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Effectiveness of E-SWS Sound Waves using the Discovery Learning Model on Student Learning Outcomes

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ABSTRACT

Learning physics on the subject of sound waves remains a challenge because abstract concepts are often difficult for students to understand. This study aims to test the effectiveness of using E-SWS sound waves using a Discovery Learning model that has been revised in accordance with the Independent Curriculum on student learning outcomes in cognitive and psychomotor aspects. The research method used is quasi-experimental with a posttest only control group design. The research sample consisted of two classes, Phase F5 and F6, at SMA Negeri 3 Payakumbuh, with F5 as the experimental class using Discovery Learning-based E-SWS and F6 as the control class using the Discovery Learning model without E-SWS. The research instruments were multiple-choice tests to measure cognitive aspects and science process skill observation sheets for psychomotor aspects. Data analysis was conducted through a two-sample t-test. The results showed that the average posttest score for the experimental class was 89.2, which was higher than that of the control class, which was 73.7. In terms of psychomotor skills, the average score for the experimental class was 78, which was also higher than that of the control class, which was 67.5. The t-test showed that the t-count was greater than the t-table, indicating a significant difference in both aspects. It was concluded that E-SWS using the Discovery Learning model was effective in improving students' cognitive learning outcomes and science process skills.

INTRODUCTION

The independent curriculum implemented in Indonesia is one of the efforts to improve learning success by creating a more meaningful, flexible, and learner-centered learning process. This curriculum is designed to equip students with essential skills in cognitive, affective, and psychomotor aspects, with the hope of improving the quality of the learning process and outcomes (Natalia & Sukraini, 2021; Suryaman, 2020). Learning in the Independent Curriculum also requires teachers to be able to present interactive, collaborative, and contextual learning activities so that students are able to construct their knowledge independently (Widyastuti et al., 2023). The implementation of the Independent Curriculum in terms of technology integration remains a challenge at this time. With the rapid development of technology, education should not only use digital tools as a supplement but must make them an important part of the teaching and learning process (Mulyasa, 2023; Anggraini, 2025).

One of the physics topics that students find difficult to understand is sound waves. The abstract concepts involved in sound waves pose a challenge for students. Students tend to have difficulty understanding the basic concepts of sound waves, such as the speed of sound, frequency, and sound intensity (Yana et al., 2020). This difficulty is caused by the abstract nature of the material and the lack of active student involvement in the learning process. Therefore, teachers must be more selective in choosing innovative learning models to establish good communication between students and between teachers and students.

The Discovery Learning model is believed to be capable of creating active and meaningful learning because it encourages students to discover concepts for themselves through exploration and problem solving, with the teacher acting as a facilitator (Siregar & Siregar, 2020). This model is in line with the spirit of the Independent Curriculum, which emphasizes student-centered learning (Indarta et al., 2022). Using the discovery learning model encourages students to think critically, ask questions, and participate actively in the learning process, thereby improving their science process skills (Sinaga, 2020). The discovery learning stage is an effective step in improving students' learning achievement and science process skills because each stage involves practicing process skills and developing students' cognitive abilities (Mokodompit et al., 2024).

In addition to learning models, the teaching materials used also have a significant effect on learning success. One effective teaching material is the Student Worksheet (SWS), which serves to guide students in understanding scientific concepts through real activities (Kosasih, 2021). SWS is a basic activity that can help teachers and students in learning activities to better understand learning concepts in accordance with the demands of the independent curriculum (Fadilah, 2024). With the development of technology, SWS has evolved into an electronic form (E-SWS) that is more interactive with audio, video, and animation features so that it can help students understand abstract concepts (Soenarko et al., 2022; Pamungkas & Fitriyani, 2023). The use of E-SWS has also been proven to increase student engagement in the learning process and improve student learning outcomes because it provides a visual and independent learning experience (Aisyah et al., 2024). One website that can be used to create E-SWS is liveworksheets, which provides interesting features for designing E-SWS that can increase students' interest in understanding the concepts being taught (Wulansari & Nuryadi, 2022).

The results of interviews with physics teachers at Payakumbuh State High School 3 show that the learning process is still dominated by the use of printed books and presentation media such as PowerPoint slides made by teachers. The Problem-Based Learning model used has not been implemented according to its syntax. The average score for the Final Semester Assessment for the physics subject for class XI Phase F is still below the Learning Objective Achievement Criteria (LOAC) of 78, indicating that student learning outcomes are not yet optimal. This condition shows that the use of technology-based teaching materials is still minimal in these schools. In fact, teaching materials such as Student Worksheets (SWS) can help students understand concepts through clear instructions and steps, as well as practice scientific process skills. Previous research by Putri Lingga Harmita (2023) developed a liveworksheet-based E-SWS for Sound Waves with 87.4% validity and high practicality (94% for teachers, 91% for students) (Harmita et al., 2023). However, the effectiveness of this E-SWS has not been tested, and the initial version was still based on the 2013 Curriculum. To meet the requirements of the Independent Curriculum, the E-SWS was revised, including adjustments to the Learning Outcomes (CP) and Learning Objectives (TP), and integrated with the discovery learning model that emphasizes active learning and concept discovery by students.

This study is novel in that it tests the effectiveness of the revised Independent Curriculum Sound Wave E-SWS combined with the discovery learning model on students' cognitive and psychomotor learning outcomes. Previous studies have proven that the discovery learning model assisted by SWS can improve learning outcomes (Suarti, 2022; Winarti et al., 2021; Nehe et al., 2023), but none have combined it with the E-SWS based on the revised Independent Curriculum liveworksheet. This study aims to determine the extent to which this combination is effective in improving learning outcomes in the cognitive and psychomotor aspects of students, while also contributing to the provision of alternative teaching materials for physics that are innovative, easily accessible, and in line with curriculum requirements. The expected benefits include improved mastery of the material, the provision of teaching material development references for teachers, and strategic input for schools to optimize the quality of physics learning.

METODS

The method used in this study is the Quasi Experiment method. This method has a control class, but it does not fully function to control external variables that affect the implementation of the experiment. The research design used was Posttest Only Control Group (Sugiyono, 2012). This design consisted of two classes, namely the experimental class and the control class with a posttest. The experimental class was taught using teaching materials in the form of E-SWS sound waves using the Discovery Learning model, while the control class used teaching materials in the form of printed books using the Discovery Learning model.

The posttest conducted by both classes was the same. In simple terms, according to Sugiyono (2012), the research design is presented in Table 1 below:

Table 1. Research Design

Group	Treatment	Posttest
Eksperimen	X	T
Control	-	T

(Source: (Sugiyono, 2012))

The experimental class was a class that received treatment in the form of using E-SWS Sound Waves with the Discovery Learning model. Meanwhile, the control class was a class that did not receive E-SWS Sound Waves treatment but used the Discovery Learning model with the help of teaching materials in the form of printed books. After the learning process was completed, both classes were given a posttest. This test aimed to determine the difference in learning outcomes between the experimental class and the control class after being given different treatments.

Time and place of research

The research was conducted during the even semester of the 2024/2025 academic year at SMA Negeri 3 Payakumbuh from May 5 to June 10, 2025. The research schedule followed the physics learning schedule for Grade XI Phase F. The research activities were conducted in accordance with the allocated time set for teaching the sound wave material. As a result, the entire research process was carried out in a planned manner and in line with the existing learning schedule.

Population and research sample

The population in this study consisted of all grade XI students in Phase F at Payakumbuh State Senior High School 3, comprising six classes. Three classes were physics specialization classes. The sample classes were determined using purposive sampling, resulting in two physics specialization classes taught by the same teacher, namely classes XI F5 and XI F6. The determination of the experimental class and control class went through normality tests, homogeneity tests, and tests of equality of two means based on the PAS scores, followed by a coin toss to determine the classes. Two sample classes were obtained, F5 as the experimental class and F6 as the control class.

Research Procedures

The research procedure consists of systematic steps used to collect data and answer research questions. This research was conducted in three main stages, namely the preparation stage, the implementation stage, and the completion stage. In the preparation stage, the researcher determined the school, prepared the permit letter, determined the population and sample, and prepared the research instruments. The implementation stage was carried out in two sample classes, an experimental class that was given treatment using teaching materials in the form of E-SWS sound waves using the Discovery Learning model and a control class using teaching materials in the form of printed books using the Discovery Learning model. This treatment aimed to see the effectiveness of using E-SWS teaching materials on physics learning outcomes. The final stage is the completion stage, which includes collecting research data, processing and analyzing data, and discussing the results obtained during the research process. This discussion aims to present the results and evaluate the learning process that has been carried out. This stage ends with drawing conclusions from the entire series of research activities.

Research Instruments

Research instruments are measuring tools or guidelines used to collect research data. The instrument used in the cognitive aspect is a multiple-choice test consisting of 15 questions, compiled with consideration of learning objectives, question indicators, and cognitive levels C1 to C3, so that the questions produced can comprehensively represent learning outcomes. Before being used, the questions were first tested for validity, reliability, discriminating power, and level of difficulty on other objects outside the specified population. A science process skills scoring rubric was used to measure psychomotor aspects, including indicators of observing, identifying problems, collecting data, analyzing data, concluding, and communicating (Annasichah et al., 2023; Fuada et al., 2023; Tadda, 2020).

Data Analysis Techniques

The data analyzed in this study were the learning outcomes of students obtained from instruments that had been designed previously (Sundayana, 2016). After obtaining the research data, the data were processed and analyzed. The data analysis techniques used for the cognitive and psychomotor aspects were the Lilliefors test to determine whether the data were normally distributed, the Fisher test to determine whether the research samples were homogeneous, and the t-test to determine the effect of treatment on improving student learning outcomes in the cognitive and psychomotor aspects.

RESULT AND DISCUSSION

Result

The research results consist of data from the final tests (posttests) of students in the cognitive aspect and data from the assessment of students' science process skills in the psychomotor aspect during the research period. In the cognitive aspect, the data was obtained from the posttest results in the form of multiple choice questions consisting of 15 items that had undergone validity testing, reliability testing, difficulty level testing, and discrimination testing (Arikunto, 2014). The posttest results data can be seen in Table 2.

Table 2. Posttest Data on Cognitive Aspects

Class	n	Highest Score	Lowest Score	$\bar{x}$	S	S^2
Experiment	34	100	73.3	89.2	9.44	89.11
Control	35	93.3	20	73.7	15.07	227.2

Based on Table 2, it is known that the average learning outcomes obtained by students in the experimental class are higher than those in the control class. The standard deviation value of the experimental class is smaller than the standard deviation value of the control class, indicating that the learning outcomes obtained by the experimental class are more evenly distributed than those of the control class. The variance value of the experimental class is smaller than the variance value obtained by the control class, meaning that the learning outcomes obtained in the control class are more diverse than those in the experimental class.

The normality test is used to see whether the data from both samples are normally distributed or not. The sample data used is the learning data obtained after conducting a posttest on the experimental class and the control class. The normality test used is the Liliefors test. From the normality test conducted, the values L_0 and L_t were obtained at a significance level of 0.05. The results of this test are presented in Table 3.

Table 3. Cognitive Aspect Normality Test

Class	n	$\bar{x}$	S	α	L_0	L_t	Description
Experiment	34	89.2	9.44	0.05	0.138	0.152	Normal
Control	35	73.7	15.07		0.137	0.149	Normal

Based on the data in Table 3, it is known that the normality test results obtained a value of L_o smaller than the value of L_t at a level of 0.05 for n_1 = 34 and n_2 = 35. The table shows that the normality test result L_o in the experimental class is 0.138, while the L_o value for the control class is 0.137. The L_t value in the experimental class is 0.152, while the L_t for the control class is 0.149. Therefore, it can be concluded that the data obtained meets the criteria of $L_0 < L_t$. In the experimental class, the value is 0.138 < 0.152, and in the control class, the value is 0.137 < 0.149, which indicates that the final test results of both sample classes come from a normally distributed population.

To ensure that the data had uniform variance between samples, a homogeneity test was conducted. This test aimed to determine whether the variance between the two samples was homogeneous. The test was conducted using Fisher's test. Thus, the similarity of variance in the students' learning data could be determined. The results of the homogeneity test are presented in Table 4.

Table 4. Cognitive Aspect Homogeneity Test

Class	n	S^2	α	F_h	F_t	Description
Experiment	34	89.11	0.05	0.392	0.561	Homogen
Control	35	227.2				

Based on the data in Table 4, the result of Fh for the experimental class and control class is 0.392. From the statistical analysis, the value of Ft is 0.561. Both sample classes have homogeneous variance if the value of $Fh < Ft$. The data shows that the sample has a value of $Fh < Ft$, namely 0.392 < 0.561. Therefore, it can be concluded that both sample classes have homogeneous variance.

After determining that the data is normally distributed and has a homogeneous variance, the data is then subjected to a hypothesis test. A hypothesis test is used to determine whether the hypothesis is accepted or rejected. The hypothesis test used for the two sample classes is the t-test. The results of the t-test can be seen in Table 5.

Table 5. Cognitive Aspect Hypothesis Testing

Class	n	$\bar{x}$	S^2	t_h	t_t
Experiment	34	89.2	89.11	5.10	1.67
Control	35	73.7	227.2		

Table 5 shows that $t_{count} = 5.10$, while $t_{(0.95:67)} = 1.67$, with the testing criteria accepting H_0 if $t_{count} < t_{table}$ and rejecting H_0 if $t_{count} > t_{table}$ at a significance level of 0.05 with df = $(n_1 + n_2 – 2)$. The t-test (hypothesis test) results for both samples show that $t_{count} > t_{table}$, indicating that there is a difference between the means of the experimental and control classes. Since the t-value is not in the H_0 acceptance region, it can be concluded that H_1 is accepted at a significance level of 0.05, which means that "E-SWS sound waves using the discovery learning model are effective on student learning outcomes in cognitive aspects".

Psychomotor data was obtained during the learning process. The indicators assessed in science process skills were observing, identifying problems, collecting data, analyzing data, drawing conclusions, and communicating. Based on this, the mean value ($\bar{x}$), the highest value, the lowest value, the standard deviation (S), and the variance (S^2) of the experimental class and the control class were obtained. The data on the assessment of science process skills (SPS) can be seen in Table 6.

Table 6. Psychomotor Aspect SPS Assessment Results Data

Class	n	Highest Score	Lowest Score	$\bar{x}$	S	S^2
Experiment	34	89.6	65.6	78	5.1	26.01
Control	35	81.3	61.5	67.5	4.4	19.36

Based on Table 6, it is known that the average learning outcomes obtained by students in the experimental class are higher than those in the control class, so it can be seen that the class that uses E-SWS sound waves has higher scores than the class that does not use E-SWS sound waves. The standard deviation of the experimental class is greater than that of the control class, indicating that the learning outcomes obtained by the control class are more evenly distributed than those of the experimental class. The variance in the experimental class is greater than that in the control class, meaning that the learning outcomes obtained in the experimental class are more diverse than those in the control class.

The normality test is used to see whether the data from both samples are normally distributed or not. The sample data used is the learning data obtained after conducting a posttest on the experimental class and the control class. The normality test used is the Liliefors test. From the normality test conducted, the values L_o and L_t were obtained at a significance level of 0.05. The results of this test are presented in Table 7.

Table 7. Psychomotor Aspect Normality Test

Class	n	$\bar{x}$	S	α	L_o	L_t	Description
Experiment	34	78	5.1	0.05	0.119	0.152	Normal
Control	35	67.5	4.4		0.135	0.149	Normal

Based on the data in Table 7, it is known that the normality test results obtained a value of L_o smaller than the value of L_t at a level of 0.05 for $n_1 = 34$ and $n_2 = 35$. The table shows that the normality test result L_o in the experimental class is 0.119, while the L_o value for the control class is 0.135. The L_t value in the experimental class is 0.152, while the L_t for the control class is 0.149. Therefore, it can be concluded that the data obtained meets the criteria of $L_o < L_t$. In the experimental class, the value is 0.119 < 0.152, and in the control class, the value is 0.135 < 0.149, which indicates that the final test results of both sample classes come from a normally distributed population.

To ensure that the data had uniform variance between samples, a homogeneity test was conducted. This test aimed to determine whether the variance between the two samples was homogeneous. The test was conducted using Fisher's test. Thus, the similarity of variance in the students' learning data could be determined. The results of the homogeneity test are presented in Table 8.

Table 8. Psychomotor Aspect Homogeneity Test

Class	n	S^2	α	F_h	F_t	Description
Experiment	34	26.01	0.05	1.34	1.77	Homogen
Control	35	19.36				

Based on the data in Table 8, the result of Fh for the experimental class and control class is 1.34. From the statistical analysis, the value of Ft is 1.77. Both sample classes have homogeneous variance if the value of $Fh < Ft$. The data shows that the sample has a value of $Fh < Ft$, namely 1.34 < 1.77. Therefore, it can be concluded that both sample classes have homogeneous variance.

After determining that the data is normally distributed and has a homogeneous variance, the data is then subjected to a hypothesis test. A hypothesis test is used to determine whether the hypothesis is accepted or rejected. The hypothesis test used for the two sample classes is the t-test. The results of the hypothesis test (t-test) can be seen in Table 9.

Table 9. Psychomotor Aspect Hypothesis Test

Class	n	$\bar{x}$	S^2	t_h	t_t
Experiment	34	78	26.01	9.16	1.67
Control	35	67.5	19.36		

Table 9 shows that $t_{count} = 9.16$, while $t_{(0.95:67)} = 1.67$, with the testing criteria accepting H_0 if $t_{count} < t_{table}$ and rejecting H_0 if $t_{count} > t_{table}$ at a significance level of 0.05 with df = $(n_1 + n_2 – 2)$. The t-test (hypothesis test) results for both samples show that tcount > ttable, indicating that there is a difference between the means of the experimental and control classes. Since the t-value is not in the H_0 acceptance region, it can be concluded that H_1 is accepted at a significance level of 0.05, which means that "E-SWS sound waves using the discovery learning model are effective for student learning outcomes in the psychomotor aspect."

Discussion

The t-test conducted in this study shows that tcount is greater than ttable, which means that the application of E-SWS using the discovery learning model is not only effective in improving students' mastery of physics concepts, but also in improving their science process skills, such as skills in observing, collecting data, processing information, drawing conclusions, and communicating learning outcomes. The Sound Wave E-SWS used in this study was initially developed using a scientific approach, with stages of observing, questioning, trying, reasoning, and communicating. This approach is oriented towards strengthening science process skills through exploratory and reflective activities. However, in this study, the E-SWS was implemented using the Discovery Learning model, so that the scientific stages contained in the E-SWS could be integrated more systematically with the discovery syntax (stimulation, problem statement, data collection, data processing, verification, and generalization).

The integration between E-SWS and the Discovery Learning model provides unique advantages in the learning process. The digital and interactive E-SWS facilitates students to explore physics concepts independently through simulations, video links, and contextual exploratory exercises. Thus, students can play an active role in every stage of Discovery Learning, especially in the process of collecting and processing data, which has an impact on improving their understanding of concepts and scientific process skills.

The advantage of using the Discovery Learning model with the help of E-SWS lies in its ability to facilitate students in discovering concepts independently through guided and interactive activities. Digital features such as drag and drop, sound wave simulations, and practical video links allow students to observe phenomena virtually. This makes it easier for students to understand abstract concepts such as speed of sound, resonance, and sound intensity. This study reinforces the findings of Suarti (2022) and Nehe (2023), who reported that Discovery Learning with the help of SWS is effective in improving physics learning outcomes. However, this study goes further by integrating interactive digital-based SWS (E-SWS). This differs from the research by Ramadhana and Hadi (2022), which showed an increase in learning outcomes only in the cognitive aspect through electronic worksheets, while this study proves a significant effect on students' psychomotor skills in the science process. These findings are also in line with Lathifah (2021) opinion that Liveworksheet-based E-SWS makes learning more flexible, interactive, and in line with the Independent Curriculum. The difference is that this study proves the effectiveness of E-SWS directly in the classroom by using a complete Discovery Learning syntax, so that students are more active and independent in learning.

Although the control class also used the Discovery Learning model, their learning outcomes were lower than those of the experimental class. This was because the printed teaching materials used in the control class were unable to fully support the Discovery Learning stages. In the stimulation and data collection stages, students tended to be passive because learning activities were limited to reading and answering questions without the support of visual media. In the verification and generalization stages, students had difficulty drawing conclusions because they could not visualize the relationship between the physical phenomena and the theory being studied. This condition resulted in a lack of in-depth understanding of the concepts and suboptimal development of psychomotor skills.

Overall, this study provides evidence that the combination of scientific-based E-SWS and Discovery Learning can improve cognitive learning outcomes as well as science process skills. This study also supports teachers' efforts to integrate educational technology with learner-centered learning models. The results of this study can be used as a reference for teachers in integrating educational technology and innovative learning models simultaneously, so that physics learning becomes more contextual, interactive, and meaningful.

CONCLUSION

Based on the results of the study, the use of liveworksheet-based E-LKPD Sound Waves with the Discovery Learning model has been proven to be effective in improving the physics learning outcomes of grade XI students at SMA Negeri 3 Payakumbuh. The t-test results show a significant difference between the experimental class and the control class in terms of cognitive and psychomotor aspects. E-LKPD helps students understand the concept of sound waves more easily and interestingly. The Discovery Learning model encourages students to actively discover concepts through exploratory activities. The combination of the two creates interactive, student-centered learning. Thus, E-LKPD can be used as an alternative innovative learning medium to improve physics learning outcomes.

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