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Effectiveness of Guided Inquiry-Based Worksheets in Improving Science Process Skills on Vibrations and Waves Material

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Abstract: Science education is a key factor in developing students' science process skills and understanding of scientific concepts. Mastery of science process skills is one of the important ways to gain knowledge. By implementing Student Worksheets based on guided inquiry, science process skills and understanding of scientific concepts can be improved. This study examines the effect of guided inquiry-based worksheets on science process skills. This study used a quasi-experimental design with a one-group pretest-posttest model to examine the effectiveness of guided inquiry-based worksheets in improving students' science process skills on vibration and wave material. The research participants consisted of students enrolled in vibration and wave courses in the third semester of the Physics Education Study Program, Universitas PGRI Pontianak, who were selected using saturated sampling techniques. The instruments used in this study were science process skills tests in the form of pretests and posttests and science process skills observation sheets during learning which included observing, classifying, measuring, interpreting data, making hypotheses, designing experiments, conducting experiments, communicating, results, concluding, identifying variables, and using tools and materials. The data obtained were analyzed using paired t-test and N-Gain analysis. Based on the data obtained, both from pretest, posttest, and observation, it can be concluded that the use of guided inquiry-based worksheets is effective in improving students' science process skills in vibration and wave material. This increase is clearly seen in the pretest and posttest scores, as well as in the observation of skills that show positive developments in all indicators of science process skills.

Keywords: guided inquiry, worksheet; science process skill; vibration and waves

Introduction

Science education is a key factor in developing students' science process skills and understanding of scientific concepts (Suman & Xavier, 2020). One of the topics that is the focus of physics education is vibrations and waves, which are basic concepts but are often difficult for students to understand (Bhattacharya et al., 2021). A good understanding of this topic is very important because it has broad applications in various fields, such as engineering, information technology, and health sciences (Banda & Nzabahimana, 2023; Toh & Park, 2020).

Mastering science process skills is one of the important ways to gain knowledge (Matsna et al., 2023). Mastering science process skills is important for future understanding of science and these skills are useful in everyday life to solve problems as well (Charlesworth & Lind, 2010). Thus, students need to know and master science process skills by conducting scientific investigations and learning. Science lessons in this school are not taught in their entirety. Students learn science as a product, not as a process. This means that in this school, science has not been taught as a product and process.

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This has an impact on students in higher education, where many of them do not yet have adequate science process skills when they begin their studies. Based on pre-research conducted by researchers during the vibration and wave practicum for the 2023/2024 academic year, only around 40% of students were able to master basic science process skills, such as observing, classifying, and measuring, while advanced skills, such as formulating hypotheses and analyzing data, were only mastered by less than 30% of students. These limitations can hinder students' ability to understand scientific concepts in depth, conduct scientific investigations independently, and solve complex problems that require a science-based approach

As a result, the learning process in higher education becomes less effective, especially on topics that require a strong conceptual understanding and practical skills, such as vibrations and waves. This condition shows the need for innovation in learning approaches that can integrate mastery of science process skills, both as a process and a product, so that students are better prepared to face academic and everyday life challenges. These data confirm that strategic educational interventions are needed to strengthen students' science process skills at all levels of learning.

One strategy that can be used to overcome this challenge is to implement Student Worksheets based on guided inquiry. Through guided inquiry-based learning, students have the opportunity to be directly involved in the learning process by conducting well-designed experiments and investigations (Aditomo & Klieme, 2020; Mamun et al., 2020; Secules et al., 2021). This approach not only helps students gain a deeper understanding of concepts but also develops their science process skills through practical experiences in actively investigating natural phenomena (Aiman et al., 2020; Solé-Llussà et al., 2022). Previous studies have consistently shown that inquiry-based learning has been shown to increase student engagement, strengthen their motivation, and improve their learning outcomes (Archer-Kuhn et al., 2020; Pajchel & Ramton, 2021). With this approach, students have the opportunity to explore topics that interest them, engage in challenging tasks, and deepen their understanding of the subject matter, which in turn can improve their motivation and learning achievement (Pajchel & Ramton, 2021). In higher education, inquiry-based learning has been shown to improve students' inquiry skills, academic achievement, and engagement (Kori, 2021). However, the effectiveness of inquiry-based learning can be further improved through improvements in models and teacher creativity in providing innovative learning experiences (Leif et al., 2023). In the context of vibration and wave topics, the use of guided inquiry-based worksheet is expected to help students explore and improve their understanding, thereby improving science process skills and reducing misconceptions. Several studies have shown that the application of student worksheets based on a guided inquiry approach significantly improves science process skills and reduces misconceptions (Hadi & Widodo, 2022; Mahyuna et al., 2024; Mutlu, 2020; Numa & Martini, 2022). These worksheets encourage active learning and creativity, leading to improved skills in making hypotheses, identifying tools and materials, analyzing data, and concluding the results of investigations (Mahyuna et al., 2024). They are very effective in improving skills related to data presentation, communication, formulating hypotheses, identifying variables, and drawing conclusions (Hadi & Widodo, 2022; Numa & Martini, 2022). In addition, the use of reflective worksheets in an inquiry-based learning environment has been shown to improve students' scientific process skills, including defining problems, formulating hypotheses, and making scientific explanations (Mutlu, 2020). This opens up space for further exploration and development of in-depth knowledge in the field of vibrations and waves.

Based on the explanation that has been presented previously, this study examines the effect of guided inquiry-based worksheets on science process skills. This guided inquiry approach emphasizes active exploration and analytical thinking, which are expected to improve understanding and hone students' scientific skills. The focus on remediating conceptual errors in complex physics topics shows the novelty and relevance of this study in the context of higher education.

Therefore, the purpose of this study is to explore the effectiveness of using Student Worksheets based on guided inquiry on students' science process skills. The results of this study are expected to contribute to the development of more effective teaching innovations in science education, especially in improving the quality of students' understanding and science process skills.

Method

This study used a one group experiment with a one-group pretest-posttest design to examine the effectiveness of guided inquiry-based worksheets in improving students' science process skills on vibration and wave material. The research participants consisted of students enrolled in the vibration and wave course in the third semester of the Physics Education Study Program, Universitas PGRI Pontianak. who were selected using a saturated sampling technique. The selected class became the experimental group that received treatment in the form of guided inquiry-based worksheets. The instrument used in this study was the Science Process Skills Test (TKPS), which consisted of multiple-choice and descriptive questions to measure students' abilities in observation, classification,

inference, hypothesis formulation, and data interpretation. This test was given in the pretest and posttest to measure changes in science process skills. In addition, guided inquiry-based worksheets specifically designed for the topic of vibration and waves were used, which included stages of inquiry-based learning such as engagement, exploration, explanation, elaboration, and evaluation. The research procedure began by giving a pretest to determine students' initial science process skills. Then, students were given treatment in the form of guided inquiry-based worksheets for several learning sessions. During the learning process, observations of science process skills were also conducted to assess students' abilities in formulating problems, designing experiments, and analyzing data in the context of vibration and wave experiments. After the treatment, students took a posttest to measure the improvement of their science process skills. The data obtained were analyzed using descriptive statistics to see the distribution of pretest and posttest scores, as well as a paired t-test to test for significant differences between pretest and posttest scores. The effectiveness of the treatment in improving science process skills was calculated using N-Gain, which provides an overview of the improvement of science process skills from the initial to the end of learning.

Result and Discussion

Science process skills (SPS) play an important role in improving the quality of guided inquiry-based learning. In this study, these skills were not only measured through observation results, but also seen in their impact on student learning outcomes. SPS indicators such as observing, classifying, interpreting data, making hypotheses, and communicating results are important foundations in developing meaningful learning.

The learning process using a guided inquiry approach provides students with direct experience to practice scientific skills. Inquiry stages such as formulating problems, designing and conducting experiments, and drawing conclusions allow students to hone these scientific skills. For example, in learning the topic of vibrations and waves, students are directed to observe wave phenomena using practical tools, make hypotheses related to wave parameters, and interpret data from experiments they design themselves. This provides an authentic experience that integrates theory with practice.

The results of data analysis from the test and post-test scores on students' science process skills showed that the average pre-test score of students was 63.4, while the average post-test score increased to 85.1, with an increase of 22.11 points. These data show a significant increase in science process skills after guided inquiry-based treatment. The N-Gain calculation shows that the guided inquiry-based learning method is effective in improving students' science process skills. The N-Gain value of 0.60 with a moderate category indicates a good increase in skills among students. Furthermore, based on the results of observations during learning, it shows an increase in students' skills in each indicator of the science process.

During the learning process, students are given various experiences through guided inquiry-based worksheet. In 3 meetings, students' science process skills were observed. The results of the observation show that students' science process skills increased from the first meeting to the third meeting. This increase indicates that students are increasingly skilled in applying scientific methods. This shows that the guided inquiry approach has succeeded in building skills that support deep understanding of concepts. In detail, the results of observations during learning can be seen in Figure 1.

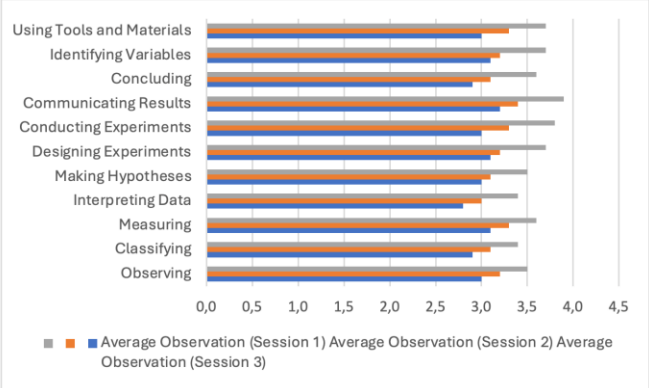

Figure 1. Results of Observation of Students' Science Process Skills

Based on Figure 1, there is an increase in students' science process skills which is in line with the increase in post-test scores. The results obtained are in line with the constructivist theory which emphasizes the importance of experience-based learning. Piaget and Vygotsky, stated that learning will be more effective when students actively build knowledge through interaction with their environment (Salsabila & Muqowim, 2024). In this context, the guided inquiry approach allows students to build knowledge through direct experience, so that learning outcomes are better. This can be explained by the concept of guided inquiry-based learning which gives students the opportunity to be more actively involved in the scientific investigation process. Details of the improvements during learning can be seen in Figure 2.

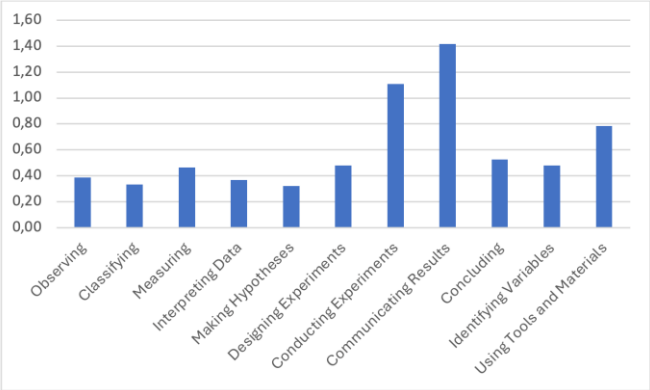

Figure 2. Average Improvement in Science Process Skills in Learning

At the problem recognition stage, students are introduced to phenomena or problems related to vibration and wave material that are relevant to everyday life. Students are invited to observe the sounds produced by various media (air, water, and solid objects). This aims to attract their attention and foster curiosity. Observations made at this stage encourage students to identify the variables involved, such as the type of media used and the frequency of the sound. This initial observation is reflected in the increase in the score on the "observing" indicator on the SPS observation sheet, which recorded a score of 3.5 at the third meeting compared to 2.8 at the first meeting. During this stage, it shows that students actively observe phenomena, which builds a foundation for deeper understanding of concepts in later stages.

In the exploration stage, students were given the task of conducting simple experiments on vibrations and waves, such as observing waves on the surface of water and measuring the wavelength of a vibrating tape. Students were given the freedom to design their experiments, choose tools and materials, and observe the changes that occurred. They were asked to record the results of their observations, classify data, and identify emerging patterns. This exploration process encouraged them to develop skills in measuring, classifying, and interpreting data, which were reflected in the increase in observation scores on the "classifying" and "measuring" indicators, which each increased from 2.9 in the first meeting to 3.4 in the third meeting. While measuring increased from 3.1 in the first meeting to 3.6 in the third meeting. The observation results showed an increase in students' abilities in this aspect from meeting to meeting, which contributed to a better understanding of the concept, as reflected in their posttest scores. In the explanation stage, students were invited to analyze the results of the experiments that had been carried out and provide scientific explanations for the phenomena observed. They formulated hypotheses based on the data that had been obtained and discussed the results of the experiments with their classmates. At this stage, students were given the opportunity to create hypotheses that could be tested further. This supports the development of "hypothesis-making" skills as reflected in the increase in observation scores from 3.0 to 3.5 at the third meeting. This explanation also provides students with a deeper understanding of the concept of vibrations and waves, which strengthens their understanding of the material. The observation results show that students who are active in group discussions and analysis tend to show higher post-test scores. This indicates that discussion-based and collaborative learning greatly supports the improvement of students' understanding and skills.

In the elaboration stage, students are asked to further develop their understanding by examining various examples of wave applications in everyday life, such as the use of sound waves in communication or electromagnetic waves in technology. Students are given the task of connecting the theories they have learned with real-world situations, which improves their ability to conclude and communicate experimental results. The development of "concluding" and "communicating results" skills is seen in the increase in observation scores, especially in the "concluding" indicator, which increased from 2.9 in the pretest to 3.6 at the third meeting and communicating results from 3.2 to 3.9.

In the evaluation stage, students are asked to reflect on the entire learning process they have done, evaluate the results of the experiment, and compare the initial hypothesis with the final results of the experiment. They are then given the opportunity to identify the variables involved in the experiment and revise their hypothesis if necessary. This evaluation helps students to identify errors in their experiments and make necessary adjustments for the next experiment. The skill of "identifying variables" increased from 3.1 to 3.7 at the third meeting, reflecting an increase in their analytical skills.

Based on the results of the data analysis, it is known that the application of guided inquiry-based worksheets is effective in improving students' science process skills. The results of the paired t-test showing a p-value (0.00) < 0,05 confirm that the difference between the pretest and posttest scores is significant, indicating that the treatment has a positive impact on improving students' skills.

Guided inquiry, which consists of various stages, allows students to develop critical, analytical, and creative skills through direct experience in experiments and observations. This is in accordance with the views of (Charlesworth & Lind, 2010), who stated that mastery of science process skills is very important for

understanding science in the future, as well as in everyday life to solve problems.

The results of this study are in line with previous findings, as expressed by (Rini & Aldila, 2023), which show that science process skills can be developed through in-depth scientific investigations. Furthermore, this study supports the theory that more actively and contextually involved learning experiences in the learning process can enrich students' understanding of science concepts. In this case, students not only learn concepts theoretically, but also understand how the concepts are applied in practice.

The results of this study provide important implications for learning practices, especially in the context of science education in higher education. Guided inquiry-based learning implemented through Student Worksheets has proven effective in improving science process skills (SPS). This finding suggests that the guided inquiry approach can be one of the superior learning strategies to produce graduates who not only master theoretical concepts but also have applicable scientific skills.

The significant increase in the SPS pretest and posttest, as well as observation results showing active student participation during learning, underscore the importance of designing SPS that is systematic and relevant to student needs. The stages of inquiry-based learning, such as engagement, exploration, explanation, elaboration, and evaluation, provide a structure that guides students to develop critical and analytical thinking skills. In this context, teachers must be competent in designing SPS that not only focus on understanding concepts but also integrate activities that encourage exploration and reflection.

From the observation results as seen in Figure 2, SPS indicators such as conducting experiments, communicating results and using tools and materials showed significant improvements over the three meetings. Overall, these three skills are connected to the hands-on experience provided in guided inquiry-based learning, where students actively participate, think critically, and gain practical experience. This causes these skills to develop faster than other skills that may be more theoretical or require more limited involvement. With an inquiry approach that emphasizes real-world problem solving, students are more prepared and motivated to improve their abilities in experimentation, communication, and use of tools, which is reflected in a significant increase in observation scores (Diani et al., 2023).

Furthermore, this study highlights the importance of collaboration between teachers and students in creating interactive learning experiences. Observations of students' science process skills during learning showed that they were not only able to complete the tasks given but were also active in discussing, providing feedback, and exploring alternative solutions. This supports the development of 21st-century skills such as communication, collaboration, and problem solving.

Although the results of this study show significant improvements, there are several things that need to be considered in its implementation. First, although guided inquiry-based treatment is effective in improving science process skills, challenges arise in its implementation in an environment with limited time. The implementation of guided inquiry-based worksheets requires a longer time commitment.

In addition, although improvements in science process skills were detected in the majority of students, variability in student responses to this treatment can also be considered. Some students still have difficulty following the stages of guided inquiry, especially if they are less experienced in conducting experiments. For this reason, additional support is needed, such as more detailed guidance or mentoring sessions, to ensure that all students can follow the learning process well.

Based on the data obtained, both from the pretest, posttest, and observation, it can be concluded that the use of guided inquiry-based worksheets is effective in improving students' science process skills in the vibration and wave material. This increase is clearly seen in the pretest and posttest scores, as well as in the observation of skills that show positive developments in all indicators of science process skills.

Conclusion

This study shows that the use of guided inquiry-based worksheets is effective in improving students' science process skills on vibration and wave material. Based on the results of the pretest and posttest data analysis, there was a significant increase in students' science process skills, with an average N-gain score in the middle category. This increase indicates that the guided inquiry-based learning model is able to support the understanding and mastery of science process skills including observation, classification, measurement, data interpretation, hypothesis formulation, experimental design, experiments, communication of results, and use of tools and materials.

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