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Revolutionizing Physics Education: Enhancing High School Students' Understanding of Standing Wave Concepts through Mictester-Based Smartphone Experiments

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Abstract: The study aims to test the effectiveness of using the audio analysis software, Mictester, on smartphones in experiments on standing waves in order to improve students' understanding of concepts in high school. The sample consisted of 19 students of 11th grade at State High School 1 SoE. The instrument used was a test sheet of conceptual understanding of standing wave matter. The results show a significant improvement in students' understanding of concepts after the application of Mictester for audio analysis on Android devices/smartphones. Thus, standing wave experiments that utilize Mictesters software for audio analytics can be an alternative in physics learning, replacing conventional experimental equipment such as oscilloscopes, thereby reducing the cost of experiments.

Keywords: Inquiry-based learning; Physics education; Smartphone-based experiment; Standing waves; Students understanding

Introduction

The development of information and communication technology (ICT) has provided various conveniences in physics learning, allowing access anytime and anywhere (Amalia et al., 2020; Goncharenko et al., 2020; Purwaningsih et al., 2020). ICT is used as a simulation media or virtual laboratory which is proven to improve understanding of physics concepts (Saputra et al., 2022), student learning motivation (Ana et al., 2022), student skills, and higher-order thinking skills (Purwasi, 2020), academic achievement (Antonio et al., 2023), and students learning outcomes (Jaiswal, 2020). Innovations in smartphones have also been used as a medium for learning mathematics and physics. For example, the integration of smartphones with geogebra software has been shown to improve understanding of math concepts (Pamungkas et al., 2020) and physics in students and college students (Malgieri et al., 2014; Solvang et al., 2021).

In the field of physics, many experiments have been developed by utilizing sensors on smartphones. For example, the use of acceleration sensors in free fall and damped oscillation experiments (Antonio et al., 2023), acceleration sensors in pendulum motion, radial accelerations analysis with accelerations sensors (Kuhn et al., 2022), magnetics fields measurement using magnetometer sensors (Arribas et al., 2015), and measurement of sound propagation speed in doppler effect experiment (Gómez-Tejedor et al., 2014). The utilization of sensors on smartphones in various physics experiments has proven to be economical and accessible. However, many smartphone applications have yet to be explored in physics experiments aimed at improving students' concept understanding. For example, the mic tester application can be used as an experimental medium to improve students' concept understanding on standing wave material.

The material of standing waves in physics is a topic that has many applications in daily life and industry. It

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is a physics material that is taught in secondary school up to the university level, and it is essential for students to understand the concept of standing waves.

Understanding the concept of standing waves can help students understand the nature of waves in general (Young et al., 2012), improve problem-solving skills (Knight et al., 2017), and have relevance in everyday life in fields of music and sound processing. Understanding the concept of standing waves helps students understand how sound is produced and transmitted through different media (Serway et al., 2012). In addition, understanding the concept of standing waves helps students understand the principles of designing musical instruments and making sensors (Kutnel et al., 2012).

Based on previous research, teaching the material of standing waves in high school faces obstacles in achieving students' learning achievement. However, there are several ways to overcome these obstacles. One way is to use inquiry-based learning modules to improve student learning achievement in standing wave materials (Mirza et al., 2022). The implementation of simulation media and laboratory work can also improve student learning outcomes in this material (Zulkifli et al., 2022). Therefore, learning models and media can be used as a solution to overcome the obstacles in teaching standing wave materials to high school students.

Factors that influence students' mastery of concepts in standing wave materials include a lack of understanding of basic physics concepts, a lack of practical experience, and students' inability to identify variables in experiments (Arief et al., 2012). Some efforts that have been made to overcome these obstacles are through project-based learning STEAM approaches that show an increase in students' mastery of concepts (Atika et al., 2023), the use of student worksheets based on video logger pro analysis improves the problem solving abilities of prospective physics teachers (Asbanu, 2023), and the combination of virtual laboratories and real laboratories improves student learning outcomes (Asbanu et al., 2023). Therefore, educators need to consider appropriate approaches to teaching the concept of standing waves that can help students understand the concept better.

The observation results in the Science class of SMA Negeri 1 SOE showed that more than 80% of the students owned an Android smartphone, but it has not been utilized in Physics learning. The study of standing wave material tends to be conducted without experiments due to the limitations of laboratory equipment such as signal generators and oscilloscopes which are expensive. However, the current technological developments can be used as an aid in teaching Physics, especially standing wave material in organ pipes. The utilization of various sensors on smartphones in Physics experiments facilitates the understanding of Physics concepts while reducing experimental cost (Sukariasih, Erniwati, et al., 2019).

Audio analysis software such as MicTester on Android smartphones can be used as a substitute for an oscilloscope. The function of MicTester software is to analyze the recorded sound frequency and can function as a standard oscilloscope (Syaifuddin et al., 2022). In this research, the MicTester Android tool was used to combine with standing wave experiments on organ pipes. The purpose of this research is to analyze the increase in students' understanding of standing wave materials through the application of the mic tester smartphone android-based experiment.

State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

Method

The research method utilized a pre-experimental design, specifically the one-group pretest-posttest design. The population of the study consisted of students in the 11th grade of SMA Negeri 1 SOE who were enrolled in the science program. The sample size of the study was 19 participants, selected using the Cluster Random Sampling technique. The data collection technique utilized a multiple-choice test consisting of 14 items to assess the understanding of the concepts, with the indicators of interpretation, classification, and explanation. The test instrument was validated and deemed reliable with a reliability coefficient of 0.75. The test items were also found to have good discriminant power and a moderate level of difficulty.

Table 1. N-gain Interpretation

N-gain	Category
$g < 0.30$	Low
$0.30 \geq g \leq 0.70$	Moderate
$g > 0.70$	High

For data analysis, the normality of the data was tested using the Kolmogorov-Smirnov test in SPSS 21 with a significance level of 5% as a requirement before conducting parametric statistical tests. If the normality assumption was met, a paired samples t-test was conducted. Alternatively, if the normality assumption was not met, non-parametric statistical tests were conducted using SPSS 21. The N-gain test was conducted to measure the improvement in the student's understanding of the concepts. The interpretation of the N-gain test results is presented in Table 1.

Result and Discussion

The results of the descriptive analysis for the pretest and posttest are presented in Table 2.

Table 2. Descriptive Statistics

	N	Min	Max	Mean	Sd
Pretest	19	14.29	57.14	31.2021	9.87634
Posttest	19	28.57	78.57	56.2858	12.72597
Valid N litwise	19				

Table 2 shows that the mean score for the pretest was 14.29 and for the posttest was 28.29, indicating that the student's understanding of the concepts was higher in the posttest compared to the pretest.

Table 3. Test of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	0.184	19	0.090	0.925	19	0.141
Posttest	0.175	19	0.127	0.938	19	0.240

Based on Table 3, the significance value for the pretest is 0.141, which is greater than 0.05, and the significance value for the posttest is also greater than 0.05. Therefore, it can be concluded that both pretest and posttest data are normally distributed.

Table 4. Paired Sample T-Test

	Mean	Standard Deviation	t	df	Sig. (2-tailed)
Pair Pretest-Posttest	-25.08368	12.32957	-8.868	18	0.000

Table 4 shows that the significance value (2-tailed) = 0.000 < 0.05, indicating that there is a significant difference in the understanding of the high school student's concepts after the implementation of the standing wave experiment based on an Android smartphone. Based on the t-test results, it can be concluded that the implementation of the standing wave experiment using an Android smartphone-based micrometer improves the student's understanding of the concepts. According to Figure 1, the average N-gain score is 0.364, indicating a moderate improvement in the student's understanding of the concepts.

The results of the t-test and N-gain showed a significant difference and improvement in students' understanding of the concept before and after conducting the standing wave experiment on an organ pipe using a micrometer on an Android smartphone. This finding is consistent with the research by Mirza et al (2022) which showed that the standing wave experiment on an organ pipe using an Android smartphone can develop students' thinking concept, as the visualization of the standing wave on the Android smartphone helps students to understand the concept. Additionally, results of Sung and Kim's research (2017) also showed that students who conducted the standing wave experiment using a smartphone had a better understanding of the concept than those who learned with conventional methods. Therefore, it can be concluded that the use of smartphones in the standing wave experiment can significantly improve the understanding of physics concepts.

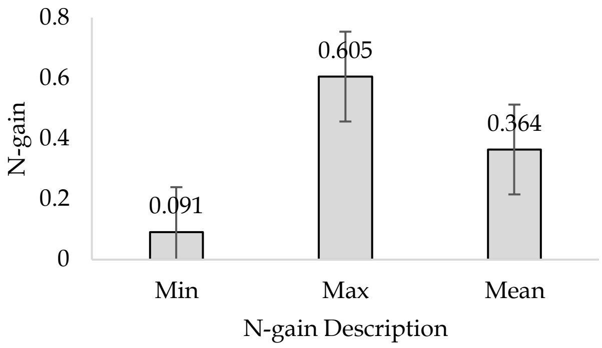

Figure 1. The N-gain graph of students' understanding of concepts

In learning activities, students actively conduct experiments because the experiments used are easy and practical to carry out. This research supports the findings by Anggraeni (2019) which showed that the use of smartphones in the sound wave experiment can increase students' enthusiasm and facilitate understanding of the concept, as the visualization of wave patterns on smartphones provides a clearer and more concrete picture. Additionally, according to Sukariasih et al. (2019), the use of smartphones in physics learning can also facilitate physics experiments, improve the understanding of concepts, and reduce experimental costs. Therefore, the use of smartphones in experimental activities can increase the effectiveness of physics learning and provide significant benefits to students.

Physics experiments with the use of sensors on smartphones provide students with an opportunity to actively engage in learning, which makes it easier for them to understand the concepts of physics (Kaps et al., 2021). The use of smartphones in physical experiments has significant benefits, as students can perform repeated observations, reducing the cognitive load of students (Hochberg et al., 2020; Kuhn et al., 2016), thus improving the mastery of concepts. Moreover, the usage of smart phones in physical experimentation also has a positive impact on students' interest and curiosity (Hagtvedt et al., 2019; Ting et al., 2014), as the experiments become more interesting and accessible (Hochberg et al., 2018). The application of experiments in physics learning has a positive effect on the reduction in student misconception (McRorie et al., 2017).

The findings from this study can be an alternative solution to overcome the limitations of laboratory equipment such as signal generators and oscilloscopes in the standing wave experiment. However, further research is needed to test the effectiveness of this learning medium with a larger sample size and involve other thinking skills as the objectives of physics learning. This is important to identify the extent to which the use of smartphones can meet the needs of students in understanding broader and more complex physics concepts. Furthermore, further research can also strengthen previous findings and provide more comprehensive recommendations for the use of smartphones as a learning medium for physics experiments.

Results should be clear and concise. The discussion should explore the significance of the results of the work, not repeat them. A combined Results and Discussion section is often appropriate. Avoid extensive citations and discussion of published literature.

Conclusion

Based on the research findings, it can be concluded that the implementation of the standing wave experiment using an Android smartphone-based micrometer improves the understanding of the concepts among high school students. The paired-sample t-test and N-gain results show a significant difference in students' understanding of concepts before and after the learning process, as well as a moderate improvement in their understanding. Therefore, this experiment can be considered an alternative solution for teaching standing waves. The limitations of this research are the small sample size and the lack of a control group to test the effectiveness of the media. Therefore, it is recommended to conduct further research with a larger sample size and an experimental research design involving a control group.

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Collecting data, M. Th. L, conceptualization, data analysis and publication, D.E.S.I.A.

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Conflicts of interest
The team stated that there was no conflict of interest that could influence the results or interpretation of the study.

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