International Journal of Education and Development using Information and Communication Technology (IJEDICT), 2018, Vol. 14, Issue 1, pp. 164-176

The development of an innovative resonance experiment using smartphones with free mobile software applications for tertiary education

Nurul Aina Syakirah Zainal Abidin and Siew Wei Tho
Universiti Pendidikan Sultan Idris, Malaysia

ABSTRACT

The purpose of this research was to design and develop hands-on practical physics activity for the determination of relationship between the fundamental frequency and wavelength of standing waves using open or closed resonance tubes. In this study, an innovative use of smartphone device for the hands-on practical activity was developed with the purpose to obtain the real experimental data and the plot graph automatically. Furthermore, this study was based on the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) instructional model. It incorporates a free mobile software application (mobile app) that can be easily downloaded from the Google Play Store to perform an innovative resonance experiment. This package can be used by lecturers and students in laboratory exercises and demonstration kits for the learning and teaching process.

Keywords: *hands-on practical activity; innovative use of smartphone; free mobile software application; physics education*

INTRODUCTION

With the rapid advancement of technology, the use of computers, smartphones and tablets can attract students' interest in the learning process. Mobile learning and computer assisted learning are able to increase the level of understanding of the students (Utulu & Alonge, 2012). They are able to learn and share knowledge via mobile learning without being limited by space and time. Besides, teachers and students both believe that the technology such as computers and mobile devices can be used as teaching tools to enhance the effectiveness of learning and teaching in understanding concepts (Liaw, Hatala, & Huang, 2010; Njoku, 2015). Through the use of mobile technology, students are able to develop their skills such as critical thinking, problem solving, communicating and collaborating with others in future. However, computers and high-end data loggers are limited to certain sites such as school laboratories because they are difficult to carry and have a relatively high cost.

This situation changes if smartphone devices are adapted and intriguing used into physics experiments as they can be used as experimental tools, since they are equipped with sensors. For example, the microphone, speaker, accelerometer, light sensor and GPS receiver are built-in sensors for smartphone devices. These sensors can be accessed through free mobile apps to conduct scientific investigation. A number of experiments can be carried out with smartphone devices (Kuhn & Vogt, 2013). Accordingly, the use of smartphones is increasingly popular in conducting experiments on physics subjects, such as resonant tube experiments (Tho & Yeung, 2014) and analysing pendulums (Vogt & Kuhn, 2012).

In general, mobile learning can help students to acquire knowledge through hands-on activities anytime and anywhere (Liu, Geurtz, Karam, Navarrete, & Scordino, 2013). The use of these free software applications in learning shows that they have a positive effect on student engagement (González et al., 2017). Moreover, the innovative use of smartphones will minimize the cost to replace the equipment used in the lab when the experiment is carried out. Additionally, smartphone devices are portable due to their small size and light weight. The selected mobile apps are freely available.

PROBLEM STATEMENT

Recently, numerous studies on mobile technology research and development have revealed that these technologies play a crucial role in science and technology (Dutta, Sarma, & Nath, 2015; Zamora, Kashihara, & Yamaguchi, 2015). Besides that, some practical work that must be performed outdoor or takes a longer time than normal laboratory lessons may be ignored (Souter & MacVicar, 2012). Furthermore, physics is one of the science subjects that are often considered to be difficult (Halim, Yong, & Meerah, 2014). There is a lack of interactive learning and teaching methods, and most teachers may still maintain a one-way teaching method. This also contributes to the factors that cause physics to be difficult to teach and understand.

Furthermore, “the annoyance of errors in scientific experiments are unavoidable, but these errors can be reduced” (Tho & Hussain, 2011, p. 43). The students will be able to find out the errors after comparing their experimental results with the theoretical results. They can repeat the whole process of the experiment in order to have more precise results. For example, Figure 1 shows the resonance experiment in an open-ended resonance tube. This experiment will determine the velocity of sound at room temperature (Cudnik & Erickson, 2014). Conventionally, the determination of the velocity of sound in this experiment is using tuning forks of certain frequency. Then, the wavelength will be defined through the resonance of an air column by changing the water level. Student can hear a sudden increase in the sound intensity or resonance when the water level is changed to the appropriate length. This will generate a systematic error. The students may obtain incorrect data due to the vagaries of personal hearing (random error).

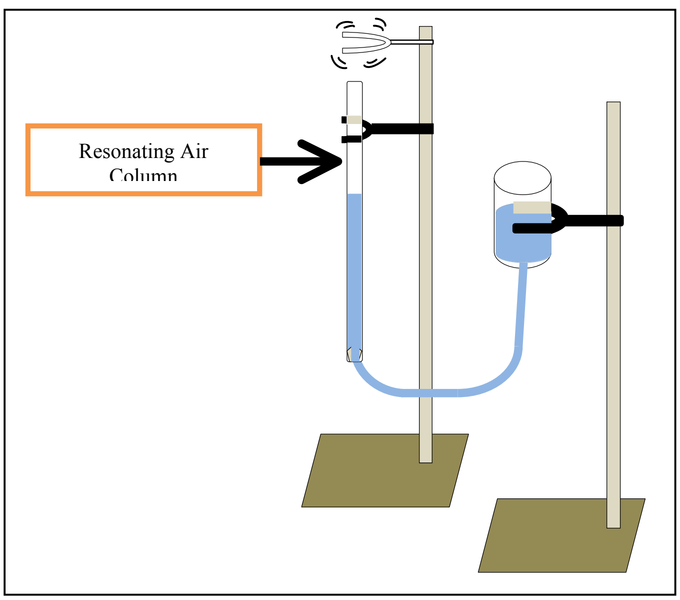

Figure 1: *To determine the velocity of sound in air*

Therefore, practical work activity should be adapted with the changes in the latest technology to encourage students to learn science particularly physics. In addition, random errors can be reduced because the data may be recorded by a free mobile app. In line with current technology, an alternative practical work activity should be developed. In this study, an innovative resonance experiment based on a smartphone-assisted laboratory method through the use of free mobile app had been developed. As a result, this innovative learning environment can be applied to overcome problems related to limited class time, "Cookbook" experiments, and general of accessibility.

OBJECTIVE OF THE STUDY

- To develop a hands-on practical activity for a resonance topic through innovative use of a smartphone and free mobile app.
- To design the experimental set for an innovative resonance experiment.
- To validate the experimental set for an innovative resonance experiment.

METHODOLOGY

In this research, the ADDIE instructional model was chosen. There are five phases in ADDIE model used to develop this activity – Analysis, Design, Development, Implementation and Evaluation (Bichelmeyer, 2005; Kruse, 2002; Wang & Hsu, 2009). The ADDIE model was chosen due to ensuring that the educational kit or product produced is effective and efficient. The ADDIE model has a systematic approach and provide an orderly framework for developed of educational kit or product.

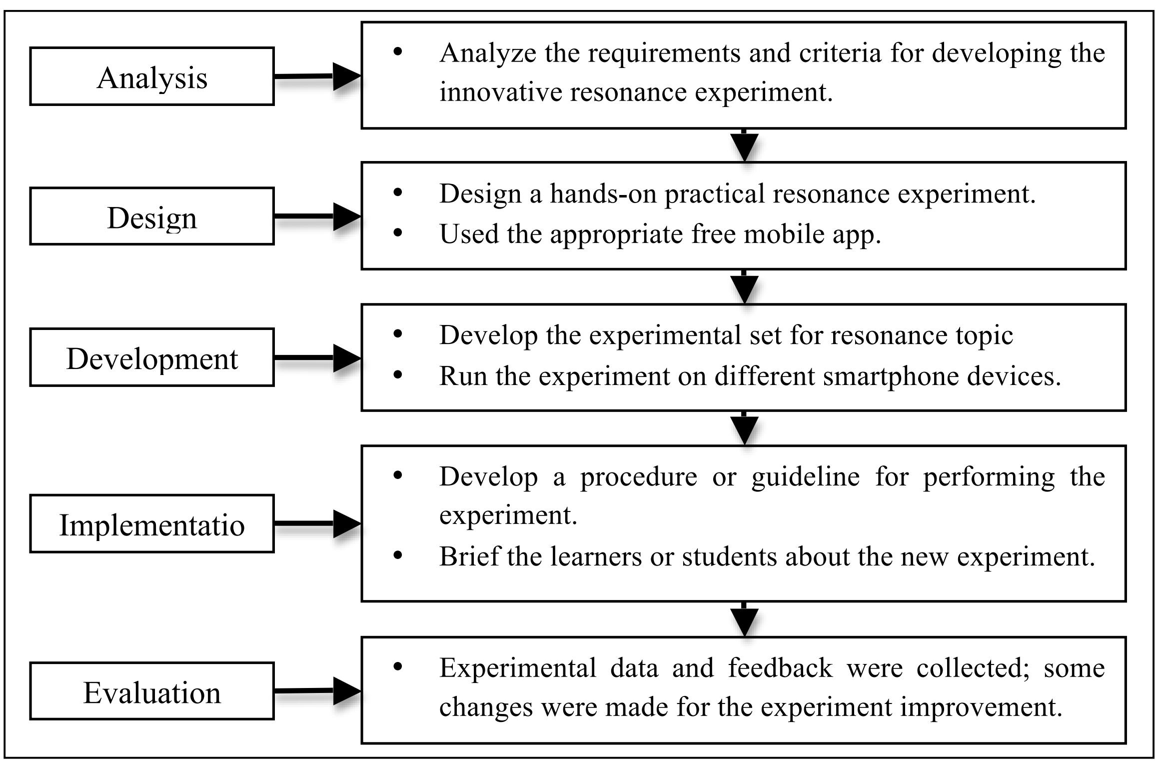

Figure 2: *Research process*

Analysis Phase

A hands-on practical physics activity that could be carried out through the use of a smartphone and free mobile app was developed. The requirements and criteria of the design experimental must be simple to operate, easy to understand, and innovative with using the latest technology at a reasonable cost.

Design Phase

In the design phase, the flowchart of the application operation was an important element. In this study, several feasible free mobile apps that could be used into this hands-on activity had been identified and eventually TrueTone version 1.5 (2011) as frequency sound generator and Advanced Spectrum Analyzer PRO version 2.1 (2017) as frequency meter were chosen to perform the experiment due to the app being freely available, user friendly interface and offered ease of data reading. Figure 3 shows the screen display of the Advanced Spectrum Analyzer PRO application.

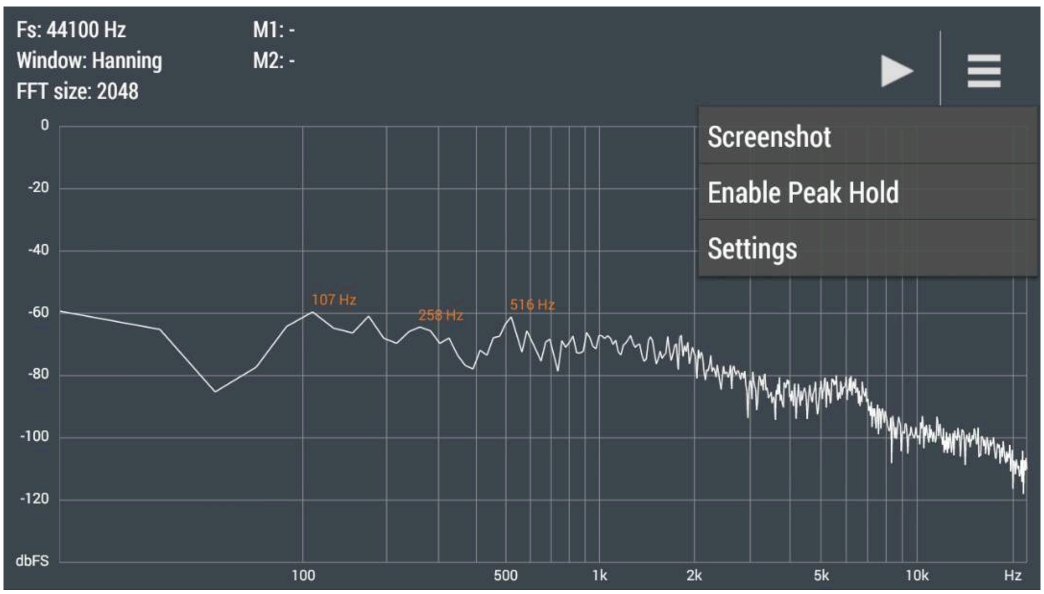

Figure 3: *Screen display of Advanced Spectrum Analyzer PRO*

At the beginning, “Enable Peak Hold” was selected. The input was the frequency sound from the TrueTone mobile app. This input was processed by a frequency meter (oscilloscope) using the Advanced Spectrum Analyzer PRO mobile app. Then, the data was plotted in the form of graphs (output). After the data using a smartphone (data logger) was recorded, a “Pause” button was pressed. In the graph, the point was dragged to find the value of fundamental frequency (first peak frequency). Then, the findings were ‘screenshot’ and saved into the containing folder. A flowchart of the free mobile app operation is shown in the Figure 4.

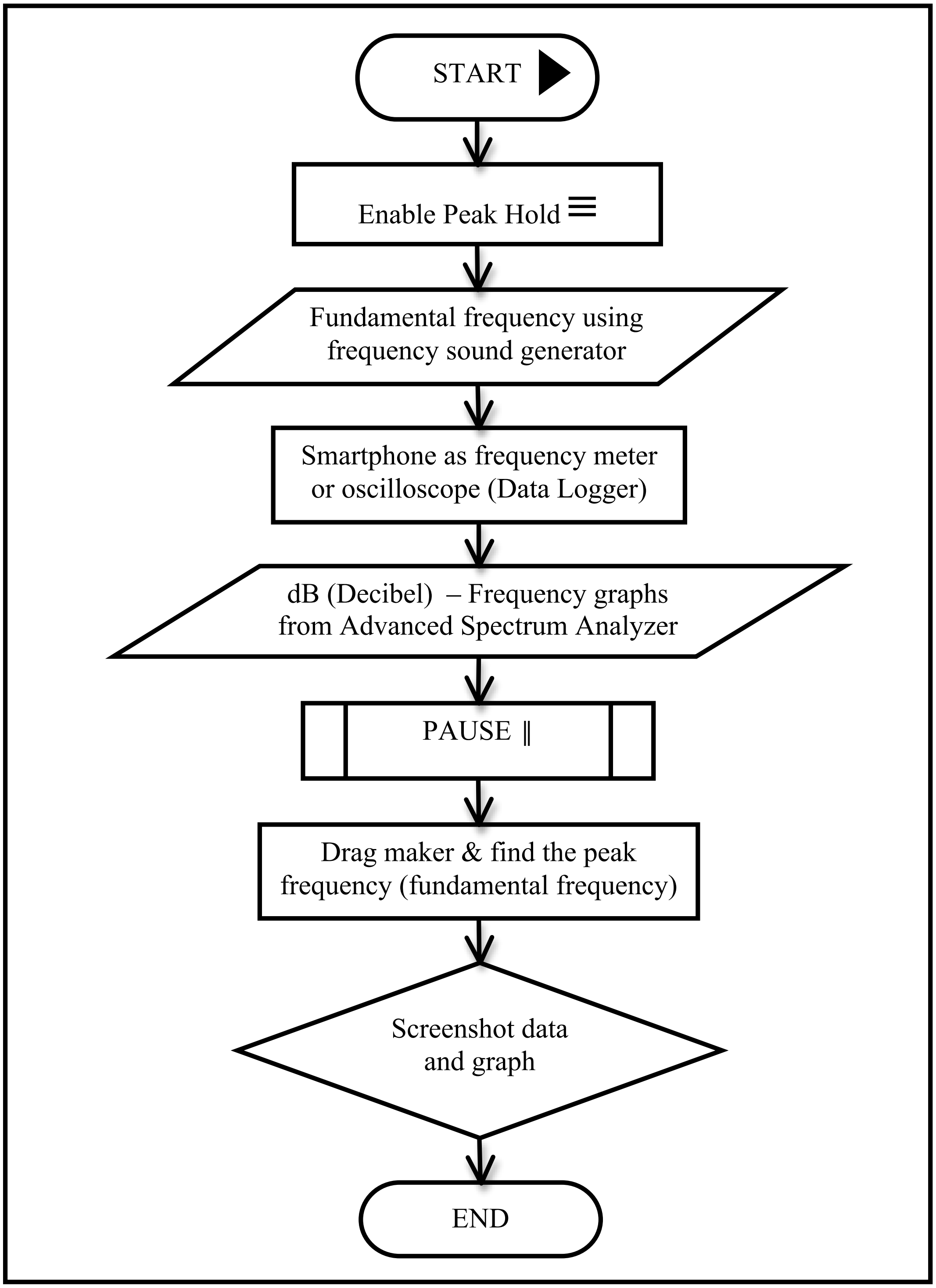

Figure 4. *Flowchart of the free mobile app operation*

Development Phase

Once the development of the experimental set was completed, the experiment was first run on different mobile devices to test its versatility for use in different mobile environments. The procedures and solutions to those problems in a different mobile environment were determined by performing and testing the experiment on different mobile devices to find and compare the results in real situation.

Implementation Phase

Procedures and guidelines for performing the innovative resonance experiment were developed. The guidelines covered the installation of free mobile app, laboratory manual, and testing procedures. The learners were briefed on new practical activity and it was also ensured that all manual and tools (smartphone and its built-in sensors) were in good condition.

Evaluation Phase

The evaluation phase was a part of the continuing the refinement of the experiment. Hence, it was important to perform the evaluation and test by researchers and students for its usability and problems. In addition, the experimental data was also a part of the evaluation. Once the experimental data and feedback were collected, some amendments were made for the experimental improvement.

EXPERIMENTAL SET DEVELOPMENT

In this study, two essential free mobile apps were used: TrueTone (a frequency sound generator) and Advanced Spectrum Analyzer (a frequency meter) to find the fundamental frequency. For conventional experiments, students need to listen and record the peak frequency. Therefore, they may record incorrect frequency because of personal hearing and systematic error.

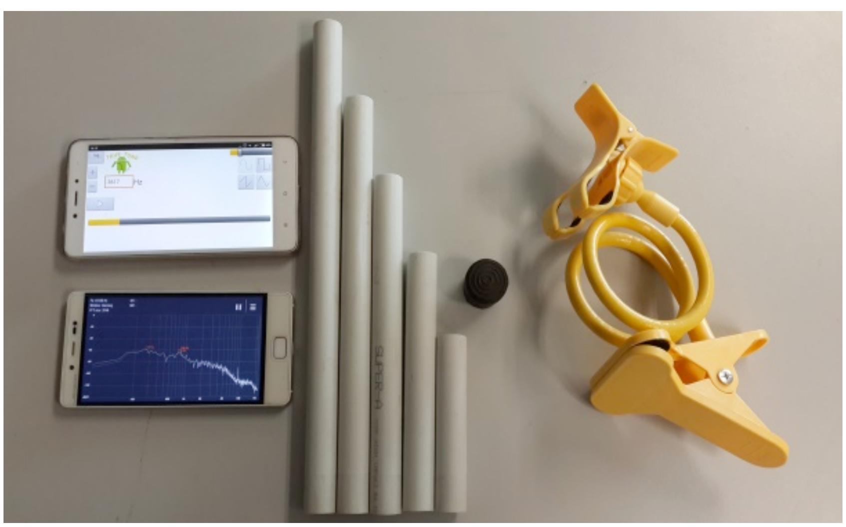

Figure 5: *Apparatus and materials required*

In this new design, students are able to determine the relationship between the fundamental frequency and wavelength of standing waves using open or closed resonance tubes. The apparatus and materials used were simple and easy to get at a low and reasonable cost (see Figure 5). Moreover, the experimental setup and the method for performing the experiment are provided in Figure 6.

Figure 6: *Set up the experiment*

Standing waves can be observed in strings and columns of air refer to the first peak frequency using Advanced Spectrum Analyzer Pro mobile app (as a frequency meter). A cylindrical air column with both ends open vibrates with a fundamental mode such that the air column length is one half the wavelength of the sound wave. For the fundamental mode, there is one node at the centre. The basic wave relationship leads to the frequency of the fundamental (Figure 7).

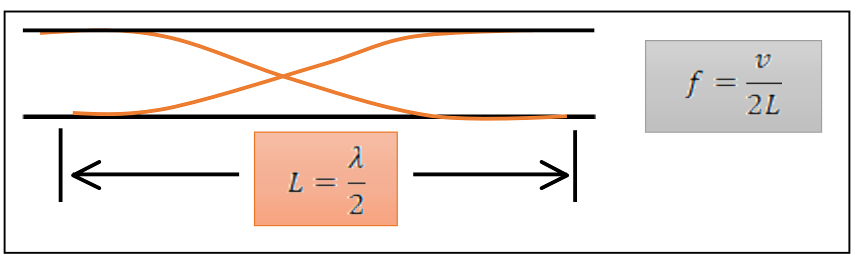

Figure 7: *The fundamental or first harmonic of open resonance tube*

A closed cylindrical air column will create resonance standing waves at a fundamental frequency and at odd harmonics. The closed end is forced to be a node mode and the open end is an antinode mode. This causes the fundamental mode, such that the wavelength is four times the length of the air column.

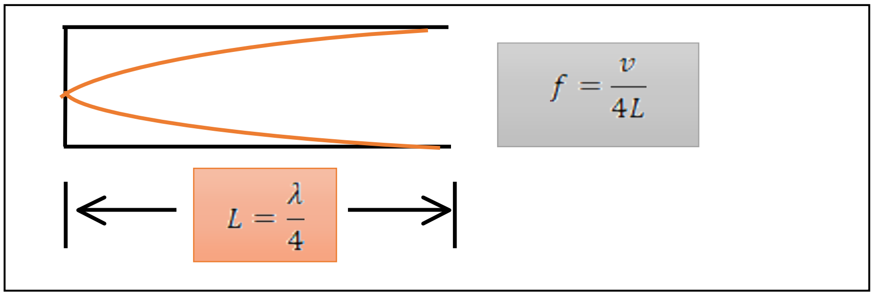

Figure 8: *The fundamental or first harmonic of closed resonance tube*

FINDINGS AND DATA ANALYSIS

This section describes the findings and data analysis of the hands-on practical work. The diameter of resonance tube used in this study was 0.02 m. In fact, the diameter can be any size according to their setting during the hands-on practical work. Figure 9 shows that the screen displays of the experimental result for 10 cm open resonance tube. The results of all the findings for open resonance tube are shown in Table 1 and Figure 10 and the closed resonance tube are shown in Table 2 and Figure 11.

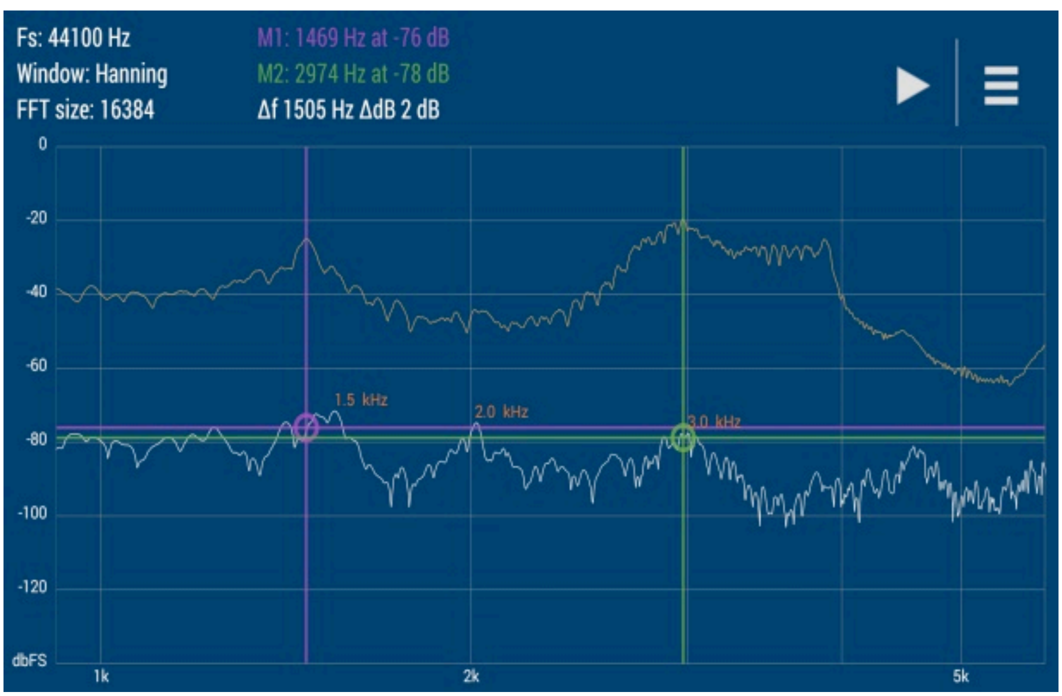

Figure 9: *The experimental result and graph of 10 cm open resonance tube*

For open resonance tube

Table 1: *Findings of open resonance tube*

Length of resonance tube (cm)	Fundamental frequency (Hz)			Wavelength (m)	Average fundamental frequency (Hz)
	Test 1	Test 2	Test 3		
10	1469	1458	1480	0.2	1469
15	1001	1012	1030	0.3	1014
20	785	772	769	0.4	775
25	640	637	635	0.5	637
30	532	527	546	0.6	535

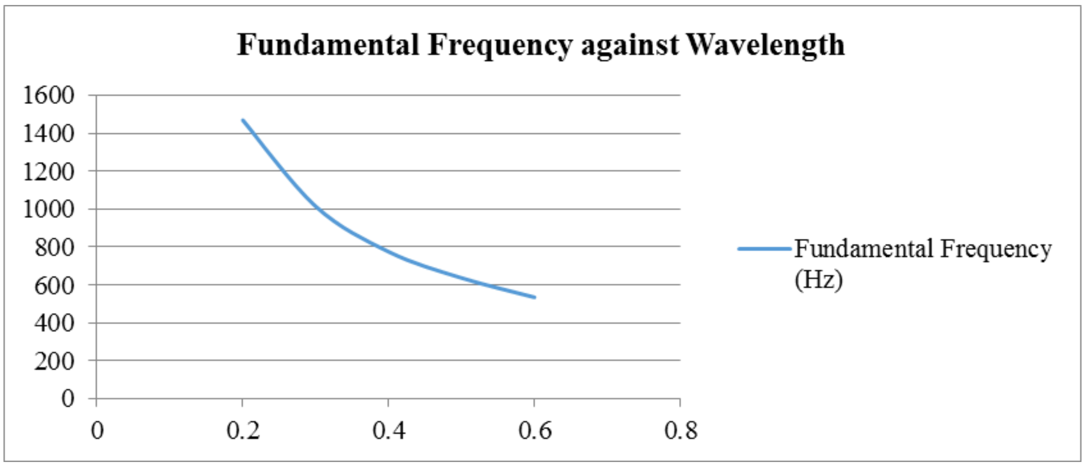

Figure 10: *Graph of fundamental frequency against wavelength for open resonance tube*

For closed resonance tube

Table 2: *Findings of closed resonance tube*

Length of resonance tube (cm)	Fundamental frequency (Hz)			Wavelength (m)	Average fundamental frequency (Hz)
	Test 1	Test 2	Test 3		
10	764	758	760	0.4	761
15	516	527	525	0.6	523
20	403	401	401	0.8	402
25	325	331	331	1.0	329
30	274	279	268	1.2	274

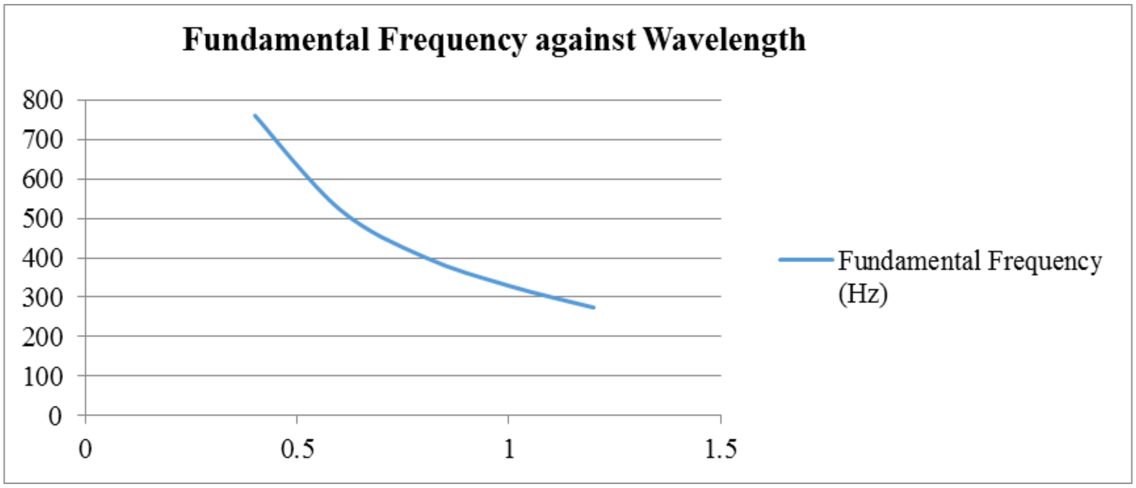

Figure 11: *Graph of fundamental frequency against wavelength for closed resonance tube*

In addition, the percentage error of fundamental frequency for both open and closed resonance tubes can be calculated in Table 3 and 4. At room temperature of 23 °C, the theoretical value for the speed of sound in air is as follows:

$$v_{air} = 331 \text{ m/s} + (0.61)T$$
$$v_{air} = 331 \text{ m/s} + (0.61)(23\ °C)$$
$$v_{air} = 345.03 \text{ m/s}$$

Thus, the speed of sound is related to its frequency and wavelength, based on the equation of $v=f\lambda$ and then the theoretical value of the fundamental frequency can be calculated as Table 3 and 4.

For open resonance tube

Table 3: *Percentage error of fundamental frequency for open resonance tube*

Length of open resonance tube (cm)	Experimental value of fundamental frequency (Hz)	Theoretical value of fundamental frequency (Hz)	Percentage error (%)
10	1469	1725	14
15	1014	1150	12
20	775	863	10
25	637	690	8
30	535	575	7

For closed resonance tube

Table 4: *Percentage error of fundamental frequency for closed resonance tube*

Length of closed resonance tube (cm)	Experimental value of fundamental frequency (Hz)	Theoretical value of fundamental frequency (Hz)	Percentage error (%)
10	761	863	12
15	523	575	9
20	402	431	7
25	329	345	5
30	274	288	5

DISCUSSION

The data can be analysed using spreadsheet software (see Figure 10 and 11). Graphs of fundamental frequency against wavelength were plotted for open and closed resonance tube and a graph of the inverse function was obtained. From the analysis of the results, the fundamental frequency depends on the wavelength. A longer resonance tube means a longer wavelength for the standing wave and a lower fundamental frequency is obtained.

One of the rationales to develop this hands-on practical work is to support the students in understanding lectures or class discussion and to verify theories. This practical work provides straightforwardness in performing experiments. Once the apparatus and smartphone devices are ready, the only requirement is to press the start button and continue the procedure, as the results and graphs will be automatically presented. Using this apparatus for the study of resonance, students will be able to observe the relationship between the fundamental frequency and the wavelength of the standing waves. At the end of the experiment, the recorded data could be further analysed using the spreadsheet software (e.g. OpenOffice Calc, Kingsoft Spreadsheets or Microsoft Excel).

This hands-on practical activity was developed to solve three major problems. Firstly, the resonance experiment conducted using this experimental apparatus produces result with small percentage error of between 5 % and 14 %. Secondly, students have flexibility to use different diameter and length of resonance tubes which is not as previously set by conventional practical work. The cost of the smartphone (acts as data logger) was reasonable since normally students in tertiary education have their own smartphone and additionally it is incorporated with free mobile app. Furthermore, this new design uses the latest technology and will attract students' interest in the learning process (Baya'a & Daher, 2009; Hwang & Chang, 2011).

CONCLUSION

A hands-on practical physics activity for studying resonance had been successfully developed. It is hoped that this hands-on practical work and others physics activities such as using free mobile accelerometer app will be used in physics laboratory exercises at the tertiary level and expanded to science laboratory at the secondary level. Contrasting with videos of science experiments or simulation experiments, this innovative use of smartphones for hands-on practical work allows students to observe real-time experimental data and carry out experiential outdoor activity in science, and perform these activities at anytime and anywhere. This technique also replaced the traditional method where students have to use their individual hearing. The data obtained from this practical activity produced results with fair accuracy because the results obtained from this experiment through the use of smartphone is closed to the theoretical value. The deviation of the experimental result ranged between 5% and 14 % from the theoretical value.

ACKNOWLEDGEMENTS

We are very grateful to Sultan Idris Education University for financial support (University Grant Research Code: 2016-0105-107-01). Thanks are also due to Sadiah Baharom and Tien Tien Lee for their helpful work on this project.

REFERENCES

Baya'a, N. F., & Daher, W. M. (2009). Learning mathematics in an authentic mobile environment: the Perceptions of Students. *International Journal of Interactive Mobile Technologies*, *3*(1), 6-14.

Bichelmeyer, B. (2005). *The ADDIE model: A metaphor for the lack of clarity in the field of IDT*. Retrieved from http://indiana.edu/~idt/shortpapers/documents/IDTf_Bic.pdf

Cudnik, B., & Erickson, G. (2014). *Physics 2121 Laboratory Manual*. Retrieved from https://www.pvamu.edu/physics/wp-content/uploads/sites/55/physics-2121-lab-manual-11-0e.pdf

Dutta, S., Sarma, D., & Nath, P. (2015). Ground and river water quality monitoring using a smartphone-based pH sensor. *AIP Advances, 5*(5), 057151. doi:10.1063/1.4921835

González, M. Á., González, M. Á., Martín, M. E., Llamas, C., Martínez, Ó., Vegas, J., ... & Hernández, C. (2017). Teaching and Learning Physics with smartphones. In *Blended Learning: Concepts, Methodologies, Tools, and Applications* (pp. 866-885). IGI Global.

Halim, L., Yong, T. K., & Meerah, T. S. M. (2014). Overcoming students' misconceptions on forces in equilibrium: An action research study. *Creative Education*, *5*(11), 1032-1042.

Hwang, G. J., & Chang, H. F. (2011). A formative assessment-based mobile learning approach to improving the learning attitudes and achievements of students. *Computers & Education*, *56*(4), 1023-1031.

Kuhn, J., & Vogt, P. (2013). Applications and examples of experiments with mobile phones and smartphones in physics lessons. *Frontiers in Sensors, 1*(4), 67-73.

Kruse, K. (2002). *Introduction to instructional design and the ADDIE model.* Retrieved from http://docshare01.docshare.tips/files/12024/120247130.pdf

Liaw, S. S., Hatala, M., & Huang, H. M. (2010). Investigating acceptance toward mobile learning to assist individual knowledge management: Based on activity theory approach. *Computers & Education, 54*(2), 446-454.

Liu, M., Geurtz, R., Karam, A., Navarrete, C., & Scordino, R. (2013). Research on mobile learning in adult education. In W. K. S. Marshall (Ed.), *On the Move: Mobile Learning for Development* (pp. 105-160). Charlotte, NC: Information Age Publishing, Inc.

Micwi (2011). *TrueTone* (version 1.5) [Mobile application software]. Retrieved from https://play.google.com/store/apps/details?id=pl.micwi.truetone

Njoku, C. P. U. (2015). Information and communication technologies to raise quality of teaching and learning in higher education institutions. *International Journal of Education and Development using Information and Communication Technology*, *11*(1), 122-147.

Tho, S. W., & Hussain, B. (2011). The development of a microcomputer-based laboratory (MBL) system for gas pressure law experiment via open source software. *International Journal of Education and Development using Information and Communication Technology*, *7*(1), 42-55.

Tho, S. W., & Yeung, Y. Y. (2014). Innovative use of smartphones for sound resonance tube experiment. *Teaching Science*, *60*(1), 39-42.

Utulu, S. C., & Alonge, A. (2012). Use of mobile phones for project based learning by undergraduate students of Nigerian private universities. *International Journal of Education and Development Using Information and Communication Technology*, *8*(1), 4-15.

Vogt, P., & Kuhn, J. (2012). Analyzing simple pendulum phenomena with a smartphone acceleration sensor. *The Physics Teacher, 50*(7), 439-440.

Vuche Labs (2017). *Advanced Spectrum Analyzer PRO* (version 2.1) [Mobile application software]. Retrieved from https://play.google.com/store/apps/details?id=com.vuche.asap

Wang, S. K., & Hsu, H. Y. (2009). Using the ADDIE model to design Second Life activities for online learners. *TechTrends*, *53*(6), 76+-81.

Zamora, J. L. F., Kashihara, S., & Yamaguchi, S. (2015). Calibration of Smartphone-Based Weather Measurements Using Pairwise Gossip. *The Scientific World Journal*. doi:10.1155/2015/494687

Original article at: http://ijedict.dec.uwi.edu/viewarticle.php?id=2373