The Effect of the STEM Integrated Project-Based Learning Assisted by Electronic Student Worksheets on Students' Science Process Skills

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Abstract: This study aims to describe the effect of the STEM-integrated project-based learning (PjBL) model assisted by electronic student worksheets on students' science process skills in simple harmonic vibration material. This research was conducted at SMA Negeri 1 Bumi Agung using an experimental design with a non-equivalent control group design. Both test and non-test instruments were used to evaluate the research. The results indicate that the N-gain in the experimental class was 0.55, indicating a moderate improvement. The observation sheet of science process skills in the experimental class showed a percentage of 75% with a good cathegory. The Mann-Whitney hypothesis test demonstrated that there was a significant difference in the average increase of science process skills between the experiment and control classes (sig. of $0.001 < 0.05$). The effect size test showed that Project Learning integrated with STEM assisted by student worksheets was effective to improve students' science process skills, with an effect size of 0.199, representing a large category.

Keywords: Electronic student worksheets; Science process skills; STEM-integrated PjBL

Introduction

The 21st century demands that HR keep up with global competition by developing diverse competencies and skills in response to technological advancements. To achieve that, learning innovations must be aligned with the demands of 21st century skills, to improve human resources (Widestra et al., 2020). These learning innovations were implemented in the 2013 curriculum, which is considered a strategy policy to develop 21st century skills (Kemendikbud, 2014). The 21st century skills can be developed by applying Science Process Skills (SPS) (Mushani, 2021). SPS teaches students how to find facts, concepts, principles, or theories in developing existing concepts (Larashati et al., 2023). SPS is seen as a way to provide meaningful learning experiences for students (Tilakaratnea & Yatigammaa, 2017).

After conducting questionnaires and observations with 106 students and teachers at SMA Negeri 1 Bumi Agung, it has been discovered that researcher identified

several problems, including 1) lack of the implementation of learning approaches, models and methods that encourage student to conduct appropriate experiments based on real life problems such as projects and inquiries because teachers still dominantly use the lecture method, 2) limited teaching materials used in learning such as rare use media and LKPD to find facts and solutions, 3) lack of resources such as tools and materials to conduct experiment, 4) low ability of students to use technology due to the lack of opportunities to be introduced and access technology that can be used in learning, 5) low value of student's science process skills that have not been fully mastered during physics lessons. These skills include observing, communication, prediction, hypothesis formulation, experiment design, tool and material use, and application of physics concepts.

According to interviews with physics teachers, it has been found that the current approach to physics education is not student-centered. The learning is adjusted to cater to students who have experienced

learning loss or setbacks due to ineffective distance learning during the pandemic. As a result, meaningful learning fails to occur as the teacher remains the primary source of knowledge, relying on lectures that are not problem-oriented. According to Budiarti et al. (2022), this inefficiency in learning poses a major challenge for educators and students, particularly in physics, where concepts can be difficult to comprehend. Therefore, a suitable solution is required to address this issue.

Science process skills is necessary for learning since it facilitates the discovery and development of scientific facts, concepts, and principles that offer direct and meaningful learning experiences for students (Asni & Novita, 2015). When it comes to practical learning, it can be challenging to comprehend if the media and methods used are not diverse (Anggreini & Permadi, 2021). To improve students' science process skills, it's important to adopt innovative learning model. Project-based learning (PjBL) is one such model, which involves a learning that enables students to practice science process skills and increase their activity levels (Nawahdani et al., 2021). With PjBL, students have the opportunity to construct their knowledge and become more empowered in their learning either independently or in groups by conducting experiments to create a product that solves a real-world problem (Larashati et al., 2023).

However, the rapid development of knowledge and technology requires 21st century learning not only to develop skills oriented to mathematics and science but also to be oriented towards technology and scientific engineering integrated into the learning process. The innovation in learning is implemented in the integration of STEM education into the educational process in Indonesia as a reference point (Firman, 2015). By integrating STEM into PjBL, students can improve their knowledge, science process skills, technology and attitudes by engaging in meaningful learning activities and exploring concepts through projects. This approach encourages students to become active participants in their learning (Jatmika et al., 2020).

One way to integrate STEM PjBL is through the use of electronically-based teaching materials, such as electronic student worksheets. This tool provides students with the attitudes, knowledge, and skills they need to succeed in STEM learning. By using electronic student worksheets, students can become more engaged in the learning process (Andriyani et al., 2019). Recent research by Kurniasih (2022) has found that using electronic student worksheets in physics and chemistry-based project-based learning can significantly increase students' learning outcomes and their motivation.

According to the research by Jatmika et al. (2020), it has been discovered that the use of PjBL integrated with STEM has a positive impact on students' science process skills. Similarly, Kurniasih's research in (2022) shows that the use of electronic student worksheets with PjBL

improves students' learning motivation and outcomes. However, to overcome these problem there has been no study conducted to evaluate the effect of a STEM-integrated PjBL model, assisted by electronic student worksheets, on students' science process skills. Hence, a research was conducted titled "The Effect of STEM-Integrated Project Based Learning Model Assisted by Electronic Student Worksheets on Students' Science Process Skills on Simple Harmonic Vibration Material".

Method

This study used experimental design research with a non-equivalent control group design which used two samples, X MIPA 4 as the experimental class and X MIPA 3 as the control class at SMA N 1 Bumi Agung. The samples were chosen based on the criteria of using smartphones in learning, high interest in learning physics and relatively similar level of science process skills. The instruments used are pre-test, post-test and science process skills observation sheets.

To assess the science process skills of students, a pre-test is administered before the learning process begins. In the experimental class used the STEM-integrated PjBL model with electronic student worksheets, while the control class used the discovery learning model. During the learning process, the observer observed the science process skills using the science process skills observation sheet. After completing the treatment, students were given a post-test.

The study used qualitative and quantitative data analysis techniques. Qualitative analysis used the result of science process skills observation sheet scores. Quantitative analysis used: 1) descriptive statistical tests, 2) normality and homogeneity test, 3) Wilcoxon and Mann-Whitney test, 4) the effect size. Normality and homogeneity test were used for prerequisite test, Wilcoxon test to compare two related sample groups and the Mann-Whitney test to compare two unrelated sample groups (Suyanto & Gio, 2017) for the hypothesis test, and the effect size was used to measure the impact of the STEM-integrated PjBL assisted by electronic student worksheets on students' science process skills.

Result and Discussion

Result

After analyzing the qualitative data from Table 1, it is evident that the average indicator score in the experimental class is higher than that of the control class in terms of science process skills.

According to Table 1, the experimental and control classes scored highest in applying concepts, while predicting and formulating hypotheses had the lowest score in the experimental class, and predicting had the

lowest score in the control class. When considering overall scientific process skills, the experimental class had a higher average percentage of 75% with a good category compared to the control class, which had an average percentage of 64% with a good category. Table 2 shows that there are differences in the average scores of students' science process skills after treatment, as found through descriptive statistical analysis.

Table 1. Science Process Skills Observation Sheet Results

Aspects of Science Process Skills Observation	Experimental Class					Control Class				Indicator Score (%)
	Meeting				Average	Meeting				Average
	1	2	3	4		1	2	3	4	
Observing	73	58	92	94	79	46	49	68	75	60
Predicting	52	61	65	71	62	37	44	54	63	50
Hypothesize	51	60	67	70	62	43	55	61	70	57
Planning an Experiment			64	80	72			52	67	60
Using Tools and Materials				82	82				73	73
Applying concept				88	88				76	76
Communicating				80	80				75	75
Average Percentage					75					64

Table 2. Quantitative Data of Science Process Skills Learning Outcomes

Statistical Parameters	Class			
	Experimental			Control
	Pre	Post	Pre	Post
Numbers of Samples (N)	27	27	26	26
Highest score	57.50	97.50	57.50	75
Lowest value	12.50	50	5	32.50
Maximum score	100	100	100	100
Average score	34.44	71.20	31.34	60.57

According to Table 2, the post-test scores for both classes have improved. Additionally, the average posttest score for students in the experimental class is higher than that of the control class. Table 3 provides a data analysis of the students' science process skills, specifically looking at each indicator and the N-gain value.

The data in Figure 1 indicates that students in the experimental class had higher average N-gain in science process skills compared to those in the control class. Both classes scored highest in communication, while the lowest scores in the experimental class were in designing experiments and predicting, and the lowest scores in the control class were in designing experiments and formulating hypotheses. Overall, the experimental class had an N-gain average of 0.55, while the control class had an average of 0.41, both falling under the moderate category.
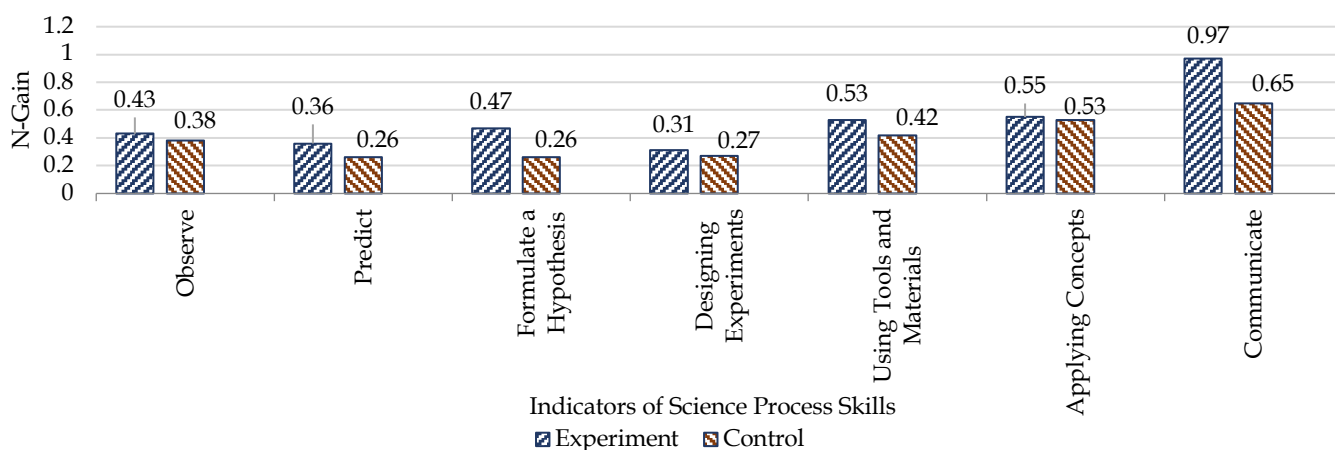

Figure 1. Quantitative data of science process skills for each indicator

The prerequisite tests, such as normality and homogeneity tests, need to be conducted beforehand. In the experimental class, the sig. values for pretest, posttest, and N-gain were all higher than 0.05, indicating that they were normally distributed. The control class, on the other hand, had a sig. value of 0.046 for the pretest, 0.001 for the posttest, and 0.429 for the N-gain, showing that the pretest and posttest were not normally distributed, but the N-gain was. The homogeneity test revealed that the pretest had a homogeneous variant, while the posttest and N-gain had inhomogeneous variants.

Due to the non-normality and non-homogeneity of the data, non-parametric statistical tests, such as the Wilcoxon and Mann-Whitney tests, were used for hypothesis testing. The Wilcoxon test showed that there was a significant difference between the average pretest and posttest scores in both the experimental and control classes, with a sig. value of 0.000. Therefore, H1 was accepted, and H_0 was rejected. This suggests that the STEM-integrated PjBL assisted by electronic student worksheets in the experimental class and the discovery learning model in the control class had a significant impact on students' science process skills. The Mann-Whitney test, using the N-gain value, showed results that are presented in Table 3.

Table 3. Mann-Whitney Test Results

Test Statistic	N-gain
Mann-Whitney U	171.500
Wilcoxon W	522.500
Z	-3.218
Asymp. Sig. (2 tailed)	0.001
Decision	Hypothesis accepted

The results from Table 3 show that the Mann-Whitney test's 2-tailed significance level of 0.001 is lower than the accepted level of 0.05. This means that H_1 is accepted, and H_0 is rejected, indicating there's a significant difference in students' SPS between the experimental and control groups. The STEM-integrated PjBL model, assisted by electronic student worksheets, has a positive influence on students' science process skills regarding harmonic vibrations. To determine the extent of this influence, an effect size test can be used. The test shows an effect size value of 0.199, which falls under the large category. Therefore, it can be concluded that the STEM-integrated PPABL model, assisted by electronic student worksheets, has a significant impact on students' science process skills regarding simple harmonic vibration material.

Discussion

The results of the data hypothesis test using the Wilcoxon test indicate that there is an increase in the scientific process skills of students before and after the treatment, which involved the application of the STEM-integrated PjBL model assisted by electronic student worksheets on simple harmonic vibration material. The significance level (0.05) was exceeded with a sig. (2-tailed) of 0.000. Additionally, the Mann-Whitney test showed a significant difference between the experimental class (STEM-integrated PjBL model assisted by electronic student worksheets) and the control class (Discovery Learning model) in the posttest of science process skills, with a sig. (2-tailed) of 0.001.

The application of the STEM-integrated PjBL model assisted by electronic student worksheets had a great influence on the science process skills of students on simple harmonic vibration material, as indicated by the effect size results (effect size $\mu^2 = 0.199$). The STEM-integrated PjBL activity assisted by electronic student worksheets helped to train students' science process skills on simple harmonic vibration material, resulting in an improvement of students' science process skills. The experimental class had an N-gain of 0.55, which was higher than the control class of 0.41, and the results of observations of science process skills of the experimental class of 75% were higher than the control class of 64%.

Figure 1 shows that the communication indicator was the highest indicator achieved by students, indicating that students were able to communicate experimental data in graphical form very well after applying STEM-integrated PjBL. That is because they can learn from mistakes in understanding data communication so that they can communicate data better. The indicators of designing experiments and prediction are the lowest indicators achieved by students in the experimental class. This is in contrast to the studies conducted by Fitriyani et al. (2018), Bhakti et al. (2020), and Lumbantobing et al. (2022), where the indicators of applying concepts and designing experiments have the highest increase because the implementation of PjBL integrated with STEM requires students to apply their knowledge to solve the real-world problems. However, in this study, the students were still not accustomed to generating many ideas as a solution to designing experiments and designing experimental steps in a detailed and structured way.

Based on the observation sheet's results, the observation indicator score decreased from 73% in the first session to 58% in the second session. This was because the complexity of the problems differed between the two sessions. In the first session, the video on simple harmonic oscillations was easy for the students to observe, whereas, in the second session, they faced difficulties in observing the virtual demonstration of the pendulum and spring laboratories. According to Saleh et al. (2020) observing does not experience obstacles because students are used to making observations. In this study, the students' difficulties were due to their lack of understanding of the object of observation and the complexity of the aspects observed. It also took them a long time to understand the object of observation. Both learning models, project-based learning and the traditional model, showed a small difference in improvement based on cognitive aspects. The same phenomena and media were given to both classes, and the students were asked to observe problems from the same video (Pramesti et al., 2022). In the PjBL model, students were encouraged to identify problems and formulate them in the form of questions based on the learning that was not limited to reading from books (Abidin, 2014), so that it could stimulate their thinking and reasoning (Lumbantobing et al.,

2022). Observing is a fundamental skill that every individual must possess in conducting scientific investigation activities (Suansah, 2015).

The experimental class showed higher scores in predicting and formulating hypotheses compared to the control class. This was due to the STEM-integrated PjBL model, which provided STEM-based problems for students to gain a better understanding of the material. By using this model, students were able to correctly answer prediction questions and apply the four STEM perspectives to search for relevant and reliable literature (Jatmika et al., 2020). Research activities involving real-world work help students gain new knowledge and improve their information-gathering skills (Chiang & Lee, 2016). Students can ask question and give opinions based on information from teacher as a facilitators to actively involve student in learning (Wiratman et al., 2023) that can improve their observation and prediction skills. Students can use observation patterns to make predictions and assumptions about a phenomenon (Sari et al., 2017). Additionally, the researcher believes that the habit of note-taking important information that is heard, seen, and understood independently activities improves memory and helps students recall what they have learned. The length of time that knowledge is stored in memory is influenced by students' active role in the learning process and their ability to find the truth of the concepts they learn rather than learning with the approach of remembering concepts (Fitriyani & Anggraini, 2018). The PjBL model encourages students to actively engage in the learning process and develop scientific process skills, which in turn affects the length of storage of knowledge in students' memory.

In the discovery stage, students are required to design experiments that involve determining the tools and materials, experimental variables, and steps involved (Purwaningsih et al., 2020). This activity is usually done in groups and results in higher skills in designing experiments in experimental classes compared to control classes. Students need to be creative and innovative in designing experiments to find solutions to existing problems. Septikasari et al. (2018) opinion emphasizes that creativity and innovation are further developed when students have the opportunity to think divergently. However, students often face difficulty in designing experiments as they have never done it before. Therefore, group discussions and longer teacher guidance are required to properly train the skills of designing experiments. The PjBL model is an effective way to improve scientific process skills when students are guided in conducting experiments (Amsikan, 2022). Students can better understand the steps of experiments through meaningful learning experiences with interaction among students during discussions (Maryani et al., 2017). According to Anggraeni (2017), scientific process skills are best trained through activities

that are carried out directly as a learning experience, which helps students better understand the process or activities that are carried out.

Figure 2. Student conduct experiment in the application stage

The figure 2 shows that students are highly enthusiastic about conducting experiments, as evidenced by the indicator value of 82% for using tools and materials, which falls under the very good category in the discovery and application stage. The students' excitement stems from the fact that project-based experiments are a new experience for them (Pramesti et al., 2022). The enthusiasm of learners to participate in designing experiments, designing tools, and conducting experiments shows that learners can work actively accompanied by direct understanding of concepts and materials (Akbariah et al., 2023). In the application stage student will prove hypothesize, interpret what something means, and solve problems (Suryaningsih, 2017). Additionally, the students can use the tools and materials correctly, carefully, and efficiently, showcasing their sense of responsibility and cooperation toward the success of their group project tasks (Wenning, 2011). Furthermore, the experimental class has a higher N-gain than the control class, as they design and determine their tools and materials to conduct experiments, allowing them to better understand the functions of the tools and materials used (Pramesti et al., 2022).

Observations show that students have a strong ability to apply the concepts they have learned, as indicated by an 88% score with very good criteria. This is evident in their ability to apply concepts to design experiments, conduct experiments, use tools and materials, and analyze experimental data effectively. According to Rustaman in Handayani (2021), they can also apply concepts to new experiences to explain what is happening. In terms of analyzing concepts, equations, and practice problems based on real-world problems, students can integrate STEM into PjBL to learn and apply scientific concepts relevant to real life through direct experience, rather than simply memorizing

concepts (Herak & Lamanepa, 2019). By utilizing the STEM integrated PJBL model can help students gain new knowledge that can be used to solve various kinds of problems in real life (Aprianty et al., 2020).

The highest average N-gain in both experimental and control classes is displayed by the communicating indicator. This is because students can learn from their mistakes when drawing graphs and tables so that they can communicate data better. Additionally, some students excel at creating graphs and presenting project results. According to Jatmika et al. (2020) research, communication skills are often trained in various forms during the learning process. However, many students struggle with graph-making, which is evident in the communication indicator test questions. In particular, aspects such as the completeness and accuracy of graph drawing are often missed by many students, especially in the control class students. Observations during the learning process reveal that the experimental data was not communicated or written correctly in the table. This was due to the absence of units listed for each quantity entered, confusing readers trying to understand the experimental results. It is crucial to communicate results effectively in writing as it greatly impacts the success of an experiment or learning. This aligns with McNutt (2013) belief that even the most remarkable scientific discoveries have little value if they are not communicated accurately and widely.

Students analyze data and present findings through tables and graphs. They use these facts and concepts to formulate a conclusion, which is then detailed in an experiment report. The students have high cognitive skills in communication, however, during the learning process, some struggled with drawing conclusions from the data and determining relationships. Previous research by Hariningwang et al. (2020) shows that students struggle to make decisions due to a lack of knowledge. Although group discussions were conducted, some students still had difficulty in making decisions. After the group representatives present their conclusion, students answer questions included in the electronic student worksheets to assess their learning. They apply the concepts they have learned to real-life problems in the given problem.

STEM is integrated into almost every stage of PjBL. Science is a key element in all stages which makes science a study of knowledge (Sartika, 2019). The implementation is in observing and predicting phenomena in the reflection stage, gathering information to develop knowledge in the research stage, applying known knowledge to project design and experiments in the discovery stage, applying concepts to conduct experiments and analyze data in the application stage, and drawing conclusions and presenting experimental results in the communication stage.

The discipline of technology as a media and facility that supports learning is integrated into PjBL in the form of the use of electronic student worksheets (Sartika, 2019). The electronic student worksheets help to construct students' understanding, increase students' interest and learning activities (Piawi et al., 2018), worksheets, videos to orient the problem in the reflection stage, using virtual labs in the research stage, using electronic student worksheets to access experimental videos as a reference for students in designing projects in the discovery stage and using google drive as a place to upload or store the results of experimental reports and practice questions that were connected to electronic student worksheets in the application and communication stage.

The STEM-based electronic student worksheets include an engineering aspect through the creation of simple tools during the discovery stage. This involves designing projects and experiments, selecting tools and materials, designing the tools, and determining the steps of the experiment (Sartika, 2019). Students can understand the science concepts applied in the tool experiences because of the simple tool-making project in the STEM-based electronic students worksheets and also involve students in actively building learning (Sulistiyowati et al., 2018). Students are more engaged when working on projects and experiments with tools that they have assembled in groups.

Mathematics is integrated throughout the PjBL process not just in measurements, but also in the ability to analyze, formulate, solve, and interpret mathematical problems in real-world applications (Asmuniv, 2015). The form of mathematical integration is taking measurements, using simple harmonic equations, formulating concepts based on PjBL, designing and conducting experiments, using mathematical formulas, and calculating period and frequency (Sartika, 2019).

Conclusion

Based on the result and discussion, it can be concluded that STEM-integrated PjBL assisted by electronic student worksheets, can be an effective alternative for teachers to improve students' science process skills in simple harmonic vibration material.

Conflict of interest
No conflict of interest.

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