

EFFECT OF 6E LEARNING BY DESIGN ON STUDENTS' PROBLEM SOLVING SKILLS IN SOUND WAVES

Isnawati^{1*}, I Wayan Darmadi¹, Nurjannah¹, Miftah¹

¹Physics Education Study Program, Tadulako University, Central of Sulawesi, Indonesia

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ABSTRACT

This study aims to examine the effect of the 6E Learning by Design model on students' problem-solving skills in learning sound wave material at MAN 2 Palu City. The research used a quasi-experimental method with a nonequivalent pretest-posttest control group design. The population consisted of all class XI MIPA students. The sample was selected using purposive sampling, with class XI MIPA I ($n = 34$) as the control class and class XI MIPA J ($n = 34$) as the experimental class. The instrument used was a problem-solving skills open-ended test. The results showed that the increase in problem-solving skills scores in the experimental class was higher than in the control class, with an N-gain value of 0,685, categorized as moderate. Hypothesis testing was conducted using the Mann-Whitney U test at a significance level of 0,05. Furthermore, the effect size was 1,4 ($d \geq 1.3$), indicating a strong effect. These results indicate that the 6E Learning by Design model effectively improves students' problem-solving skills on sound wave material.

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Corresponding Author:

Isnawati, Physics Education Study Program, Tadulako University, Central of Sulawesi, Indonesia

Email: Isnawati@untad.ac.id

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INTRODUCTION

In today's modern era, education and technology play a very important role in preparing the younger generation to face global challenges and the era of the industrial revolution 4.0. The challenges of the 21st century are closely that occur in people's lives, which in turn are closely related to science and technology (Putri, 2019).

Innovative utilization of technology is an important step in preparing a competent workforce to compete in the global industrial arena. In an effort to form individuals who are competent and ready to face the challenges of the 21st century, the government has made efforts to improve various aspects of life including education, one of which is in terms of improving the 2013 curriculum into the Merdeka Curriculum. The Merdeka Curriculum provides greater space for the development of critical and creative thinking skills through learning that is flexible and relevant to the needs of students in the real world. The focus of assessment in the independent curriculum is on students' self-skills in analysing, creating and solving problems in everyday life (Nafi'ah et al., 2022).

However, curriculum changes have not fully improved the quality of education in Indonesia. Based on the results of the PISA 2022 survey, the average score of Indonesian students in math is 366, while in reading and science each is 356 and 383. These figures are still low, achieving below the OECD average and significantly lower than the global average (OCDE, 2024).

One of the causes of the low quality of education in Indonesia is caused by the low skills of students in the field of science, one of which is in the branch of physics caused by the difficulty of physics material. Factors that cause students' difficulties in physics materials are curriculum which is dense, material lessons that are difficult to understand (Mahmudah et al., 2022), the use of media and laboratory facilities that are not optimal, and learning models that do not actively involve students (Supardi in Sandari, 2020).

The teacher-dominated learning process means that students have fewer

opportunities to practice problem-solving skills (Ardianti et al., 2021). Ramadayantya et al. (2021), state that physics learning currently focuses more on mastering concepts. Meanwhile, Nurjannah et al. (2021), add that suboptimal mastery of concepts may lead to low student learning outcomes.

In an effort to address this, it is crucial to ensure that physics learning is directed toward developing essential 21st-century problem-solving skills, one of which is through the 6E Learning by Design approach. This model consists of six learning stages: Engage, Explore, Explain, Engineer, Enrich, and Evaluate, designed to create meaningful, collaborative, and student-centered learning experiences. Previous research has shown that the 6E model can improve learning outcomes, foster scientific attitudes, strengthen logical thinking skills, and develop students' scientific process skills (Rumiyati, 2022; Lin et al., 2019; Sanjayanti et al., 2019; Sulistiowati et al., 2019).

However, despite some studies having proven the effectiveness of the 6E Learning by Design model in science education, most of these studies have not specifically examined the relationship between this model and students' problem-solving skills in the topic of sound waves. In fact, based on interviews with students at MAN 2 Kota Palu, the topic of sound waves is considered one of the most challenging physics topics to understand. This is due to the numerous abstract concepts and mathematical formulas that must be mastered, particularly in the subtopics of the Doppler effect, intensity, and sound intensity level.

Previous research also indicates that despite the relevance of this material to daily life, students still struggle to conceptualize it (Jannah et al., 2023; Kahfi & Sulistiawati, 2023). While prior studies confirm the benefits of the 6E Learning by Design model in science education (Sulistiowati et al., 2019; Sanjayanti et al., 2019; Rumiyati, 2022), limited attention has been given to its potential for enhancing problem-solving skills in physics, particularly in complex and abstract topics such as sound waves. Therefore, this study introduces the novelty

of applying the 6E Learning by Design model to enhance students' ability to understand and solve problems related to sound waves. Based on the description above, the researcher intends to determine the effect of the 6E Learning by Design model on sound waves material on students' problem solving skills.

METHOD

This study used a quasi-experimental design with the form of nonequivalent pretest-posttest control group. This design was chosen because the selection of research subjects was not randomized, but both experimental and control groups were given pretest and posttest treatments so that comparisons between groups were possible. The implementation of the research was carried out in three stages, namely: (1) the design stage includes the preparation of learning tools such as teaching modules and research instruments, as well as validation by an expert. The validation process was carried out by one physics lecturer who assessed the content suitability, language clarity, and the coherence between the learning tools and the research instruments; (2) the implementation stage, which includes giving pretests, implementing learning in each group, and giving posttests; and (3) the final stage, which is processing and analyzing the research data.

The research was conducted at MAN 2 Palu City in the 2024/2025 academic year. The research population included all students of class XI MIPA, which consisted of three classes, namely XI H, XI I, and XI J. The research samples were class XI I as the experimental group and class XI J as the control group. The learning process was carried out in two meetings, with each meeting lasting 120 minutes, and both groups were taught by the same teacher to maintain instructional consistency. The sample selection was carried out using a purposive sampling technique, which was based on specific criteria, namely equal academic ability.

The research instruments was a six-item problem-solving skills open-ended test. The questions were developed based on indicators of problem solving skills adapted

from Docktor et al. (2016). Before being used in research, the instrument has gone through test validity construct through expert judgment to ensure suitability in measuring the skills in question.

Data collection was done through giving pretest and posttest to both groups. The improvement of students' problem solving skills was analyzed using the N-Gain test. Prerequisite testing with data normality and homogeneity tests, then hypothesis testing is carried out using the Mann-Whitney U nonparametric test because the data is not normally distributed. To determine the magnitude of the treatment effect, the effect size test was also conducted (Khairunnisa et al., 2022).

RESULT AND DISCUSSION

This study aims to determine the effect of the 6E Learning by Design model on students' problem solving skills on sound waves. 6E Learning by Design on sound waves is divided into two parts, namely 6E Learning by Design on the characteristics of sound waves on strings, open organa pipes and closed organa pipes, and 6E Learning by Design on intensity, intensity level, doppler effect, and sound flight.

The 6E by Design learning model on the material of sound wave characteristics on strings, open organa pipes, and closed organa pipes is carried out through six learning steps. At the beginning of learning, students are directed to pay attention to a picture of two astronauts who are communicating in space using a radio. Then from the picture there is a question and answer between students and teachers. The activity shown by the teacher is to explore the memory of the wave concept. This is in accordance with stated by Mirnawati (2020); Junanah et al., (2025) that image media helps students visualize abstract concepts, so that the material becomes more concrete and easy to understand. In addition, images can also increase students' interest and motivation to learn.

In the Engage step, which aims to arouse students' curiosity so that they can actively participate in the learning process, participants learners identify the phenomenon of the buzzy sound on the

handphone placed on the table, the phenomenon of guitar that can produce different tones, that can produce different tones contained in the LKPD that has been distributed.

Furthermore, in the Explore step, which aims to provide opportunities for students to build their own understanding of the topic / material, students search, select, and collect information from the questions given in the LKPD related to the phenomena contained in the previous step from various sources including the internet. In this case the teacher acts as a facilitator by providing material and guiding students to focus on learning. The students' inquiry process is a guide in the exploration process. The Explain step, aims to provide opportunities for students to communicate and improve what has been learned.

Engineer step, which aims to provide opportunities for learners to build a deeper understanding of the material. In this step, students conduct experiments related to sound that can propagate through the medium, determine the harmonic series pattern of resonant frequency of strings on guitars and organ pipes using simple tools, then students analyze the information or data obtained from the experimental results. Through experiments, learners can prove the theory they have learned and find concepts from the experimental activities carried out so that they can improve students' understanding of physics concepts (Rose Amanda Puri & Riki Perdana, 2023).

The next step is Enrich, which aims to provide opportunities for learners to explore more deeply what has been learned and to transfer the concept to more complex problems. At this stage learners find out the working principle of carpet or foam as a sound absorber from the case study given.

The final step is Evaluate, where learners and teachers determine how much learning and understanding is gained. Learners in this step solve the problem.

6E by Design learning on the material of sound intensity, intensity level, doppler effect, and sound flight is carried out through the same steps as the material of sound wave characteristics. In this second meeting material, in the engineer step, students conduct doppler effect experiments using crocodile physics software.

While learning process in the control class was carried out by conventional learning with lecture and discussion methods. The researcher first explained the concepts of the material by linking it to everyday life so that students were more motivated to learn, guided students to work on problems, then the results were discussed together. At the end of the lesson, the teacher asked representatives of students to conclude what had been learned together.

The improvement of students' problem solving skills can be seen through the score data presented in Table 1 which shows that the experimental class improvement is higher than the control class.

Table 1. N-Gain Test Results of Experimental and Control Classes

Pemusatan dan penyebaran data	Kelas kontrol		Kelas Eksperimen	
	Pretest	Posttest	Pretest	Posttest
Skor Terbesar	50,0	83,8	40,8	92,3
Skor Terkecil	6,2	34,6	7,7	33,1
Rata-rata	21,6	56,3	25,6	76,7
Medium	15,8	52,3	25,0	83,1
Modus	14,6	51,5	24,6	83,1
Standar Deviasi	12,7	11,5	9,5	17,0
N-gain	42,4		68,5	

To determine whether after applying the 6E Learning by Design model on sound waves material there is a significant difference with conventional learning applied

to the control class, the pretest and posttest data on both classes were analysed using IBM SPSS Statistic with two independent samples difference test. Before testing the hypothesis,

normality and homogeneity tests were conducted. The results of the normality test based on the Shapiro-Wilk test show that the problem solving skills of experimental and control class students are not normally distributed because the Sig. value or the experimental group = $<0,001 > \dot{y} = 0,05$ and the Sig. value of the control group = $0,004 < \dot{y} = 0,05$. The homogeneity test using Levene showed that the data varied homogeneously because Sig. = $0,064 > \dot{y} = 0,05$.

Both data are not normally distributed and very homogeneously then an independent sample test is performed with the Mann-Whitney U test. The results of independent sample testing show the Sig. (2-tailed) = $<0,001 > \dot{y} = 0,05$. Based on these results, it can be interpreted that the null hypothesis is rejected, which means that there is a significant difference between the problem solving skills of students in the control class and the experimental class. Furthermore, based on the effect size test, it is obtained at 1,3999, which shows that the effect of the 6E Learning by Design model on students' problem solving skills on sound wave material is classified in a very large category.

The increase in problem solving skills of students who get learning with the 6E by

Design model on sound waves material is higher than conventional learning. This is in accordance with Khaeroningtyas et al., (2016) that learning that requires students to find their own concepts of the material being studied can make learning more meaningful for students. The 6E Learning by Design model is basically a combination of inquiry and design. In the exploration stage, students are guided by the Learner Worksheet to find their own material concepts to solve problems. Saimon et al. (2024) state that the various phases of the 6E by Design learning model provide opportunities for learners to understand problems, find solutions, and evaluate them. So that it can help learners to learn about how to solve problems. Learners are given the opportunity to explore deeper understanding through the application of concepts during the engineering process.

Furthermore, based on the results of the final test of problem solving skills, an increase in problem solving indicators is obtained as in Figure 1 which shows that there are five indicators of problem solving skills measured in experimental and control classes. Experimental group scored higher in all indicators, except the specific application on physics.

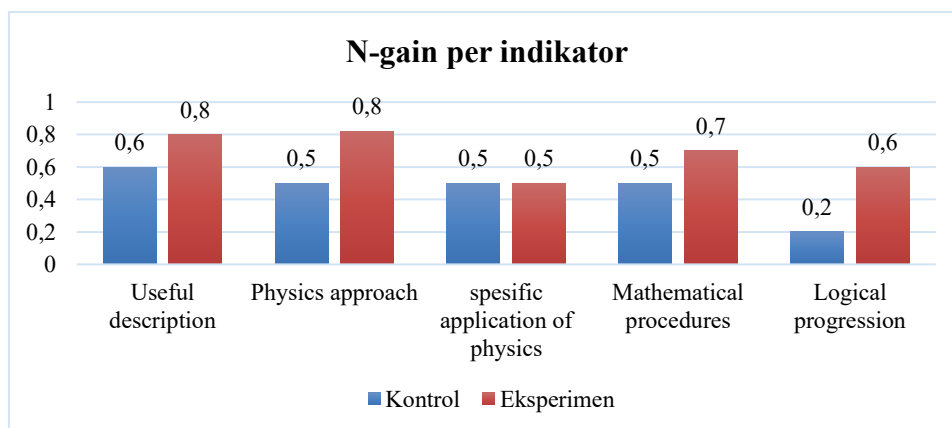


Figure 1. Analisis N-gain Indikator Keterampilan Pemecahan Masalah

In the useful description indicator where students mention information from the problem including mentioning the quantities and units of physics that are considered necessary with the right increase in the experimental class higher than the

control class. This is because in the explore step students in the experimental class are trained to find information from the problem statement given. According to Walidain et al. (2023) the ability to describe problems effectively is very important in problem

solving because it is the basis for determining the next step of solving.

In the physics approach indicator where students can apply appropriate physics concepts such as being able to with the formula equation correctly, the experimental class experienced a higher increase than the control class. This is because students in the experimental class have understood the basic concepts of sound waves. Sujarwanto (2019) in his research said that understanding the basic concepts of physics is very important in determining the right problem solving strategy.

Furthermore, in the indicator of spesific application of physics, namely students using physics principles that are in accordance with the information from the problem contained in the problem, both control and experimental classes both experienced the same increase. This equal increase is likely due to the difficulty of students in understanding the concepts of the Doppler effect, especially in determining positive or negative signs in the formula (Silaban & Jumadi, 2022). In addition, the division of groups that were too large (more than 5 people) in the experimental class made some students less active in participating, so that the learning process did not run optimally (Nurani et al., 2021).

On the indicator of mathematical procedures, where students apply mathematical steps in a systematic in solving. The experimental class experienced a higher increase in physics problems which included the ability to use the right formula, perform correct calculations, and write down the results obtained along with the units than the control class. This is because students in the control class are less careful in completing mathematical steps so that the results obtained contain errors. In addition, conceptual errors or errors in the use of formulas in physics approach indicators also cause errors in the results of the calculations performed.

In the logical progression indicator, namely students make concise problem solving conclusions, the increase in students in the experimental class is much higher than the control class. This is because students in the experimental class were able to conclude

the physical and mathematical meanings in a logical and organized manner. For example, students are able to explain the effect of pipe length in an open organa pipe on the frequency obtained based on the calculation results on the mathematical procedure indicator, the effect of air column height on the frequency in a closed organa pipe, and the effect of the doppler effect on the frequency heard, although some students are still unable to explain the problem solving steps in a focused and consistent manner. Meanwhile, in the control class, almost all students were unable to make conclusions related to the solution results obtained with their physical meaning.

Thus, the implemented learning strategy plays a crucial role in enhancing students' physics problem-solving skills. This is evident from the highest gains observed in the Physics approach and Useful description indicators in the experimental class, each with an N-gain of 0.8. The improvement in Useful description is likely due to students being trained to identify and articulate key information from problems, including physical quantities and units, where the *explore* phase of the 6E Learning by Design model helps students focus on information identification. Meanwhile, for Physics approach, students in the experimental class already possessed a basic understanding of sound wave concepts, making it easier for them to correctly apply physics concepts in problem-solving. These findings are consistent with previous studies, such as those reported by Walidain et al., (2023) and Ardianti et al., (2021), which indicate that a solid grasp of basic concepts and the ability to effectively describe problems are essential for improving problem-solving skills.

In contrast, the indicator showing the least improvement was Specific application of physics, with an N-gain of 0.5 in both the experimental and control classes. This is likely due to students' difficulties in understanding the Doppler effect, particularly in determining positive or negative signs in formulas, as well as overly large group sizes in the experimental class, which led to some students being less active and the learning process being less optimal.

Overall, these findings remain consistent with the existing literature, which highlights that a strong conceptual foundation and problem-description practice enhance problem-solving skills (Sujarwanto, 2019; Walidain et al., 2023). However, difficulties in the specific application of physics underscore practical challenges, as reported by Silaban & Jumadi (2022) regarding the Doppler effect, and large group participation issues (Nurani et al., 2021), indicating the need for learning strategies that focus more on complex concepts and effective group management.

CONCLUSION

Based on the hypothesis testing using the Mann-Whitney U test, a Sig. (2-tailed) value of < 0.001 was obtained, which is less than 0.05. This indicates that there is a significant difference in physics problem-solving skills between students who received learning through the 6E Learning by Design model and those who received conventional learning. Furthermore, the effect size test yielded a value of 1.4, indicating that learning using the 6E Learning by Design model has a very large effect on improving students' problem-solving skills in learning sound waves topic.

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AUTHOR CONTRIBUTIONS

Auhtor one: Conceptualization, methodology, investigation, data curation, formal analysis, writing – original draft, visualization, and project administration.;
Author two: Supervision, validation, writing – review & editing.

Author three: Supervision, validation, writing – review & editing.

Author four: Supervision, validation, writing – review & editing.

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