean is smaller than the median, and the mode is smaller than the median, ranging from 51.8 to 52.95 to 55.5. This means that there are a large number of students with high scores, but there are still students with low scores. These high scores can be attributed to the treatment given to this group of students, although the results are not uniform across all students.

Figure 2 presents the distribution of posttest scores for students in the control class. The data is visualized using histograms and frequency polygons to depict the distribution of scores across each class interval. This representation provides an overview of student learning outcomes without treatment.

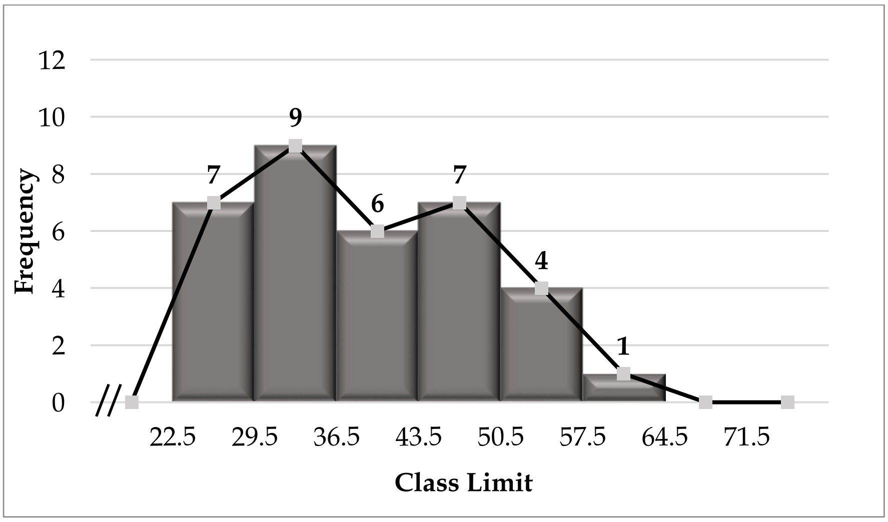

Figure 2. Histogram and Polygon of Posttest Scores for the Control Class

Figure 2 above shows that 7 students had the lowest posttest scores between 22.5 and 29.5, and 1 student had the highest posttest score between 57.5 and 64.5. In addition, 9 students had the highest posttest score frequency between 29.5 and 36.5. There is a variation in frequency at each edge of the class, as shown by the up and down distribution curve in Figure 2. Like the shape of the curve sloping to the right, which indicates a positive skew. This result is supported by statistical calculations, which show the mean value is greater than the median and the median value is greater than the mode, namely 38.97>37.6>32.3. This indicates that there are more students with low scores and fewer students with high scores. This condition indicates that using learning models in the control class is not effective in improving student understanding as a whole.

Following the collection of experimental and control class posttest data, the normality and homogeneity tests were performed as prerequisites. The normality test was conducted using the Chi-Square test with a significance level ($\alpha = 0{,}05$) which aims to see the research data is normally distributed. The results of the normality test are presented in Table 4. Additionally, The Fisher test was used to conduct the homogeneity test, which looks for homogeneous variance in both research data. Table 5 displays the findings of the homogeneity test. According to the precondition test results, both data originate from a population that has homogeneous variance and is normally distributed. The independent sample t-test was then used to evaluate the hypothesis. The results of the hypothesis testing analysis are presented in Table 6. Table 6 demonstrates that the results of the computation of the hypothesis test with a significance level ($\alpha = 0{,}05$) using the independent sample t-test were H_a accepted and H_0 rejected. Based on these results with a 95% confidence level, it can be inferred that students' problem-solving abilities are impacted when the scaffolding problem solving model.

Table 4 contains the results of the posttest normality test for the experimental and control classes. The data provides an overview of the data distribution in each class. This information plays a crucial role in reviewing the characteristics of the data obtained during the research process.

Table 4. Results of Chi-Square Normality Test

Data	N	χ^2_{hitung}	χ^2_{tabel}	Information
Experimental class posttest scores	35	5.903	7.81	Samples are taken from normally distributed populations.
Posttest score of control class	34	4.338		

The results of the homogeneity of variance test for posttest data in the experimental and control classes can be seen in Table 5. The data presented shows a comparison of variance conditions between the two classes studied. This data was used to examine whether there were similarities in characteristics in the groups used for the study.

Table 5. Results of Fisher's Homogeneity Test

Data	F_{hitung}	F_{tabel}	Conclusion
Posttest (Experiment – Control)	1.042	1.79	Homogeneous data

Table 6 presents the results of the hypothesis test on the posttest data in the experimental and control classes. The comparison of the final results between the two classes after participating in the learning process is shown through the available data. This data provides a clear picture of the differences in research results between the two groups.

Table 6. Results of the Independent Sampel T-Test

Statistics	Experimental Class	Control Class
Average	51.8	38.97
Number of Students (N)	35	34
t_{hitung}	5.341	
t_{tabel}	1.669	
Decision	H_a accepted	

Based on Table 6, the results of the hypothesis test using the t-test with a significance level of 5% on the posttest data show that the calculated t_{value} of 5.341 is greater than the t_{table} of 1.669 so that H_0 is rejected and H_a is accepted. This indicates that there is a significant difference between the problem-solving abilities of students in the experimental class and the control class. When viewed from the average value, the experimental class has a higher score (51.8) compared to the control class (38.97), which indicates that the problem-solving abilities of students in the experimental class are better. This difference shows that the application of the problem-solving scaffolding learning model has a positive influence on students' problem-solving abilities. Thus, this model can help students understand and solve problems in a more focused manner through systematic learning stages.

Table 7 presents the average posttest scores for each indicator of students' problem-solving ability in the experimental and control classes. The data show the achievement levels for each indicator and the comparison between the two classes. These results provide a baseline for further analysis in the following discussion.

Table 7. Results of the Experimental and Control Classes' Posttest on Problem-Solving Ability

No.	Problem Solving Ability Indicator	Experimental Class		Control Class	
		Percentage (%)	Category	Percentage (%)	Category
1	Understanding the Problem	54	Enough	37	Low
2	Describing Problems in Physics	79	High	60	Enough
3	Planning a Solution	85	Very high	80	High
4	Implementing the Solution	73	High	62	High
5	Evaluating Solutions	57	Enough	28	Low
Average		70	Tall	53	Enough

In each problem-solving ability indicator, the experimental class had an average posttest percentage of 70%, categorized as high, while the control class had an average percentage of 53%, categorized as sufficient, as shown in Table 7 above. Planning a solution was the indicator with the highest percentage in the experimental class, indicating that students had a greater ability to systematically organize problem-solving procedures. Furthermore, students selected relevant physics concepts and chose appropriate equations based on the information they had obtained. However, the indicator with the lowest percentage was problem understanding, indicating that students still had difficulty finding the given conditions.

Discussion

Scaffolding problem-solving model has a significant influence on students' problem-solving abilities in the material of effort and energy. This influence is caused by the scaffolding problem solving model which involves students being active in learning with the help of teachers. This is consistent with research by (Maesari et al., 2019), which states that the problem solving model requires students to be active in solving problems. Then according to (Kamelia & Pujiastuti, 2020) stated that the role of scaffolding is important in improving students' thinking skills.

Students in the experimental class received a sufficient category on the problem understanding indicator, outperforming the control class, which was in the poor category. This shows that conceptual scaffolding in learning has helped students to better understand the context and important information in the posttest questions. However, the less-than-optimal achievement shows that students still have difficulty identifying problems comprehensively. This result is in line with research by (Wardani et al., 2021) which states that students often skip the process of understanding problems and go straight to solutions, especially if they are not used to problem-based models. Therefore, scaffolding needs to be provided continuously so that conceptual understanding can develop further.

Students in the experimental class received a high category score in the indicator of describing problems into physics concepts. This shows that students are able to identify quantities, concepts, and relationships between variables in the context of physics problems. These results are also supported by the procedural scaffolding provided through exploration syntax. This is in line with (Zakiyah, 2022), who stated that providing scaffolding based on conceptual questions is effective in helping students solve the problems they face. Thus, this model encourages students to think scientifically from the beginning of the solution process.

When compared to the control class, the experimental class received a very high category in the planned solutions indicator. This indicates that students not only understand the concept, but are also able to choose relevant solution strategies and organize the solution steps systematically. Strengthening the concept carried out through discussions in reconstruction syntax is very helpful for this achievement. (Sukmawati et al., 2024) emphasize the importance of providing conceptual reinforcement for the concepts owned by students through questions or problems.

The experimental class's students scored highly on the indicator of implementing solutions. These results indicate that students are able to perform mathematical operations and solve problems until the end. However, some students still make mistakes in their calculations. This result supports the assertion made by (Pambudi et al., 2020) that students can find problems, write appropriate equations, and apply mathematical principles systematically to find accurate and relevant solutions. This indicator is supported by the syntax of presentation and communication, where the teacher encourages students to complete the solution steps independently but in a directed manner.

The indicator for evaluating solutions is in the low category, indicating that students' metacognitive abilities to reflect and verify answers can still be optimized. This is because students are not yet accustomed to reviewing solutions or assessing the suitability of the results to physics concepts. This finding is in line with (Mufidaturosida, 2021) that evaluating answers to solutions is a high-level thinking skill that requires time and practice. Therefore, metacognitive scaffolding needs to be provided consistently so that students are accustomed to evaluating solutions critically.

During the study, researchers faced several obstacles in implementing scaffolding problem solving model, namely in several indicators of problem-solving ability. First, in the problem identification indicator, students had difficulty finding the problem as a whole. Students tend to rewrite the information contained in the problem without analyzing it. This is because students are not used to analyzing problems and only focus on mathematical solution procedures. To overcome this, researchers can help students understand problems in a more concrete way by conducting simulations or experiments directly. Second, in the solution evaluation indicator, students are too focused on working on the next problem or material so that they do not pay attention to solution evaluation. To overcome this, researchers can teach students to find solutions with more contextual ideas.

Scaffolding problem-solving model help students build conceptual understanding gradually and form critical thinking patterns from the stage of understanding the problem. These results strengthen that the learning process that emphasizes the stages of thinking and strengthening concepts can encourage students should learn physics more actively and reflective. Additionally, developing physics lessons in accordance with 21st century skills can be accomplished by using scaffolding problem-solving model. Then the results of the study also emphasize the process that positions students to build their knowledge independently and gradually.

CONCLUSION

Based on the results of statistical data analysis, the use of the scaffolding problem-solving learning model has an impact on students' problem-solving abilities in the material of work and energy. The average score of students' problem-solving abilities who used this model was proven to be higher than students who followed the direct teaching approach. This shows that providing gradual assistance in each learning syntax can strengthen students' problem-solving abilities. Through systematic stages, students can develop a more structured and independent thought process in dealing with complex physics problems. Therefore, the scaffolding problem-solving learning model is highly relevant to be implemented as a solution in creating more effective physics learning. The application of this model is expected to be a reference for educators to build a foundation for problem-solving abilities in students in a sustainable manner.

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