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Development of Sound Experimentation Tool using Android-Based Sound Analysis Oscilloscope Software

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Abstract: Experimental activities are part of physics learning process with the aim of gaining knowledge and having good understanding of physics concepts. Sound and organ pipes are the main subjects discussed in physics and engineering lessons. These materials contain facts accompanied by actualization in everyday life in social life. However, the fact in high school (SMA) physics learning is that experimental activities in supporting students' learning and understanding have not been widely carried out. This is due to the lack of practical support tools. The purposes of this research are to design a sound experimentation tool design of an open and closed organ pipes and to determine the value of the speed of sound which propagates through air medium using a data acquisition technique assisted by sound analysis oscilloscope software. This type of research is a Research and Development research with five stages referring to the ADDIE model. The first stage was analysis, that was done by conducting a study of the problems of physics learning at senior high school level, especially in sound chapter. The second stage was design, namely designing experimentation tools. The third stage was development, that was done by providing materials that were used in the experiment. The fourth stage was implementation, that was testing the tool which had been made combined with sound analysis oscilloscope software, and the fifth was conducting an evaluation and feasibility test based on the validity of the experimental data. The data analysis technique used average and linear regression by utilizing the results of data from frequency analysis using sound analysis oscilloscope software. The results showed that the experimentation tool in this study was able to be used as learning media for the sound and open and closed organ pipes materials. The experimental results obtained that the speed of the sound waves propagation in air for an open organ pipe was v = 332.19 m/s with an accuracy rate of 97.70%. While the value of the speed of the sound waves in air for a closed organ pipe was v = 334.69 m/s with an accuracy rate of 98.44%.

Keywords: Sound; Organ pipe; Sound analysis oscilloscope software; Data acquisition

Introduction

The development of science and technology in the industrial revolution 4.0 era has a significant impact on the development of science learning, especially physics at the high school level. In practice, in an effort to build concepts and master the understanding of physics, it means that students are required to master a systematic investigation process and be able to draw conclusions based on theories and models in a physics lesson. Experimental-based learning model is a way of learning by involving students in order to gain experience and prove a process and experimental results, for example assisted by virtual laboratories thus they can improve conceptual and practical competence (Masril et al., 2018; Putra, 2013). These use of learning simulations in experimental activities has positive and effective impact in explaining the phenomena of physics material

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contextually, for example by using PhET simulation (Farida et al., 2020). Android-based learning in the form of a virtual physics laboratory can increase learning independence and concept understanding holistically (Arista et al., 2018).

Based on the observation facts of high school physics learning in the city of Semarang, especially in the organ pipe (open and closed) chapter, experimental activities have never been carried out due to the lack of availability of tools that can facilitate students in the process. The analysis of this fact becomes the basis for carrying out an innovation in physics learning, especially in the organ pipe (open and closed) chapter in making an experimentation tool using data acquisition technique assisted by sound analysis oscilloscope software by utilizing an Android smartphone which almost all students have. A data acquisition system is a process of taking, collecting, and preparing data to produce the required data (Djunaidi et al., 2011). In the process of data analysis using data acquisition, especially in the organ pipe chapter, it can be done by analyzing the frequency of the software output used in smartphones (Muhafid et al., 2014).

The topic of discussion proposed in this study is specifically about sound waves experimental activities using organ pipes (open and closed). Sound waves are longitudinal waves with the integration of stimuli in the human sense of hearing, namely the ears (Giancoli, 2001). The discussion of sound waves becomes an interesting topic for experimental activities. Sound waves are basically the result of density and strain in a gas medium, which are produced when an object is vibrated and causes a disturbance in the medium, resulting in the propagation of speed of sound (Tipler, 1998). In general, the expansion of the power series in solving the solution equation as a polynomial function in the form of geometry is the result of the general wave equation using the Trefftz method (Maciag et al., 2005). In this study, the general wave function is simplified. The general function of waves and their derivatives are shown in the following equations (1) and (2):

$$T = \frac{1}{f} \quad (1)$$

$$\lambda = \frac{v}{f} = v\,T \quad (2)$$

The speed of sound can be determined as the slope of the wave length plot and period. In the concept of an organ pipe (open and closed), frequency can be measured by using the following equations (3) and (4):

$$f_n = \frac{2n+1}{4L} v \boldsymbol{\rightarrow} \boldsymbol{\lambda} = \frac{4L}{2n+1} \quad (3)$$

$$f_n = \frac{n+1}{2L} v \boldsymbol{\rightarrow} \boldsymbol{\lambda} = \frac{2L}{n} \quad (4)$$

Meanwhile, the function of the speed of sound in a gas depends on the temperature of the gas. The general equation (5):

$$v = \sqrt{\boldsymbol{\gamma}\frac{RT}{M}} \quad (5)$$

With the ideal gas condition, it is shown in the following equation (6):

$$v \sim \sqrt{\boldsymbol{\gamma}\frac{RT}{M}} \quad (6)$$

The comparison of the speed of sound for different temperatures is shown by the following general equation (7):

$$v = v^I \sqrt{\frac{T_{gas}}{T^{I(gas)}}} \quad (7)$$

(Giancoli, 2001)

The research literature review explains that the use of experimental tools resulting from the speed of the sound waves propagation in air with the TOF method and assisted by Audacity software was successful in explaining the value of the speed of sound in air approaching the value of the speed of sound from the theory (Astuti, 2016). In addition, the use of a bamboo flute can be used as a physics learning medium to calculate the speed of sound in air using the *audacity software* (Nursulistyo, 2015; Nursulistiyo, 2018; Azalia et al., 2022). The development of a sound experimentation tool with the help of audacity software concluded that the effect of wind speed is proportional to the speed of sound (Siti et al., 2020). Physics experiments can use a smartphone microphone as a sound wave catcher which is used as a measuring tool through an android application with a maximum accuracy value of experimental results, thus it can increase student motivation in learning (Gimenez et al., 2016; Osorio et al., 2017). Research related to the use of audacity software to conduct experiments using flutes obtained experimental results in the form of basic tone frequencies that match the concept of an open organ pipe (Maleaki et al., 2015). The use of software in analyzing the frequency and intensity of sound was also carried out by social science disciplines using the Praat program which produced a fairly thorough analysis (Pranoto, 2018). Furthermore, there was an audio data augmentation method to classify sound types based on frequency values (Pandeya et al., 2018).

Based on research studies that have been carried out, research on the development of sound experimentation tools with the help of organ pipes (open and closed) through the integration of sound analysis oscilloscope software in Android smartphones has never been conducted. Therefore, it becomes an opportunity in the research process to produce novelty in the field of physics learning.

Based on the preliminary study, the formulation of the problem discussed in this research is twofold, they are (1) How to develop a sound experimentation tool, especially on organ pipes (open and closed) to calculate the speed of sound which propagates in air assisted by data acquisition technique on android-based sound analysis oscilloscope software and (2) what the level of accuracy of the result of the speed of sound measurement in air of the organ pipe (open and closed) by using the android-based sound analysis oscilloscope software.

Method

This research method used the type of Research and Development. It is a research method used to produce certain product and to test the effectiveness of the product (Sugiyono, 2016). This study used the ADDIE development model (Mulyatiningsih et al., 2014). ADDIE stands for Analysis, Design, Development or production, Implementation or delivery and Evaluation. The product development stages with this research and development model are described as follows:

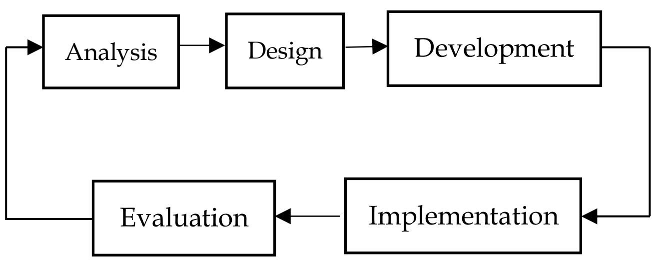

Figure 1. ADDIE development model

The development procedure in this study used the working principle of data acquisition assisted by sound analysis oscilloscope software which can be downloaded in any android smartphone. The tools and materials used in this experiment included an android smartphone, sound analysis oscilloscope software, ruler, paralon pipe (uPVC pipe with a diameter of 1.5 cm), thermometer, and sound source.

This experiment was carried out by blowing a paralon pipe that had previously been cut to a certain size which was sampled as an open organ pipe thus the sound was captured by the android smartphone's microphone which was transferred to the sound analysis oscilloscope software thus the frequency value can be obtained. Furthermore, the data recorded in the sound analysis oscilloscope software was analyzed by linear regression method, while in the closed organ pipe category, it was done by covering one of the paralon holes with rubber, then it was tapped to make the sound heard and recorded in the sound analysis oscilloscope software, and analyzed by linear regression method.

The linear regression method can be used to determine the speed of sound in air (Ishafit, 1998). The linear programming equation (8):

$$y = ax + b \quad (8)$$

With a as the gradient of the line and b as the point of intersection of the straight line with the vertical axis. Based on the equation (8), it can be made a model in which $y = s$; $x = t$; and $a = v$. The general solution of the regression equation can be converted into an equation for the speed of sound, equation (9):

$$s = v\,t \quad (9)$$

In the experimental results, the average frequency of the five experiments for one length variation was calculated using the following equation (10) and (11):

$$\bar{f} = \frac{\sum f}{N} \quad (10)$$

$$S_f = \sqrt{\frac{\sum(f-\bar{f}^2)}{(N-1)}} \quad (11)$$

When the average frequency data had been obtained, then the next step was to calculate the speed of sound which propagated in the air using experimental data in the form of pipe length and its frequency using the formula of each organ pipe (open and closed) with the linear regression-assisted data acquisition technique.

$$S_\partial = \sqrt{\frac{\sum(y-\bar{y})^2}{N-2}} \quad (12)$$

$$S_a = S_v\sqrt{\frac{N}{N\sum x_i - (\sum x_i^2)}} \quad (13)$$

In the process of measuring relative uncertainty in terms of precision and accuracy, the following equation was used (Djonoputro, 1984).

$$Level\ of\ Accuracy = \left|\frac{v_{experiment} - v_{theory}}{v_{theory}}\right| 100\% \quad (14)$$

$$Level\ of\ Precision = \frac{S_a}{v} 100\% \quad (15)$$

Result and Discussion

Development of Sound ExperimentationTool Assisted by Sound Analysis Oscilloscope Software

The process of developing a sound experimentation tool began with the use of cable paralon which was cut into five sizes. The experimentation process in determining the frequency used android smartphones that can facilitate students in the data collection process as well as material for the novelty of research that the use of sound analysis oscilloscope software which can be easily found in Play store has never been done as a medium in the data collection process to determine the speed of sound. The ease of using the sound analysis oscilloscope software has become the researcher's choice in the process of making the sound analysis oscilloscope software a method in conducting experiment to determine the speed of sound based on data acquisition technique.

Development of an experimentation tool in determining the speed of sound in air was assisted by sound analysis oscilloscope software with data acquisition technique in the experiments of open and closed organ pipes which were previously connected to the android smartphone's microphone with the aim of capturing sound signals and then analyzed using sound analysis oscilloscope software that had been installed on android smartphone to detect the frequency of the sound obtained. In the experimental process, the room temperature value was also taken into account as another variable that can affect the accuracy of the measurement results, thus a thermometer was needed to calculate the room temperature.

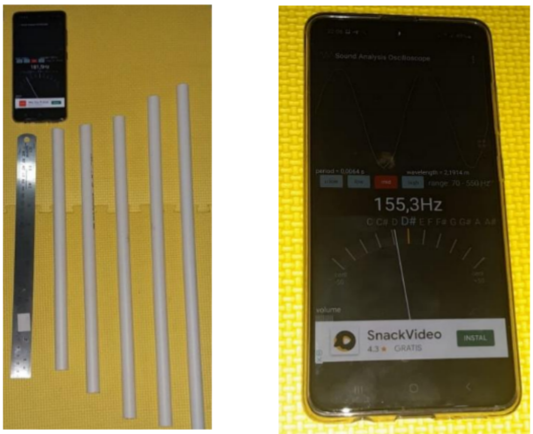

Figure 2. Organ pipe experimentation tool series

The process of making open and closed organ pipes shown in Figure 2 was carried out by making five different length modifications, namely (1) L = 0.46 m; (2) L=0.43 m; (3) L=0.39 m; (4) L=0.35 m and (5) L=0.32 m. The purpose of making these varying lengths of organ pipes was to obtain different frequency values in proving the concept of the relationship between the variable length of the organ pipe (open and closed) and the resulting frequency. The process of reading the frequency value used the Android version of Sound Analysis Oscilloscope Software.

Accuracy Level of Speed of Sound Measurement Results with the help of Sound Analysis Oscilloscope Software

Based on the data of experimental results on sound frequency measurement of open organ pipes, in which each experiment was repeated five times from each open organ pipe length, the data obtained were shown as in Table 1.

Table 1. Frequency of Open Organ Pipe Sound Source

L (m)	*f (Hz)*	*1/f (s)*	*2L (m)*
0.46	358.5	0.002789	0.92
0.43	390.3	0.002562	0.86
0.39	432.4	0.002313	0.78
0.35	479.2	0.002087	0.7
0.32	512.8	0.00195	0.64

Based on the table analysis of the experimental results, table 1 shows that the shorter the open organ pipe, the greater the frequency of the sound produced. It shows that the experimentation tool designed was able to prove the concept of an open organ pipe theoretically as shown in the graphic Figure 3.

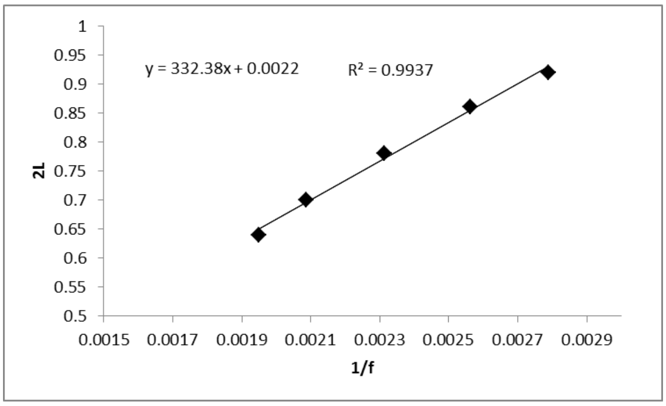

Figure 3. Graph of the relationship between pipe length (L) and frequency (f) of open organ pipe

Supported by the results of the analysis from Figure 3, we can see that the longer the pipe, the smaller the frequency of the sound produced. It means that theoretically, the relationship between frequency and pipe length can be proven directly and shows that the shorter the organ pipe, the greater the frequency of sound produced, thus the experimentation tool designed was able to prove the theory on an open organ pipe. In addition, Figure 3 of the following graph also explains the value of the speed of the sound source by referring to the linear regression formula which was close to the v_{theory} value (340 m/s) that was v=332.19 m/s.

Furthermore, the analysis of the closed organ pipe experiment resulted in the data as shown in table 2 below. The results showed that the shorter the closed organ pipe, the greater the frequency of the sound produced.

Table 2. Frequency of Closed Organ Pipe Sound Source

L (m)	*f (Hz)*	*1/f (s)*	*4L (m)*
0.46	170.8	0.005855	1.84
0.43	193.4	0.005171	1.72
0.39	209	0.004785	1.56
0.35	226.2	0.004421	1.4
0.32	240.7	0.004155	1.28

The analysis of the frequency value of the sound source in a closed organ pipe as shown in table 2 means that the experimentation tool designed was able to prove the concept of a closed organ pipe theoretically as supported by Figure 4.

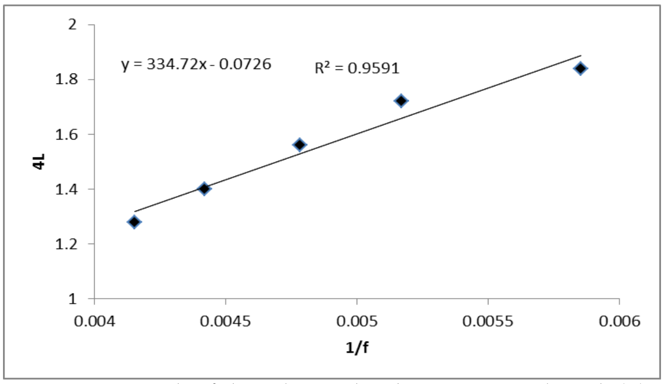

Figure 4. Graph of the relationship between pipe length (L) and frequency (f) of closed organ pipe

Based on Figure 4 from the graph above, we can see that the longer the closed organ pipe, the smaller the frequency of the sound produced. It shows that theoretically the relationship between frequency and pipe length can be proven directly and shows that the shorter the organ pipe, the greater the frequency of sound produced, thus the experimentation tool designed was able to prove the theory on a closed organ pipe. In addition, the graph in Figure 4 also explains that the value of the velocity of the sound source by referring to the linear regression formula was close to the v_{theory} value (340 m/s) that was v=334.69 m/s.

Based on the results of the discussion that have been described, the experimental findings on the value of the speed of sound waves in open and closed organ pipes produced different values for the value of sound wave velocity theoretically. The difference was due to humidity temperature and noise level at the sampling location. This was in accordance with the results of previous research conducted using audacity software to analyze the level of sound waves as a result of the effect of relative humidity on open and closed organ pipes (Chiriacescu et al., 2021; Hockicko et al., 2020; Mariyo et al., 2019). The novelty of this research is the use of android-based sound analysis oscilloscope software to analyze the speed of sound in open and closed organ pipes that have never been used in sound wave experimental activities. The data from the research conclude that the value of the experiment for the speed of sound waves was also not too far from the theoretical result of the speed of sound. Therefore, this software becomes one of the alternative media in physics learning in relation to the sound of the organ pipe. Experimental activities in determining the value of the speed of sound waves in organ pipes and harmonic motion, which were achieved mostly using Audacity Open Source Software resulted in experimental sound velocity values that were not much different from the use of Sound Analysis Oscilloscope Software (Jaafar et al., 2019; Jaafar et al., 2018; Jaafar et al., 2019).

Conclusion

Based on the results of research and discussion, it is concluded that the results of research and development using the ADDIE model obtain the value of the speed of sound waves in air using data acquisition technique assisted by Sound Analysis Oscilloscope Software for the open organ pipe category was v= 332.19 m/s with an accuracy level by 97.70%. The closed organ pipe category obtained a value for the speed of sound waves in air that was v=334.69 m/s with an accuracy rate of 98.44%. An experiment to determine the value of the speed of sound was obtained by using the data acquisition method assisted by the Sound Analysis Oscilloscope Software with linear regression analysis was less close to the theoretical value of the speed of sound waves in air (v_{theory}= 340 m/s), this was due to the difference in temperature and noisy room conditions which cause a frequency collision thus the sound reading of the sound source was disturbed. Suggestion for further research is that when conducting experiments, pay attention to the condition of the room (made it sound proof) thus the frequency of the sound source recorded in the Sound Analysis Oscilloscope Software will be not interfered.

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