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Development of Closed Organa Pipe Props as Learning Media to Determine the Speed of Sound Propagation in Air Assisted by Physics Toolbox Sensor Suite

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Abstract

Teaching aids can help students to gain an understanding of the concepts they learn. Based on the facts obtained at SMAN 1 Waru through teacher interviews and observations of the physics laboratory, the sound wave material of the sound source sub-chapter on organ pipes has never been practiced. The school needs more props to facilitate organ pipe practicum activities. This development's main objective is to create feasible closed organ pipe props in terms of accuracy and precision of sound propagation speed. The analysis stage is the initial stage in the ADDIE model development research. The ADDIE model development research carried out only until the Development stage, because the purpose of this research is only limited to developing and conducting trials in terms of accuracy and precision of the data obtained to produce a closed organa pipe props as a valid learning media to be implemented based on the validator's assessment. The speed of propagation of sound in air is obtained by multiplying the frequency value by the wavelength. The average value of the wavelength produced is (344.22 ± 0.034) m/s. The value of the sound propagation speed in the air produced using the developed closed organa pipe is not exactly the same as the theory but the value is almost close. The difference between the speed of propagation of sound in the air by experiment and theory is 1.22, so with a precision of 99.99% and the percentage of accuracy error is 99.65%, it is classified as a fairly high level of accuracy. Therefore, it can be concluded that the developed closed organa pipe props can be used as learning media to determine the value of sound propagation velocity.

Keywords: *Props, Closed Organa Pipe, Sound Waves*

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INTRODUCTION

The world of education is always required to continue to adjust in improving the quality of education through the advancement of Science and Technology (IPTEK) (Budiman, 2017). Science and Technology have a role in facilitating the teaching and learning stages for teachers and students. Based on the analysis of the development of science and Technology in education conducted by (Mulyani & Haliza, 2021) the current development of science and Technology allows the development of devices and applications that have the function of being learning media. Learning media is an educational support facility or something that can assist learning activities. Besides that, it also fosters enthusiasm for learning among students (Moto, 2019). Teaching aids are an innovative form of three-dimensional learning media that students can use to understand abstract material concepts; besides that, through teaching aids in the learning process, they can provoke the activeness and creativity of students (Sidiq & Syaripudin, 2022). Teaching aids used in practicum become a learning media that can foster students' motivation to learn, especially in physics subjects (Prabowo & Sucahyo, 2018).

This is also following the results of research from Saleh (2014), which suggests that the stages of physics learning carried out through the help of teaching aids can help students understand the concepts they learn.

Sound wave material is an abstract semester XI class material; students must understand the concept, not just memorize the formula, so it requires props as an intermediary or visualization (Wicaksoni,et.al, 2013). Sound wave resonance is one way to find out the speed of propagation of sound waves. Besides that, it can also find related quantities, among others, wavelength, propagation speed, and fundamental tone of the sound. *Organa pipe* is a hollow pipe that can produce sound (resonance) through airflow. With the help of organ pipes, it can be easier to observe the resonance of sound waves. Based on the results of the analysis conducted by Kallesta & Erfan, (2017) related to the factors that cause physics learning difficulties in sound material, namely, students experience deficiencies in understanding sound wave material and find it difficult when working on sound wave material questions, this is because the teacher is lacking in motivating students, besides that the delivery of sound wave material without accompanying props.

The researcher conducted a pre-study on students of class XI SMAN 1 Waru through three methods: a questionnaire of students, an interview with one of the teachers, and laboratory observation. Based on the results of the g-form questionnaire distributed to students of class XI SMAN 1 Waru, it is known that 94% of students consider physics learning to be a subject that is difficult to understand. Students stated this because physics subjects have many formulas and abstract material, so students choose to memorize formulas. In addition, it is supported by the results of students' daily grades. On average, 72 still need to meet the KKM. Based on the results of a face-to-face interview with one of the physics teachers, it was conveyed that the learning media used in grade 11 in the 2022/2023 school year were whiteboards and power points, while practicum activities were rarely carried out. Practical activities that students in grade 11 have carried out in the 2022/2023 school year are the material of equilibrium of rigid bodies. Through observation of the physics laboratory at SMAN 1 Waru, practicum tools supporting sound wave material facilitated by the school are Melde's Law and Sonometer. The fact obtained at SMAN 1 Waru through teacher interviews and physics laboratory observations is that the sound source subchapter's sound wave material on organ pipes has never been practiced. The school needs more props to facilitate organ pipe practicum activities.

Research conducted by Laeli & Ishafit (2023) developed props as experiments on closed organ pipes using jars and covers. The experimental data obtained is the average speed of sound propagation in the air and its relative error of (327 ± 4) m/s. This research concludes that the experiment can be applied as a learning medium to determine the value of the speed of sound propagation in the air. Then another study conducted by Iswanto et al. (2021) obtained scores from media experts, material experts, and learning experts of 82%, 93%, and 89%, respectively, meaning that the developed device's interpretation is excellent. It can be concluded that the sound resonance training device developed meets the requirements and can improve students' science process skills. Another study also conducted by Dessitasari & Sucahyo (2021) has differences from existing studies because, in this study, they developed open and closed organ pipes using plastic mica. The developed tool has an average validity level of 87.5%, with a feasible category. In the open organ pipe, the value of sound propagation speed in the air was obtained as (322.6 ± 5.376) m/s with a precision of 98.4% and an accuracy of 94.89%. While in the closed organ pipe, the sound propagation speed in the air obtained was (335.4 ± 8.133) m/s with a precision of 97.6% and an accuracy of 98.65%. These results make the experimental tool feasible and can be applied as a learning media.

Similar research conducted by Suranti (2021) received a score of 89.83%, meaning that the practicum tool is efficient to use by users. Further development of the sound wave propagation speed practicum tool. Similar research was also conducted by Syauqi and Sucahyo (2018); it was found that the results of learning media in the form of KIT resonance tube experiments met the effectiveness and practicality with an average of 93.95% and were feasible to use as Physics learning media on sound wave material. Aminulloh and Widodo (2018) have developed sound props showing that props on sound material are effective for learning media to increase learning motivation and understanding of student concepts. In addition, Abidin and Tho (2018) also developed innovative resonance experiments using smartphones with free mobile software applications. The results of this research to study resonance have been successfully developed. The data obtained from this practicum activity provides results with reasonably good accuracy because the results obtained from experiments using smartphones are close to theoretical values. The deviation of the experimental results ranged between 5% and 14% of the theoretical value.

The learning media developed is different from some of the previous media development. The innovation in closed organ pipe experiment props is that researchers will use acrylic pipes, which are clear, transparent, robust, lighter than glass, durable, and able to withstand heat. In addition, the speakers used are Bluetooth

speakers. So that these props can be used in the long term and manufacturing can reach in terms of finance. Based on these explanations, the problem formulations proposed in the study are (1) How is the feasibility of the developed closed organ pipe in terms of accuracy and precision of the sound propagation speed value obtained?

METHOD

This research is a type of teaching aid development research that uses the ADDIE method (Analysis, design, develop, implement, evaluate). ADDIE is a development model with advantages in its systematic stages of work. Each phase is evaluated and revised from the stages passed so that the resulting product becomes valid. The stages of the ADDIE model are presented in Figure 1.

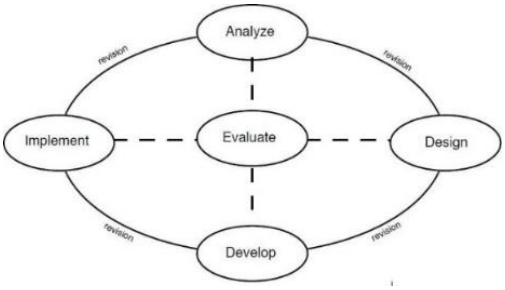

Figure 1. Tahap ADDIE (Branch, 2009)

The analysis stage is the initial stage in the ADDIE model development research. Researchers analyzed learning activities and media at SMAN 1 Waru by conducting pre-research. The design is a stage in which a design of teaching aids will be developed to align with the planned objectives. At the development stage, media development was carried out in the physics study program, State University of Surabaya which had planned the results in the form of closed organa pipe props which were then validated to determine the validity of the tools developed. The ADDIE model development research carried out only until the Development stage, because the purpose of this research is only limited to developing and conducting trials in terms of accuracy and precision of the data obtained to produce a closed organa pipe props as a valid learning media to be implemented based on the validator's assessment.

The procedure used in this study is the working principle of the props developed using the physics toolbox suite application as a substitute for AFG can produce frequencies and can also be a tone generator connected to a Bluetooth speaker so that it can become a sound source. The analysis technique used is descriptive statistical analysis. According to (Sholikhah, 2016) descriptive statistical analysis is used to analyze data by describing the data that has been collected. The process data describes the data used in the average score, standard deviation, accuracy, and precision as follows:

Calculate the average speed of propagation of sound obtained using the following formula

$$\bar{V} = \frac{\sum V}{\mathrm{N}} \quad (1)$$

$$SV = \sqrt{\frac{\sum (V-\bar{V})^2}{\mathrm{N}(\mathrm{N}-1)}} \quad (2)$$

The resulting sound propagation speed precision can be calculated using the following formula (Djonoputro, 1984)

$$\text{precision} = 100\% - \left(\frac{\mathrm{Sv}}{\bar{V}} \mathrm{x} 100\%\right) \quad (3)$$

The relative uncertainty determines the measurement accuracy using the following equation (Djonoputro, 1984):

$$\text{accuracy} = 100\% - \left(\left| \frac{\mathrm{Vpercobaan} - \mathrm{Vteori}}{\mathrm{Vteori}} \right| \mathrm{x} 100\% \right) \quad (4)$$

RESULTS AND DISCUSSION

The developed closed organ pipe props have components: acrylic pipes, Bluetooth speakers, smartphones, physics toolbox sensor suite applications, meters, pistons, and sponges. The closed organ pipe props developed have undergone several revisions from expert lecturers, shown in the figure 2.

Figure 2. Developed Closed Organ Pipe Trainer

The results of the measurement of the speed of propagation of sound in air in a closed organa pipe when the first resonance occurs are shown in the table 1.

Table 1. Test Data on the Speed of Sound Creation in Air

f (Hz)	L (m)	λ (m)	v (m/s)
200	0,430	1,72	344
250	0,345	1,38	345
300	0,280	1,12	336
350	0,250	1,00	350
400	0,215	0,860	344
450	0,191	0,764	343
500	0,170	0,680	340
550	0,157	0,628	345
600	0,143	0,572	343
650	0,132	0,528	343
700	0,122	0,488	341
750	0,115	0,450	345

The experiment conducted was to determine the speed of propagation of sound in the air through a closed organa pipe. Based on the experiments that have been carried out using the manipulation variable is the frequency that is changed in the physics toolbox sensor suite application with a range of 200-750, the range is determined because the Bluetooth speaker has limitations so that if you use a frequency that is too low and too high it will produce a high / low sounding tone. In the concept of physics, the high and low of sound is the condition of sound waves received by humans based on frequency. The greater the frequency, the higher the tone of sound heard. The lower the frequency, the lower the pitch of the sound. In sound waves, high frequency is indicated by the tightness of the ends of the deviation with each other. So that in this closed organa pipe props when using a high frequency, the length of the air column of resonance (L) is getting shorter or not detected because the waves produced are getting tighter.

In this experiment, the length of the organa pipe at the fundamental tone of resonance (L) is obtained to find the wavelength. The speed of propagation of sound in air is obtained by multiplying the frequency value by the wavelength. The average value of the resulting wavelength is listed in table 1 which is (344.22 ± 0.034) m/s. Based on Table 1, the value of sound propagation velocity in air produced using the developed closed organa pipe is not exactly the same as the theory but the value is almost close. In theory, the value of sound propagation velocity in air is 343 m/s at a temperature of 20ºC. The difference in the speed of propagation of sound in the air by experiment and theory is 1.22 then with a precision of 99.99% and the percentage of accuracy error is 99.65% classified with a fairly high level of accuracy, thus it can be said if the developed closed organa pipe props can be used in closed organa pipe practicum to determine the value of the speed of propagation of sound.

The value of the speed of sound in experiments and theory is different because two things influence the speed of propagation of sound, the type of medium. Sound waves most often travel through the air medium because particles in liquid or solid substances exert a more substantial influence on each other than air particles; liquid and solid substances better conduct air. In addition to the type of medium, the speed of sound propagation also depends on the temperature of the medium. When there is an increase in the temperature of a substance, the molecules in it move faster, causing the frequency of rapid collisions between particles to increase. These

more significant molecular collisions can transfer energy in a relatively shorter time interval (Giancoli, 2014). However, other factors influencing the room used when conducting experiments are not soundproof; a noisy room can cause frequency collisions. Thus, sound resonance in closed organ pipe props will be disturbed.

Similar research by developing a closed organ pipe using a glass tube and a speaker equipped with a jack cable assisted by the Physics toolbox sensor suite was conducted by Syauqi and Sucahyo (2018); the results of the learning media in the form of a resonant tube experiment KIT meet the effectiveness, practicality with an average of 93.95%, and are feasible to use as Physics learning media on sound wave material and in contrast to previous research conducted by Dessitasari & Sucahyo (2021), developing organ pipe props that can be used open or closed with speakers equipped with jack cables assisted by the physics toolbox sensor suite. The results of the validation of the learning media that have been developed are very valid, with a validity percentage of 87.5%. Then obtained, the acquisition of the value of the speed of propagation of sound in the air in a closed organ pipe, the acquisition of the speed of propagation of sound in air is found to be worth (335.4 ± 8.133) m / s with a precision of 97.6% and an accuracy of 98.65%. Another study was conducted by Laeli & Ishafit (2023) by developing props as experiments on closed organ pipes using simple materials such as jars and covers, a paragon measuring 1 cm in radius and 25 cm, 30 cm, 35 cm in length, as well as three pieces of cloth meter, water, and with the help of the Tone Generator and Spectroid applications that have been installed on smartphones, the results of experimental data analysis obtained the average speed of propagation of sound in air with a relative error of (327 ± 4) m/s.

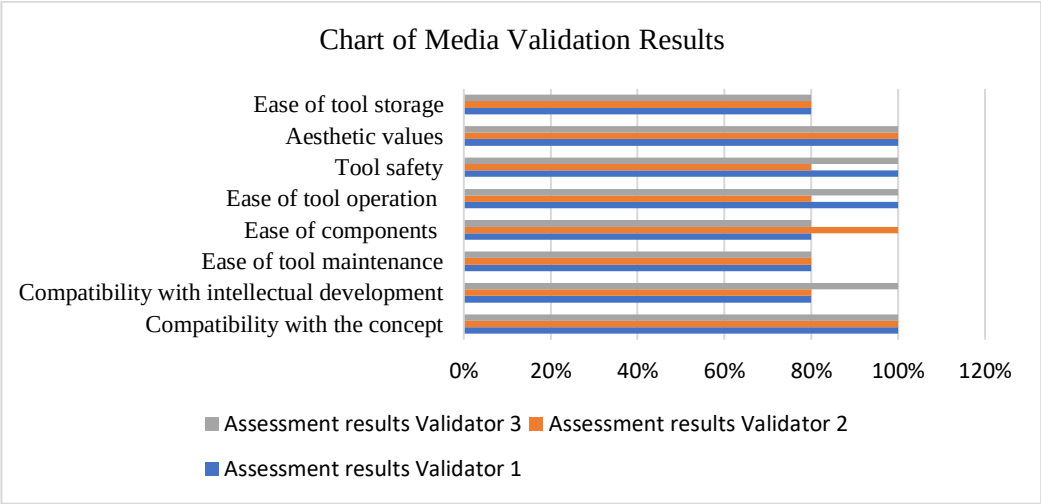

Figure 4. Chart of Media Validation Results

Three media expert lecturers have validated the developed closed organ pipe trainer. These aspects include suitability for the concept to be taught, suitability for the intellectual development of students, ease of maintenance efforts, ease of obtaining components and their mounts, operational ease of use of tools, the safety of tools used for students, aesthetic value (color, shape), ease of finding, retrieving and storing tools (Kemendikbud,2011). The developed closed organ pipe props are said to be valid, with an average overall percentage of 91%. The advice given by the validator is to replace the Bluetooth speaker used with a speaker size that matches the diameter of the acrylic pipe used, so that the sound produced does not leak. According to Riduwan (2015), this percentage is very valid. So that the closed organ pipe props developed have an increase in validity compared to previous studies, so that the closed organ pipe props developed have an increase in validity compared to previous studies; based on the two previous studies that have theoretical differences, the speed of sound propagation in the air at room temperature 20◦C is 343 m/s. This research develops from existing research by using acrylic pipe material as a closed organa pipe tube because acrylic pipes have several advantages, namely lighter weight, impact resistance, outdoor weather resistance, environmentally friendly, and Bluetooth speakers because currently there are rarely smartphones that have plugs for jack cables. So that the closed organa pipe props developed become more efficient. As for the limitations of the developed closed organa pipe props, namely the Bluetooth speaker used when the frequency is too low or too high, it produces poor sound.

CONCLUSION

From the results and discussion, it is obtained that the value of the speed of propagation of sound in the air in the developed closed organ pipe props is closer to the theory with a value of (344.22 ± 0.034) m/s with a precision of 99.99% precision and 99.65% accuracy. The developed closed organ pipe props have an overall percentage of 91% with very valid criteria and are suitable for use as learning media.

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