



Implementation of PJBL-STEAM to Improve Science Process Skills in Vibration and Wave Material at Vocational School

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Abstract

Education becomes the sword of poverty by improving the quality of people in a country. Therefore, various research in education continues to be carried out to get all the best recommendations and evaluation material in the field of education, as done in this study. This study aims to determine how applying the PjBL-STEAM improves students' science process skills on vibration and wave material at SMK PGRI Pontianak. The form of this research is a quasi-experiment that is a pre-experimental design type, one-group pretest-posttest design. The research sample was class X students at SMK PGRI Pontianak, totalling 25 people. The instruments used were tests, questionnaires, and interviews. This study used descriptive statistical analysis techniques and inferential statistical analysis. In the pretest, 40% of students had science process skills in the unskilled category, and 48% were in the less skilled category. In the post-test, 76% of students' science process skills were in the highly skilled category, and 12% were in the skilled category. Then, based on the results of the Wilcoxon Test, the value of Asymp. Sig (2-Tailed) of 0.000 ($r < 0.05$) shows that there is a difference in the science process skills of students in the pretest and post-test, with the level of effectiveness in the high category ($3 > 0.7$). Based on the response questionnaire data, the result of students' response analysis to the learning process is that 95% of students gave very good responses, and 5% were categorised as good. The research concludes that applying the PjBL-STEAM effectively improves students' science process skills on vibration and wave material at SMK PGRI Pontianak.

Keywords: effectiveness; PjBL-STEAM; science process skills

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INTRODUCTION

21st-century learning requires educational institutions to create students who not only master cognitive aspects but also have skills that support the development of the 21st century. Increasingly rapid technological advances characterise the development of the 21st century, so it is important to adapt and pay special attention to

teachers in determining the right and effective learning model to be implemented in the learning process (Arnyana, 2019; Bartolome et al., 2018; Musdiani, 2019). In the 21st century, students are also expected to meet the 4C criteria, namely critical thinking, creativity, collaboration, and communication, so these criteria need to be developed in students, and it is important to make it a standard ability

that all students must possess. This makes it important to consider choosing the right learning methods and approaches for teachers to achieve the 4C criteria (Arnyana, 2019; Musdiani, 2019; Permana et al., 2021; Supena et al., 2021; Weng et al., 2022).

Concerning the explanation above, physics is one of the sciences students often consider difficult and boring. Students find it difficult and get bored quickly in studying physics because of the many formulas, the decline of formulas, and complicated calculations in solving the questions (Muizuddin, 2019). In line with the results of interviews conducted with physics teachers at SMK PGRI Pontianak, learning physics at vocational school differs greatly from senior high school. Physics material in vocational school tends to be more complex and needs to be understood by students in depth. This is because vocational school students will apply physics knowledge or concepts directly related to the physics material being taught in their respective majors. Students in vocational school also need to explore the concepts or physics material taught so that when applying directly and carrying out practices in the field, they avoid mistakes or unwanted things. It also aims to minimise obstacles that may occur to students. In contrast to how physics is taught in high school, teaching physics in vocational school focuses more on students learning physics concepts and practising them directly, as well as linking physics knowledge or concepts with objects in the field they study and adjusting to the focus of their respective majors (Hayati et al., 2013).

SMK PGRI Pontianak focuses on engineering majors, including Automotive Light Vehicle Engineering, Business and Motor Vehicle Engineering, and Audio Video Engineering. Graduates are expected to be able to practice the material taught

directly. In physics material, students are also taught and trained directly to practice or apply themselves at school. One example is, in physics measurement material, students at SMK PGRI are directed to directly measure motor parts using a screw micrometre, a calliper, and other supporting measuring instruments directly. The application is carried out to measure the feasibility of motorcycle gears or other tools; then it must be adjusted to the applicable Operational Standards. Other examples are measuring motor vehicle linings' thickness and motorcycle engine parts. Not only that, another example is in electrical material; students directly practice how to use an ammeter (electric current strength measuring instrument) and make simple electrical circuits directly related to motorcycle and car electrical circuits, which are used as mandatory project assignments and are then displayed in a transparent and neat design so that they can be seen from any side (Hayati et al., 2013; Siregar, 2017).

In connection with the explanation above, it is necessary to apply science process skills as a necessity for students to improve their quality and is needed in making it easier to understand physics concepts through a series of science process skills carried out, as well as in meeting its standardisation as a graduate of a vocational school engaged in engineering in the automotive field. This also makes teachers pay more attention to the balance of understanding from students in SMK related to theory and the skills of their students in practising directly. In connection with the above problems, it is important to adjust the learning system in the 21st century to meet the needs of students and the demands of the world of work for students' future (Kivunja, 2015; Lestari, 2018; Malik, 2018).

The Project Based Learning (PjBL) model is reviewed as a suitable model to be applied in the current situation (Baran

et al., 2021; Diana & Sukma, 2021; Kanza, 2020), especially at SMK PGRI Pontianak on vibration and wave material. PjBL is a learning process that directly involves learners to produce a project. Applying this PjBL model provides a great opportunity for learners to make decisions when choosing topics, conducting research, and completing a particular project (Venalia, 2022). This PjBL Model, which involves making students' projects, makes students feel they exist in the real world and can produce realistic and real products. Students feel and carry out the manufacturing process directly (Fitriyah & Ramadani 2021; Jalinus et al., 2019; Syahril et al., 2021), stated that science process skills are basic skills that facilitate learning in science, which allows students to actively develop a sense of responsibility, improve learning and be trained in designing and carrying out research methods, even though starting from the basics or cases that are still simple (Nasrah, 2021). This science process skill is a person's skill in using reason, thought and action effectively and efficiently to achieve certain results (Muizzuddin, 2019; Nadia et al., 2021; Risda et al., 2023).

Science process skills aim to help students be more active in understanding and mastering the science they do, such as observing, classifying, interpreting, predicting, hypothesising, planning experiments/research, opinion, and communication (Prasasti, 2017). Teachers need to understand these skills because they are important as basic capital in science learning (Rauf et al., 2016).

Based on the title and authority of the purpose of this study, it is expected to improve the quality of education in Indonesia. The unique thing in this research is that science process skills are tested in vocational schools, which generally have less weight in studying theory than other types of schools in

general (Suryaningsih, 2022). Thus, it was collaborated to see the validity of PjBL-STEAM (Science, Technology, Engineering, Art, and Mathematics). Chistyakov et al. (2023), which was emphasised as a recommended model in the 21st century. Being unique is also because the skills tested are students' needs in the 21st century (Permana et al., 2021).

PjBL-STEAM applies the STEAM approach. STEAM is an integrated approach with science, technology, engineering, arts and mathematics, which aims to increase student engagement, innovation, problem-solving skills, creativity and innovation, as well as other cognitive benefits (Perignat & Katz-Buonincontro, 2019; Suwardi, 2021). In this research, we used STEAM learning steps modified according to the George Lucas Educational Foundation. The learning step begins with recognising the problem, continues with project planning, preparing a work plan, monitoring the project's progress, and ends with evaluation and reflection (Suryaningsih, 2022).

Constructivism theory is the basis of PjBL, which is integrated with STEAM (Sari et al., 2024; Sukmawati et al., 2023; Suparlan, 2019), which prioritises students building their knowledge (Badriyah et al., 2020). The evaluation provided is to test the results of the projects carried out by students and carry out a final test with six questions that have been validated and adapted to the six indicators of science process skills contained in the questions. During class practice, students create a project in the form of a smart Parker product that uses the basic concept of vibration (sound) in physics material. The reflection given to students is to solve problems according to their respective fields, which can be solved using physics concepts learned at school.

Based on the explanation, this

research focuses on the effectiveness of PjBL-STEAM in improving students' science process skills, especially in vibration and wave material at the vocational school level. This research aims to answer the question, "Can PjBL that integrates with STEAM be effectively chosen by teachers to be applied in teaching physics in this material and at that level? This is, of course, supported by theoretical basis and previous research. By answering this, this research can add references for selecting appropriate learning models by teachers.

METHOD

The research design used in this study is a pre-experimental design (Storga, 2016). Pre-experimental design research results are dependent variables (bound) not solely influenced by independent variables (free). This happens because there are no control variables, and the sample is not randomly selected (Sugiyono, 2017). The design used in this study is a one-group pretest-posttest design (Sugiyono, 2017).

Table 1 One grup pretest-posttest design

Pretest	Treatment	Posttest
O_1	X	O_2

Description:

O_1 = Pretest Score

X = Treatment given (Independent Variable)

O_2 = Posttest Value

Through the pre-experimental design, one-group pretest-posttest can produce more accurate experimental results because, at the beginning of the study, a pretest was conducted before being given treatment and a post-test was given after treatment so that researchers could compare before and after treatment. This research was conducted at SMK PGRI Pontianak in the even semester of the 2023/2024 school year. Science process skills in this research have six indicators, which are the main focus, including observing skills, making conclusions,

applying concepts, predicting skills, communicating and formulating hypotheses. According to Sugiyono (2017), the population consists of individuals with characteristics that tend to be the same, so they are general. SMK PGRI Pontianak. has class X students totalling 1 class consisting of a combination of TAV (Audio Video Engineering), TBSM (Motorcycle Engineering), and TKR (Light Vehicle Engineering) majors. The sample to be used is class X, with 25 students. Obtaining data related to the focus of research made by researchers is very important. So, to get this data, researchers used four data collection techniques: measurement techniques, interview techniques, observation, and documentation studies. Table 2 shows which validation criteria.

Table 2 Validation criteria

Criteria	Value Range
Very valid	$3.5 < V_a < 4$
Valid	$2.5 < V_a < 3.5$
Less Valid	$1.5 < V_a < 2.5$
Invalid	$0.5 < V_a < 1.5$

(Sugiyono, 2017)

Then, Table 3 shows the category of science process skills.

Table 3 Category of science process skills

Score Percentage	Category
0% - 20%	Very Bad
21% - 40%	Bad
41% - 60%	Sufficient
61% - 80%	Good
81% - 100%	Very Good

(Inayah et al., 2020)

The hypothesis test used in this research is the sample T-pairing for normally distributed data and the Wilcoxon Signed Rank test. Test for data that is not normally distributed. Hypothesis testing using SPSS version 26.0 for Windows. If the data is normally distributed, continue with statistical tests parametric, namely

the paired sample T-test. If the data is not normally distributed, the Wilcoxon test is used. To determine the magnitude of the effectiveness of STEAM implementation in improving students' science process skills seen from normalised gain (N-Gain). The effect size criteria can be seen in Table 4.

Table 4 Effect size criteria

Interval	Criteria
$0.2 \leq ES < 0.5$	Low
$0.5 \leq ES < 0.8$	Medium
$0.8 \leq ES < 1.3$	High
$ES \geq 1.3$	Very High

(Rahmandani et al., 2023)

Table 5 shows the gain of the index.

Table 5 Gain index

Percentage	Interpretation
$-.00 \leq g < 0.00$	Decrease
$g = 0.00$	No Increase Occurred
$0.00 < g \leq 0.30$	Low
$0.31 < g \leq 0.70$	Medium
$0.71 < g \leq 1.00$	High

(Sukarelawan et al, 2024)

The effectiveness of the STEAM approach is large and can be calculated using the effect size formula.

RESULT AND DISCUSSION

In this study, PjBL-STEAM learning is carried out by creating an Arduino-based project related to vibration and wave material, namely creating a project designed and tested by students themselves on smart parking solutions by looking at problems directed by the teacher. The main objective of this study was to determine the effectiveness of the PjBL model with the STEAM approach to improving science process skills on vibration and wave material at vocational schools (Suwardi, 2021). This research was conducted at SMK PGRI Pontianak, which consists of light vehicle mechanical engineering, automobile mechanical engineering, and audio-video engineering.

The PjBL-STEAM learning process

was carried out twice in accordance with the PjBL steps (syntax), which had been integrated with the STEAM approach. This is done to integrate projects that students have created with approaches involving science, technology, engineering, art, and mathematics. The syntax consists of problem recognition, project planning, preparation of work plans, monitoring the project's progress, and evaluating project results. Where students produce projects that involve the process of understanding science, technology, engineering, art and mathematics (Dywan & Airlanda, 2021).

Problem recognition in this research involves applying a reference card containing problems relevant to the vocational school field. So, students are directed as someone who solves problems with the output in the form of an innovative idea in the form of a smart parking project, which can be created by designing using physics concepts, namely the concept of sound. This is followed by project planning, which directs students to prepare the tools they need and the concepts they will use and apply in creating Arduino-based smart parking. Work plans are prepared together with a group of friends. They prepare to execute and connect the tools that need to be connected to the tools, as well as prepare their respective PCs. Monitoring the progress of the project is carried out by controlling and checking the tools and then seeing the movement of the Arduino-based smart parking tool, which can be monitored via the students' PC. The final stage is evaluating project results; students test the function of the tool and compare it with the calculation results, carrying out a final evaluation.

The findings of the research results are sorted based on the order of the problem formulation in Chapter I. The first problem formulation is answered in the section on students' science process skills on the pretest and post-test. The next step is to analyse the difference in

science process skills on the pretest and post-test to determine the difference in students' science process skills (Syafitri, 2021). The goal is to determine if there is a difference between the pretest and post-test scores on the research sample. The research was also conducted by making observations using observation questionnaires validated by experts and conducting interviews with students. Interviews were conducted based on an interview guide and conducted with several students (Fitriana et al., 2019).

The results show that they feel happier in this PjBL-STEAM learning because learning is considered more challenging, not boring, and more interesting and useful. The observation results also show an increase in the last meeting, which shows that students' science process skills have increased when viewed in terms of observations made directly in the classroom. The next problem formulation is testing the effectiveness of treatment, which aims to determine whether the PjBL-STEAM improves students' science process skills on vibration and wave material (Badriyah et al., 2020). Furthermore, the formulation of the fourth problem was answered in the section on students' responses to the learning process, which aims to determine the student's response to the learning process using the PjBL-STEAM approach (Haddar et al., 2023).

Data on science process skills of learners before and after treatment

Figure 1 shows a very significant difference in the pretest and post-test results before and after treatment. The results of the data analysis presented in diagram form show that after implementing PjBL-STEAM, the science process skills results significantly increased and were dominated by the highly skilled category. Analysis was carried out by conducting a pretest, providing

treatment, and ending with a post-test. These results can be seen in Figure 1.

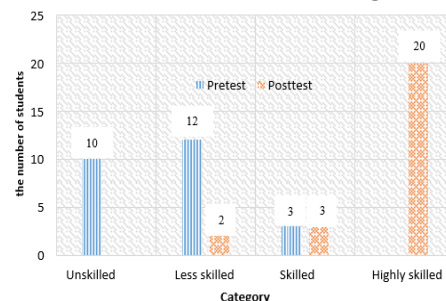


Figure 1 Science process skills data

Figure 1 shows data on improving students' science process skills, as shown in the orange graphic image. This data is also relevant to previous research, which states that the implementation of PjBL-STEAM is effective in improving students' science process skills (Syafitri, 2021).

Science process skills for each indicator before and after treatment

After categorising students' Science Process Skills based on the scores obtained from the pretest and post-test results, they analysed the increase in science process skills on each indicator before and after treatment. This stage is carried out by counting the number of students categorised as unskilled, less skilled, skilled, and highly skilled for each indicator item. After that, the researcher calculated the interpretation of each category by dividing the number of students in the category by the number of students and multiplying by 100% to get the percentage. The data below shows a significant increase in each question indicator number. A very clear difference can be seen in indicator number 4, which experienced an increase in students' post-test results. The data about an increase in each question indicator after being given treatment. These results can be seen in Figure 2.

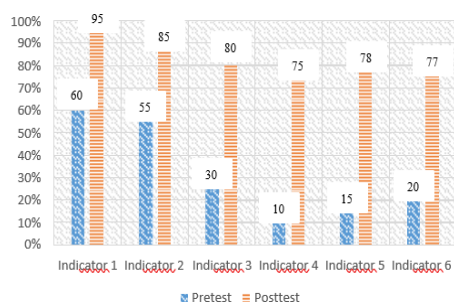


Figure 2 Science process skills data of each indicator before and after being given treatment

Science process skills in this research have six indicators, which are the main focus, including observing skills, making conclusions, applying concepts, predicting skills, communicating and formulating hypotheses. Indicators in Figure 2 are the term for the question indicators given to students; namely, there are 6 question indicators. This is

relevant to previous research, which stated that there was an increase in each question indicator given to students from the pretest before learning with the PjBL-STEAM model to the post-test after implementing the learning model (Fitriana et al., 2019).

Differences in science process skills of students before and after treatment

This test was carried out by conducting a data normality test and a data homogeneity test. The T test was used if the data meets the requirements, namely, it is normally distributed and homogeneous. If it does not meet the requirements, it is not normally distributed or homogeneous, and the statistical test that was used is the Wilcoxon test. The result of the Test of Normality can be seen in Table 5.

Table 5 Test of normality result

Kolmogorov-Smirnov			Shapiro-Wilk		
Statistic	df	Sig.	Statistic	df	sig
.260	25	.000	.815	25	.000
.237	25	.001	.832	25	.001

The data in Table 5 is data from the normality test using the Shapiro-Wilk test. The data shows that the data is not normally distributed because if the probability ($\text{sig} \geq 0.05$), then H_a is rejected and H_o is accepted (normally distributed data). If the probability ($\text{sig} < 0.05$), then H_a is accepted. H_o is rejected (data not normally distributed). Based on the conditions for using the Wilcoxon test, if the significance asymptomatic value is ≥ 0.05 , then H_a is rejected, and H_o is accepted, meaning there is no difference in science process skills before and after implementing the PjBL-STEAM model (Hasyim, 2018). Meanwhile, if the significance asymptom is < 0.05 , then H_a is accepted, and H_o is rejected; this shows differences in science process

skills before and after implementing the PjBL-STEAM model. The result of the statistics ties can be seen in Table 6.

Table 6 Statistics test result

Score-test	
Z	-6.173 ^b
Asymp. Sig. (2-tailed)	.000

Based on the Wilcoxon test results Table 6, it can be concluded that the significance asymptom < 0.05 is (0.000 < 0.05), so it can be concluded that H_a is accepted and H_o is rejected. So, there are differences in science process skills before and after implementing the PjBL-STEAM model. This is in line with research that states that implementing STEAM-PjBL can grow and improve the skills students need to

face the challenges of the 21st century (Nurhasanah et al., 2023).

Increasing students' science process skills after implementing the PjBL-STEAM model

Figure 3 shows the results of improving science process skills.

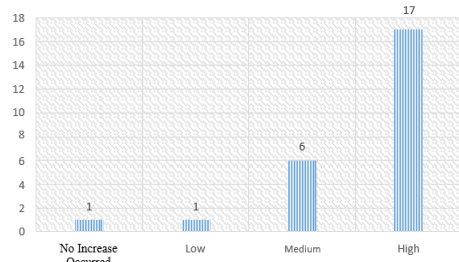


Figure 3 The results of improving science process skills

Based on Figure 3, the increase in students' science process skills is in the high category, while the very high category is not a single one. Figure 3 shows the number of students who have improved their science process skills. High growth dominates with a total of seventeen students. This is in line with research which states that implementing PjBL-STEAM can help improve science process skills effectively (Nasrah, 2021).

The effectiveness of PjBL-STEAM in improving students' science process skills

In the next stage, the effectiveness of implementing the PjBL-STEAM model was tested using the effect size formula. The result of the average pretest and post-test scores, as well as the standard deviation, which can be seen in Table 7.

Table 7 The result of the average pretest and post-test scores

	Pretest	Post-test
Valid	25	25
Missing	0	0
Mean	20.40	50.00
Median	20.00	50.00
Std.		

Deviation	10.59	11.18
Minimum	10.00	20.00
Maximum	40.00	60.00
Effect Size = 3		

Based on the results in Table 7, three is in the interval with high criteria ($3 > 0.7$), with the PjBL-STEAM model's effectiveness being high (Sari, 2018). The normalised gain result is obtained using SPSS, the results of which can be seen in Table 8.

Table 8 Normalised gain result

No	N-Gain score (%)	
	Experiment class	Control class
Average	65.80	36.5
Minimum score	68.80	10.00
Maximum score	82.50	62.40
N-Gain	0.96	0.96

Based on the results obtained in Table 8, the normalised gain result is 0.96. This result is at high criteria. In line with these results, previous research also stated that there were very significant changes (Nasrah, 2021) in the experimental class after being given treatment in the research.

Student responses to the learning process using the PjBL-STEAM

The instrument used to determine student responses is a questionnaire comprising 15 statements divided into positive and negative statements, which are also equipped with an assessment rubric. The following is the distribution of student responses via the questionnaire, which can be seen in Figure 4.

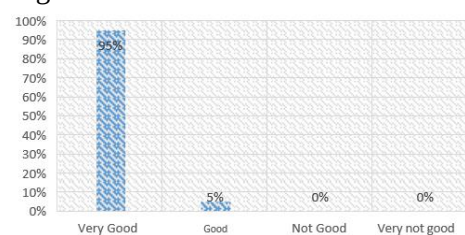


Figure 4 Students response categories

Based on the data of Figure 4, it can be concluded that most students responded very well to PjBL-STEAM learning and were happy with this learning model. This is also relevant to research, which says students enjoy this learning process (Badriyah et al., 2020). This result is the same as research from Knight (2021) about students' responses to PjBL-STEAM learning. Most of the students gave positive responses about this system of learning. Based on the questionnaire given to students, it can be concluded that the student's response to the science process skills trained by the teacher in learning is very good (Sunanto, 2021).

CONCLUSION

Based on the results of data analysis and discussion and a series of studies conducted, the PjBL-STEAM is effective for improving science process skills at SMK PGRI Pontianak with an effective level in the very good category. This research implies that the PjBL-STEAM model can improve students' science process skills, especially those proven in vocational school. This research proves that PjBL-STEAM is highly recommended for physics learning, especially when applying waves and sound material.

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