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Implementation of Physics Learning Media Using *Kakula* Musical Instruments on Student Learning Outcomes on Sound Wave Materials

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Physics education at the high school level still faces challenges in improving student learning outcomes on abstract concepts such as sound waves**.** Many instructional approaches lack contextual or culturally relevant elements that can make learning more engaging and meaningful. This research explores the integration of local cultural elements into physics education using the Kakula musical instrument as a contextual learning tool. Using a quasi-experimental method guided by the Educational Reconstruction model, this study examines the academic validity of the learning media and its impact on student learning outcomes**.** The *kakula* instrument, rich in acoustic properties, was used to teach the concepts of waves and sounds within a problem-based learning framework. The experiment showed a statistically significant improvement in learning outcomes, with average post-test scores increasing from 59.94 to 70.53. Statistical tests, including normality, homogeneity (Bonett and Levene), and a t-test, showed a p-value of 0.0001 < 0.05, which means that the null hypothesis is rejected. The alternative hypothesis is accepted, indicating a significant effect of physics learning media using the Kakula musical instrument on student learning outcomes on the topic of sound waves**.** The results of the research can serve as a basis for developing culturally integrated teaching materials while preserving local heritage and enriching science education practices**.**

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INTRODUCTION

The rapid development of educational technology affects the way learning materials are delivered in the classroom. Despite the use of modern learning media, physics learning in many schools, especially in terms of waves and sounds, still faces challenges in improving student learning outcomes. This is due to the complexity of the material that requires a connection between theory and physical phenomena that exist around students (Anderson, 2019; Awad & Barak, 2018).

The concepts of waves and sound are abstract in nature and require strong visualization skills to be fully understood. Students often struggle to connect physics formulas with real-world events, such as how sound propagates through a medium or how resonance occurs in everyday life. When instruction is delivered only through textual explanations or conventional lecture methods, students tend to develop a shallow understanding and rely heavily on rote memorization. In fact, to truly grasp these concepts, a contextual approach is needed one that links the material to real-life situations that students encounter (Aydin-Ceran, 2021; Yulianti et al., 2024).

Furthermore, limitations in facilities and teachers' skills in utilizing educational technology optimally also pose significant challenges. Not all teachers are able to design or effectively integrate digital learning media, such as interactive simulations or virtual experiments. This results in learning processes that are less engaging and fail to provide meaningful learning experiences for students (Hwang & Chen, 2017). In fact, with the appropriate use of technology, abstract topics like waves and sound can be visualized more concretely, thereby helping students build a stronger conceptual understanding (Siregar & Fahmi, 2024). One approach that can be used to overcome this challenge is to utilize learning media that is closer to students' daily lives (Dhar et al., 2021).

However, the current body of research still lacks scientific investigation into the integration of local cultural elements, such as traditional musical instruments, into physics learning. While several studies have explored the use of multimedia and digital tools to enhance conceptual understanding, the potential of culturally relevant tools, particularly traditional instruments like the *kakula*, remains underexplored. These instruments possess unique acoustic properties that could support the teaching of sound wave concepts in a more contextual and engaging way.

Thus, there is a scientific gap in examining how traditional musical instruments can be systematically integrated into physics learning and whether such integration can significantly affect students' understanding of wave and sound concepts. This study addresses that gap by empirically testing the effectiveness of physics learning media based on the *Kakula* instrument in improving student learning outcomes.

The traditional musical instrument, *kakula*, which is an integral part of local culture, has great potential for describing concepts in physics, particularly waves and sounds. Kakula has basic principles that are closely related to sound waves and vibrations that can be directly related to physics theory (Rahayu, 2021). The use of this traditional musical instrument as an educational tool can provide direct experience to students in observing and practicing the concepts taught, thus facilitating their understanding of material that is often considered abstract (Anwar et al., 2020; Rahmat et al., 2023; Sari, 2020).

Meanwhile, waves and sounds are often considered difficult for most students. Learning that still focuses on theory without real applications can make it difficult for students to understand the concept (Hidayati, 2022). Therefore, the implementation of traditional musical instrument-based learning media, *Kakula*, is expected to increase students' understanding of the concept of waves and sounds. In addition, the use of contextual media can also introduce students to the richness of local culture, creating a more interesting and interactive learning atmosphere (Mulyadi, 2021; Sasmita et al., 2021).

This study aims to examine the effectiveness of the traditional musical instrument, *kakula*, as a learning medium for improving the learning outcomes of high school students regarding the concepts of waves and sounds. With this approach, it is hoped that students will find the material taught easier to understand and become more interested in learning physics, especially concepts related to waves and sound, which are an integral part of daily life.

Problem-based learning (PBL) is one of the learning models that can be used to develop 21st-century skills, especially critical thinking skills. In this learning, there is a learning syntax to stimulate critical thinking skills to improve student learning outcomes. PBL is learning that is obtained through the process of understanding the resolution of a problem. According to Lidinillah (2007), this learning approach is centered on the problems presented by the teacher, and students solve the problems with all their knowledge and skills from various sources that can be obtained (Pertiwi et al., 2023).

Based on the problems described above, there is still a lack of scientific research examining the use of traditional musical instruments in physics education, particularly in teaching wave and sound concepts. The use of the traditional *kakula* instrument as a learning medium offers a novel, culturally relevant, and contextual approach that has not been widely explored in science education. Therefore, this study aims to examine the effectiveness of implementing physics learning media using the traditional *kakula* musical instrument to improve high school students' learning outcomes on wave and sound materials.

METHODS

The method used in this study is quasi-experimental with a quantitative approach. In this study, the population is 182 students in grade XI of SMA Negeri 5 Palu, with a sample of 36 students in class XI Merdeka 6. The data collection techniques employed were observational, test-based, and documentary. The way to find out is to test one group of experiments that received the treatment, as shown in Table 1.

Table 1 Model one group pretest-posttest design

No	Class	Pretests	Treatment	Post-tests
1	Experiment class (X)	O1	X1	O2

Furthermore, the interpretation of learning implementation criteria is based on expert assessments, indicating its feasibility for use in the learning context, as shown in Table 2.

Table 2 Implementation categories

Categories of Interval Learning	
80% - 100%	Excellent
60% - 79%	Good
40% - 59%	Pretty Good
20% - 39%	Not Good
< 20%	Bad

The normality test was used to find out whether data on student learning outcomes before and after treatment came from a normally distributed population. The calculation of normality used in this study was assisted by SPSS version 25.0 for Windows, utilizing the Kolmogorov-Smirnov test statistics. The test criterion is that if the significance value (sig.) < 0.05, the sample distribution is considered abnormal, while if the significance value (sig.) > 0.05, the sample is considered normally distributed.

This homogeneity test is conducted to determine whether the learning outcome data of students in the experimental class exhibit homogeneous variance or not. To determine the homogeneity of the data, the researcher used the homogeneity of variance test in SPSS version 25.0 for Windows. The significance level used is $\alpha = 0.05$. If the value of the analysis of the homogeneity test data is α, then the data can be said to be homogeneous, while if the value of the homogeneity test data is α, then the data is said to be inhomogeneous.

The hypothesis test aims to determine if there is a statistically significant difference between two unpaired samples. Normal, homogeneously distributed data were analyzed using an independent-samples t-test in the SPSS program version 25.0 for Windows. The hypothesis is that if the P-value of sig (2-tailed) is > α, where $\alpha = 0.05$, then Ho is accepted and Ha is rejected. If the P-value sig (significance) (2-tailed) < α, where $\alpha = 0.05$, then Ho is rejected and Ha is accepted.

RESULTS AND DISCUSSION

Data Processing Results

a) Learning Test Results

The test results showed that most learners had achieved the expected competencies, with a significant improvement in learning outcomes. The results of the student test are presented in Table 3.

Table 3 Results of pre-test and post-test experimental classes

Yes	Criterion	Pre-test dates Experiment	Experimental Post-test Data
1	Number of Samples (Students)	36	36
2	Baku Junction	1.19	1.51
3	At least	58	68
4	Median	60	70
5	Maximum	62	73
6	Average	59.94	70.53

b) Statistical Test Results

The results of the statistical analysis showed a significant difference between the scores before and after treatment, indicating the effectiveness of the learning intervention on the students' learning outcomes. The following are the results of the statistical tests using SPSS, presented in Table 4.

Table 4 Statistical data pre-test and post-test learning outcomes

	Class	
Statistical Data	**Exhibitions Pre-tests**	**Experiment Post-tests**
Minimum Score	58	68
Maximum Score	62	73
Mean	59.94	70.53
Variance	1.42	2.27
Standard Deviation	1.19	1.51

Normality Test Analysis Results

The results of the normality test analysis showed that the data were distributed normally, thus meeting the basic assumptions for parametric statistical analysis. The following are the results of the normality test analysis, as shown in Table 5.

Table 5 Normality test for experimental classes

	Normality Test for Experimental Classes			
		Kolmogorov-Smirnov (K-S)		
	Class	**StDev**	**Ks**	**P-Value**
Learning Outcomes	Experimental Pretest	9.731	0.110	0.150
	Post-test Experiment	7.293	0.134	0.098

Based on Table 5, the P-value of the pre-test data in the experimental class was 0.150>0.05, so the data was distributed normally, and the P-value of the post-test data in the experimental class was 0.098>0.05, so the data was distributed normally. The pre-test and post-test data from the experimental class were found to be normally distributed.

Homogeneity Test

The results of the data processing for the experimental class pre-test are presented in Table 6.

Table 6 Homogeneity test pre-test and post-test experiment

Homogeneity Test Pretest and Posttest Experimental Class					
		Test Statistics	**df1**	**df2**	**P-Value**
Result	*Bonett*		1	70	0.294
Learn	*Living*		1	70	0.328

Hypothesis Testing

Data that were normally and homogeneously distributed were then tested using an independent sample t-test with the SPSS application. Therefore, the instructional media based on the traditional *kakula* musical instrument used in this study is expected to have a similar effect, namely to improve students' conceptual understanding and learning outcomes significantly.

The hypothesis is that if the P-value sig (significant) (2-tailed) > α, where α = 0.05, then Ho is accepted and Ha is rejected. This means that there is no influence of the *Kakula* learning media on students' learning outcomes. Conversely, if the P-value (significant) (two-tailed) < α, where α = 0.05, then Ho is rejected and Ha is accepted. This indicates that there is an influence of the *Kakula* learning media on students' learning outcomes.

The test results obtained a P-value (0.0001) < 0.05, which means that Ho was rejected and Ha was accepted, indicating that the *kakula* learning media had a significant effect on students' learning outcomes. The average increase of 10.59 points highlights the important impact of the *Kakula* instrument as a teaching medium on students' academic performance.

These findings are consistent with the study conducted by Riyantini and Firm (2021), which stated that instructional media utilizing the bonang musical instrument a part of Javanese local culture can enhance students' understanding of sound wave concepts. Students found it easier to comprehend the relationships between frequency, resonance, and the length of the instrument's tubes.

Furthermore, Musniar et al. (2025) also discovered that the use of physics teaching materials based on local wisdom significantly improves students' critical thinking skills and learning outcomes. They emphasized that a culture-based approach fosters both emotional and cognitive engagement in science learning, especially when dealing with abstract topics such as sound and waves.

These findings are further supported by recent international studies. For instance, research by Yulianti et al. (2024) on the physics of the *gamelan saron* showed that the acoustic characteristics of traditional instruments are highly effective in concretely and contextually illustrating the concepts of resonance and sound waves. Additionally, a study by Fitriyani et al. (2025) demonstrated that incorporating the *kentongan* (traditional wooden slit drum) into STEM-based modules enhanced student creativity and provided meaningful learning experiences by connecting science concepts with local cultural values. Moreover, Nugraha et al. (2023) found that integrating the *suling* (bamboo flute) into smartphone-based experiments using the Phyphox app significantly improved students' critical thinking skills on sound wave topics, as students could directly observe changes in frequency and air column length through a familiar cultural context.

In line with these findings, Wibowo (2020) argued that local culture can be used as a contextual learning approach that strengthens students' comprehension, as it makes learning materials feel more relevant and familiar. Therefore, the use of traditional musical instruments such as the *kakula* functions not only as instructional media but also as a means of cultural preservation and a tool for improving overall learning quality. These results can be seen in Table 7.

Table 7 Independent sample test results

Independent Sample Test							
		T-Value	***Df***	***P-Value***	***Mean Difference***	***95% CI For the difference***
Learning Outcomes	*Equal variance assumed*	32.87	70	<0.0001	10.59	10.00-11.18
	Equal variance Not assumed	≈ 32.87	≈ 68.41	<0.0001	10.59	10.00-11.19

The learning intervention in this study was conducted over four meetings, each lasting 90 minutes, within a two-week period. The learning model applied was PBL, utilizing the traditional musical instrument, the *kakula,* as a teaching aid to help students understand the topic of sound waves. In the first meeting, the activity focused on administering a pretest to assess students' initial understanding of the basic concepts of waves and sound. Students were given essay-type questions that covered various learning outcome indicators.

The second meeting served as the core of the learning process by applying the PBL syntax. The activity began with orienting students to the problem, where the teacher presented a contextual issue related to the phenomenon of varying sounds produced by traditional musical instruments, such as the *kakula,* even when played in the same way. Next, students were divided into small groups and guided to discuss the possible causes of the sound differences based on wave theory, such as the influence of tube length on frequency and resonance. The teacher then facilitated students' inquiry, both individually and in groups, by providing stimuli and guiding questions. Afterward, students developed and presented their ideas in a group discussion, proposing solutions to the problem. The activity concluded with group presentations, during which the teacher provided feedback, clarified concepts, and summarized the lesson with the whole class.

The third meeting focused on practical activities, which continued to utilize the PBL syntax as the instructional approach. The teacher began by posing a new experimental challenge: how to prove directly that the length of the *kakula* tube affects the pitch of the sound it produces. Students continued working in groups to design and conduct experiments using several *Kakula* instruments of different lengths. During this session, they observed the sounds produced, recorded data on frequency and amplitude using supporting applications, and discussed their observations. The activity concluded with group presentations on their experimental findings, followed by an open discussion facilitated by the teacher to relate the experimental results to sound wave theory.

The results of the study demonstrated a significant improvement in students' learning outcomes after the implementation of physics learning media based on the traditional *kakula* musical instrument. This improvement reflects not only a quantitative increase in test scores but also a deeper conceptual understanding of sound wave phenomena.

In physics, sound is classified as a longitudinal wave, which propagates through a medium by alternately compressing and rarefying it. The *kakula*, a traditional wind instrument typically made from hollow bamboo or wood, has physical characteristics that are directly related to several core concepts in sound wave physics.

First, the frequency of the sound produced by a *kakula* is determined by the length and diameter of its tube. Longer tubes generate sounds with lower frequencies (lower pitch), while shorter tubes produce higher frequencies (higher pitch). This supports the physical principle that, in a fixed medium, frequency is inversely proportional to the wavelength.

Through playing the *kakula*, students can observe that the tube length directly affects pitch, allowing them to experience the relationship between frequency and wavelength tangibly.

Second, the phenomenon of resonance can be observed when the *kakula* is played. When air is blown into the instrument at a frequency that matches its natural frequency, resonance occurs, resulting in a stronger and clearer sound. Students can perceive that certain notes sound louder and more sustained, which illustrates the concept of acoustic resonance and energy amplification at natural frequencies.

Third, the amplitude of the sound wave, which determines the loudness of the sound, can be demonstrated by varying the force of the air blown into the instrument. A stronger airflow produces greater vibration amplitudes, which result in louder sounds. This hands-on experience allows students to connect the concept of amplitude with sound intensity.

By engaging directly with the physical properties of the *kakula*, students gain a concrete understanding of how tube length influences frequency, how resonance amplifies sound, and how amplitude affects loudness. These connections between the physical structure of the instrument and abstract physics concepts help bridge the gap between theory and real-world observation.

Therefore, the *kakula* serves not only as a culturally relevant learning medium but also as an effective scientific tool that facilitates the teaching of key physics concepts related to longitudinal waves, frequency, wavelength, resonance, and amplitude. Its integration into the classroom supports both conceptual understanding and cultural appreciation, enriching the overall science learning experience.

CONCLUSION

Based on the study's results, statistical tests revealed significant differences between students' pre-test and post-test scores. This result indicates that the use of physics learning media based on the *kakula* musical instrument had a significant effect on students' learning outcomes on sound wave material.

However, this study has certain limitations that should be acknowledged. One of the main limitations is the relatively small sample size, which may limit the generalizability of the findings to broader student populations. Future studies are recommended to involve larger and more diverse samples to strengthen the validity and applicability of the results.

In addition, although this study focused on sound wave material, the success of *Kakula* as a culture-based learning medium suggests the potential for applying similar strategies to other physics topics, such as vibration, resonance in strings, or even energy transformation in mechanical systems. Exploring various traditional instruments from different regions could enrich physics instruction and make abstract concepts more accessible to students.

For physics teachers, especially those in culturally rich areas, this study implies that integrating local cultural elements such as traditional musical instruments into learning media is not only possible but also beneficial. It supports contextual learning, engages students emotionally and cognitively, and promotes the preservation of local heritage. Teachers are encouraged to innovate and explore culturally rooted media to enhance physics education in a way that is both meaningful and locally grounded.

CONFLICT OF INTEREST

The authors stated that there was no conflict of interest in the implementation or reporting of this research.

AUTHOR CONTRIBUTIONS STATEMENT

WW led the conceptual design, data collection, and script preparation; RS provided statistical and technical analysis support; UW contributed to instructional design and validation procedures; and KAAU guided the integration of educational technology and the final editing of the manuscript. All authors agreed to the final version of the paper.

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