# The Effect of a Technology-Enhanced Learning (TEL) Module on the Achievement of Form Four Students in the Topic of Waves and Sound

**[1*]Norfazilah Mohamad Yusuf, [2]Nurulhuda Abd Rahman, [3]Nuraini Ghazali**
[1,2]Department of Physics, Faculty Science and Mathematics,
Universiti Pendidikan Sultan Idris, Tanjong Malim, Perak, Malaysia
[3]SMK (P) Methodist, Jalan Raja Permaisuri Bainun,
Ipoh, Perak, Malaysia

[*]Corresponding author: abbafazilah@gmail.com

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## ABSTRACT

The purpose of this study was to determine the effect of a Technology-Enhanced Learning (TEL) module on the achievement of form four students in the topic of waves and sound. Constructivism was used as the underpinning theory and Sidek's Model as the model used for module development. A true-experimental design was used to determine the effect of the module on students' achievement. The instrument used was a self-developed, validated test which was used for both pre-test and post-test. The validity of the module and the instrument was verified by three experts in the related field. Experts agreed that the TEL module has had a high content validity with 90% agreement among the three experts. A sample of 60 Form Four students who took Physics as one of their subjects were selected and assigned randomly into a control group (n=30) and an experimental group (n=30). The treatment for the experimental group was conducted for four weeks. The result of the independent sample t-test [$t(58) = -5.53$, $p < 0.05$] showed that the achievement of the students in the experimental group ($M = 70.33$, $SD = 10.31$) was significantly higher than the students in the control group ($M = 55.53$, $SD = 10.42$). In conclusion, the main finding showed that the TEL module was effective in enhancing students' achievement in the waves and sound topic. The conclusion implies that the TEL module can be used by Physics teachers as an effective teaching and learning resource.

**Keywords:** Technology-Enhanced Learning; Waves and Sound; Student's Achievement, Zone of Proximal Development, Physics Education

## INTRODUCTION

The implementation of technology is breaking the barrier in all education innovations by accelerating the learning transfer from a teacher to students. Ministry of Education (MOE) has introduced Pelan Pembangunan Pendidikan Malaysia (PPPM) 2013-2025 that encourages 21st century learning which focuses on developing students' communication, collaboration, creative and critical thinking skills (4Cs). By adapting technology such as smartphones apps and computer software in learning Physics, teachers could better instill these four 21st century's skills. However, the key to the successful integration of technology during learning is the competency of both teachers and students in applying and adapting relevant technology so as to facilitate and optimise learning.

Prior to 2020, Physics has been taught with not much difference from how it was taught 30 years ago; where the equipment and laboratory apparatus were and still are limited and costly up to this day. For example, in teaching sound waves, teachers face difficulties when operating the cathode-ray oscilloscope. In addition, the frequency sound generator is insufficient thus conducting experiment remains as a challenge for teachers. Subsequently, teachers usually forego doing experiment and thus making students demotivated as learning activity reverts back to learning by listening. However, the new curriculum (KSSM) for Physics that has only been implemented this year (2020) puts emphasis on learning through technology and thus technology becomes a crucial learning tool which would assist teachers and students not only to achieve the learning standards, but also for better construction of scientific knowledge and understanding and the 4Cs. The integration of information and communication with technology can seamlessly be done during laboratory activities. For example, computer-based simulations and representations are more likely to be effective in developing scientific reasoning as they may promote students' ability to relate between theory and observation of phenomena to ultimately generate a conclusion (Peffer, Beckler, Schunn, Renken, & Revak, 2015). As a result, the desired students' achievement will increase as the product of students' interest and understanding of science.

There are many researches that demonstrate the use of technology especially smartphones and computer applications in teaching and learning (Fitzgerald et al. 2011; Kuhn & Vogt, 2013; Sans et al., 2013; Vieyra & Vieyra 2014; Kuhn, Vogt & Hirth, 2014; Kuhn, Molz, Gröber, & Frübis 2014; Meibner & Haertig, 2014; Klein, Hirth, Gröber, Kuhn, Müller 2014; Azael Barrera-Garrido 2015; Jaafar et al. 2016). However, there is a lack of research on developing a module that contains a collection of technology-enhanced, inquiry-based activities on sound waves. In addition, to the researchers' knowledge, there is no such module being developed that is aligned with the new Physics curriculum. A study by Norlidah Alias & Saedah Siraj (2012) shows a lack of empirical evidence in Malaysia related to the effectiveness of a Technology-Enhanced Learning (TEL) module in concept construction and how it affects students' achievement.

Prior to the development of TEL module, the researchers had conducted a relevant study using a sample of 70 Physics teachers in Malaysia. The questionnaire was constructed into three dimensions; which were 28 questions on determining the most difficult Physics chapter, the needs for technology and teachers' knowledge of TEL. The result showed that Sound and Waves is among the most difficult Physics chapter to learn besides Electromagnetism and Electricity. Data from the descriptive analysis showed that the level of the need for Technology Hardware and awareness on Technology-Enhanced Learning are moderately high. These findings showed that teachers possess the knowledge and awareness to implement TEL without restriction of time and place.

Thus, this present study emphasises on the need to develop a TEL module for the topic of sound waves that can eventually serve as a reference for Physics teachers in implementing inquiry-based, technology-enhanced activities. This would be an alternative to the more traditional lab and direct teaching. The TEL module consists of a self-learning module and experiment manual that necessitate the use of smartphone and computer software. It involves the use of free downloadable softwares and smartphone applications. It also includes both formative and summative assessment tasks. It can cater to the issues of deficiency, costliness and complexity of measuring instruments such as CRO, visual analyzer and time of instruction. In addition, students should be able to carry out the activities aside from the ones done in the laboratory and beyond their school hours by using the self-learning module component of the TEL module.

Therefore, the objectives of this paper are to report on the development and validation of TEL module in the topic of sound waves and on the effectiveness of the developed TEL module in promoting students' academic achievement. The research questions are:
This study consists of four research questions:

(1) Does the developed TEL module have a good validity?
(2) Does the developed TEL module have a good reliability?
(3) Is there any significant difference between the achievements of the control group who underwent learning conventionally compared to the experimental group who underwent learning using the TEL module?

(4) Is there any significant difference between the achievements of the experimental group before and after undergoing learning using the TEL module?

## LITERATURE REVIEW

On reviewing the literature, the researchers came up with three relevant themes namely the learning theories for module development such as constructivism-behaviorism theory, the challenge in learning sound waves, and effects of implementing TEL on teacher's and student's learning experience.

### Learning Theories for Module Development: Bridging Behaviorism and Constructivism

Educational technology in parallel with this learning theory expects that learning and behavior can be modified by a stimulus-response approach. Through behaviorism theory, computer-enhanced learning process exhibits response element and a feedback element of instruction (Gagné, 1974). Similarly, by integrating behaviorism strategy into TEL module, the developer intended that the module would allow teachers to focus on the reinforcement of desired modification of behavior or learning problem internally.

Through the use of technology in TEL module such as computer software and smartphone apps, it is possible to achieve two current education assumptions which are— to empower students to be responsible for their own learning and to design engaging activities based on student's respective needs. Therefore, the use of such module is a good effort in bridging the behaviorism and constructivism theories to improve the educational instruction.

Constructivism on the other hand is a term which holds many different perspectives and approaches (McPail, 2015). The basic premise is that students learn by relating new information with their prior knowledge in the process of sense-making. Thus, prior knowledge has a significant impact on the acquisition of new knowledge. The TEL module comes with a self-learning module that encourages students to equip themselves with some prior knowledge before the class sessions. In addition, the developed activities and the technology selected can help students engage in and gain skills at tasks that are beyond their unassisted abilities. The tools help students learn by doing through performing at a higher level than they would otherwise.

According to Vygotsky, as one of the proponents of the Constructivist Theory, learning is seen as the process of knowledge acquisition and is best achieved when there is an interaction between the learners and an expert or more knowledgeable person. The learner's developing skill would be at best with knowledge experience in the zone of proximal development (ZPD) of which learning becomes better with the help of experts rather than performing alone. This would align with KSSM curriculum whereby it is vital for students to learn by collaboration and interaction in groups and also include assessment by peers - as believed that the process is as important as the product.

The ZPD is interpreted as an area of what the learner cannot do, but can be done with guidance. Therefore, in developing the TEL module, the module developer planned for experts to be the trainers in utilising and employing Technology-Enhanced tools such as software and smartphone apps in order to achieve the learning objectives. Following Vygotsky, social interaction between the learner and with the more knowledgeable person such as peer or trainer will gradually help the learner to develop the ability of solving problems independently. Figure 1 shows the implementation of TEL module in the learning environment.

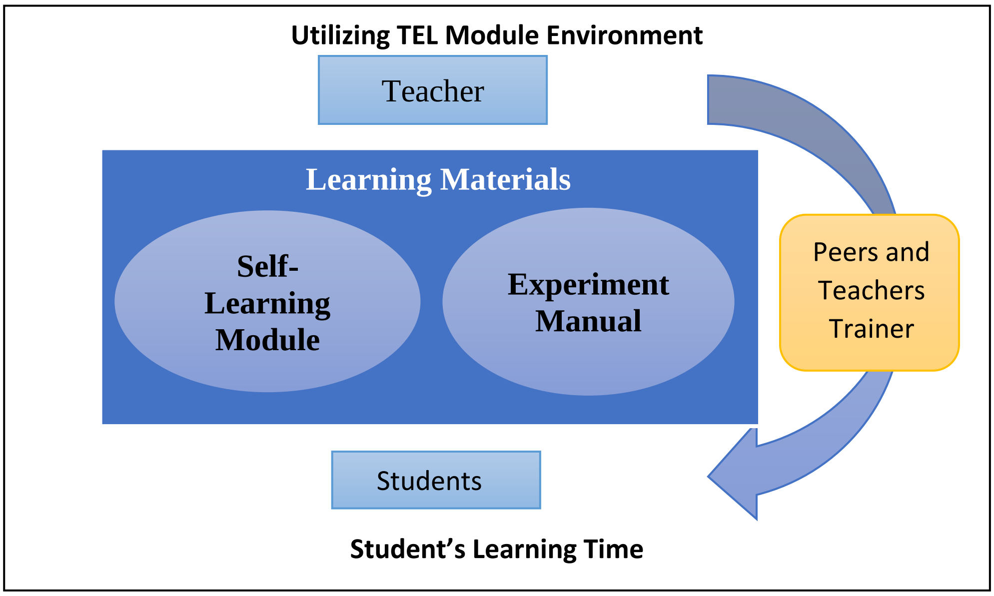



Figure 1: Implementation of TEL module in the Learning Environment

Figure 1 signifies the learning environment of the experimental group which utilised TEL module in learning waves and sound. The TEL module which consists of two booklets, Self-Learning module and Experiment Manual had set sufficient learning time for students in achieving the learning goals. Thus, students' learning is self-directed by motivation and assistance from peers and teachers as the trainers in conducting the experiment with technology tools to enhance learning.

**Learning Sound Waves and its Challenges**

Experiments and phenomena of the wave properties in introductory Physics for secondary school students are always shown by demonstrating the water wave except for the interference phenomenon since teachers have always preferred conducting the interference of light wave instead. This is due to the fact that properties of water wave can easily be seen and measured. On the other hand, sound wave is an entity that cannot be seen and thus it cannot be measured without the use of technology such as computer and smartphones. Additionally, the incorporation of technology in Physics laboratory can increase students' motivation and thus plays an important role in the learning process (Zakaria, Fatin, Mohamad & Norazrena, 2017). However, to facilitate and optimise learning by using technology, Trust (2017) suggests the need to provide training courses for teachers to have hands-on experience with the new technology which includes both software and hardware.

**Effects of Implementing TEL on Teachers' and Students' Learning Experience**

Learning Physics involves observation of the world. Some observations are made possible only with the use of certain instruments or devices. Thus, students must be equipped with the appropriate skills in using certain devices such as smartphones to observe those phenomena and measure the variables of interest related to the phenomena.

Smartphones are easily obtainable, user-friendly everyday device that allow students to manoeuver it easily as measurement device. For secondary school students, they need to be introduced to the free sensor application in the app store. There are varieties of sensors which act as measurement devices such as accelerometer, gyroscope, magnetic, light, sound generator, or sound spectrum, allowing students to observe and record data for further analysis. Through this, it stimulates the students' scientific interest by exploring it outside of class (Vieyra & Vieyra, 2014), acts as content-delivery tool (González, 2015) and reduces cognitive load (Hochberg, Becker, Louis, Klein, & Kuhn, 2020).

The teachers' role in TEL is to structure the engagement of the students in practicing higher order thinking skills and not just to pass the knowledge passively (Laurillard, 2008). In a good way, learning with technology has improved the students' interaction with the phenomena to be studied and the way they collect data (Wang et al., 2014), increased information and technology skills (Laili, Maizatul & Md Nasir, 2015), boost students' understanding on the concept the construction (Yahya, Hermansyah, & Fitriyanto, 2019) and eventually let them gain control over the task, instruments and resources (Liu, Wu, Wong, Lien, & Chao, 2017).

The adoption of laboratory outside of the school by implementing TEL is not a new agenda. Tho and Yeung (2018) had implemented a remote laboratory (RL) system to enrich authentic scientific investigation activities. Furthermore, the implementation of technology in classroom allows different approach for teachers while students are able to study at anytime and anywhere (González et al., 2015). Eventually, students become more independent in the learning process and better in conceptual understanding when they use smartphones for academic purposes both in and out of school (Arista & Kuswanto, 2018). Moreover, the active participation of the student which is likely to support, understand and grasp on difficult and abstract Physics concepts subsequently will positively affect students' interest in learning (Maryam, Fahrudin & Susanto, 2019).

However, the chances of misusing the smartphones in the classroom could happen when students engage with non-academic activities (Anshari, Almunawar, Shahrill, Wicaksono, & Huda, 2017). Nevertheless, the effective use of smartphones brings in more advantages than disadvantages to undergraduate students' lives (Ifeanyi & Chukwuere, 2019).

## METHODOLOGY

This research was a developmental research which used the Sidek's Module Development Model (Sidek & Jamaluddin, 2005) to design a module that also included the experimental design in to test the effect of the use of module on students' achievement. The experimental design was the pretest-posttest control group design (Campbell & Stanley, 1963).

The population was 120 Form 4 students who took Physics from a secondary school in Kinta Utara district. The Form Four science stream students were selected because the topic of sound waves is part of the Form Four Physics KSSM curriculum's syllabus content. 60 respondents were then selected using the simple random technique and randomly assigned into control and experimental group equally.

### Instruments and Pilot Study

The instruments used in this study were an achievement test and a questionnaire to measure TEL module reliability. Both instruments were self-developed and later validated by three experts in the field. The profile of the validity panel is as in Table 1

**Table 1:** The Experts' Profile of Content and Face Validity of TEL modules

| Number | Profile | Institution | Expertise |
|---|---|---|---|
| 1 | Assoc. Prof. Dr. (University Lecturer) | UPSI | Physics Optics/ Gravitation/ Mechanics |
| 2 | Dr. (University Lecturer) | UPSI | Physics Education/ Teacher Training/ Electronics |
| 3 | Dr. (University Lecturer) | UPSI | Physics Education / Teacher Training |

The validity of the TEL module produced an average value of 97% agreement among three experts in the field. A pilot study was conducted to refine the TEL module and secure data for the reliability of instrument. 30 students who were not involved in the actual study took part in the pilot study. The students were briefed on the purpose of the study before they used the modules in learning through experiments in the lab on the topic of waves and sound. The learning time was 630 minutes; which equivalent to 10 hours and 30 minutes within the span of two weeks. The students were free to use this module beyond the face-to-face learning time. The reliability of the instrument and thus the TEL module is considered good with the value of 0.81 for the Cronbach's Alpha coefficient indicating that the TEL Module has good reliability. A reliable module means that the users consistently agree that they are able to achieve the learning outcomes set by the module and that they can follow the activities suggested by the module (Sidek & Jamaluddin, 2005).

## Field Research

The field research consisted of three phases which was pretest (F1), treatment (F2) and posttest (F3). The teachers and students were briefed during the conduction of research. Students were divided into two groups namely experiment and control group.

During F1, students were given an achievement test on the topic of waves and sound. The time allocated for them to answer the questions was one hour and 30 minutes. The objectives of the pretest were to identify students' prior knowledge about waves and sound and determine whether the control and experimental groups are equivalent. The results showed that both the groups were indeed equivalent. The same test was given at the end of the intervention period which was done in F3. The effectiveness of the module was determined by the significant difference in the posttest min score between the control and the experimental groups using independent sample t-test analysis.

The second phase was the treatment phase (F2) that took two weeks to complete for both the control and experimental groups. For the control group, the teacher conducted the lesson as per the usual method as shown with detailed manner in Table 1. Students were free to discuss and collaborate with peers or teachers in the classroom or the laboratory. For the experimental group, the teacher conducted the lessons using the TEL module. The application of smartphones and laptops was the key variable of the study to differentiate experimental group from the control group. TEL module is a learning module that requires the students, deliberately grouped into four members per group, to prepare at least one laptop that has been installed with freeware and smartphones installed with several applications. The TEL module consists of two booklets: Self-learning module and Experiment Manual. Each one has expected learning time for students in achieving the learning goals. The students used the self-learning module before class sessions for a total of five hours to prepare for class sessions. The purpose was for them to acquire some prior knowledge about the topics. The students then completed four topics in the Experiment Manual during face-to-face learning sessions. The elements of technology in the Physics module and the summary for each type of intervention are as follows:

**Table 2:** Teaching and learning interventions for "Fundamental of Waves"

| Physics topics | TEL module Web Tools | Assessment | TEL module activities | Conventional activities |
|---|---|---|---|---|
| Fundamental of Waves | Visual Analyzer & Tracker | D.I.Y Brain Teaser, Work Out, & Cool Psycho | Experiment Manual:<br>-Real-time graph<br>-The frequency generated can be observed in real-time. | Explanation using PowerPoint slides<br>Exercise |

**Table 3:** Teaching and learning interventions for "Damping & Resonances"

| Physics topics | TEL module Web Tools | Assessment | TEL module activities | Conventional activities |
|---|---|---|---|---|
| Damping & Resonance | Chromatic Tuner | Summative Assessment | Experiment: Generation of frequencies and | Video of resonance<br>Demonstration of |

| | | | | |
|---|---|---|---|---|
| | | | musical notes depending on the level of water in a wine glass. YouTube videos | Barton's pendulum Explanation using PowerPoint slides |

**Table 4:** Teaching and learning interventions for "Reflection of Waves"

| Physics topics | TEL module Web Tools | Assessment | TEL module activities | Conventional activities |
|---|---|---|---|---|
| Reflection of Waves | Frequency Sound Generator & Advance Spectrum Analyzer | Formative & Summative assessment | Observation on the different value of reflected angle when using different medium of sound reflector | Experiment of reflection by using analog stopwatch and hearing. |

**Table 5:** Teaching and learning interventions for "Fundamental of Waves"

| Physics topics | TEL module Web Tools | Assessment | TEL module activities | Conventional activities |
|---|---|---|---|---|
| Interference of Waves | Frequency Sound Generator & Advance Spectrum Analyzer | Formative & Summative assessment | Experiment in relation with theory $= \frac{ax}{D}$ Students are to design their own experiment by manipulating any variable of interference | Experiment using frequency sound generator and hearing |

The development of TEL module phases can be broken into smaller units such as Text Content, Graphics and Media Technology. Appendix A shows a snippet of the TEL Module.

Appendix A

Interactive design
Figure 2 shows the visual stimulation in the activity of Mindful Reading.

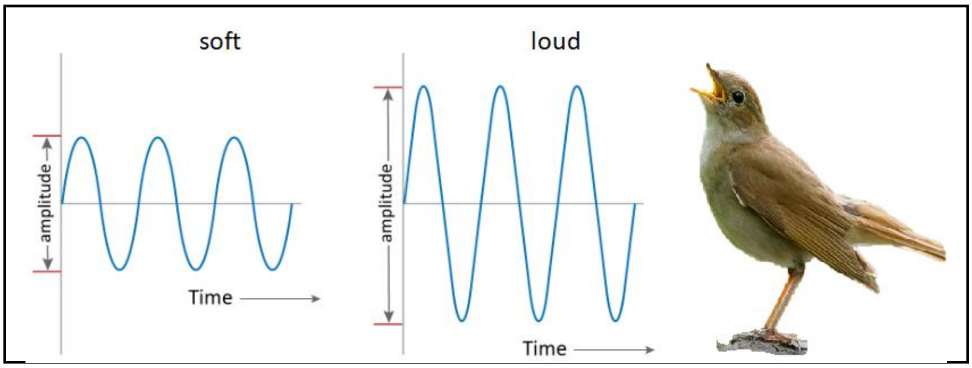



**Figure 2:** The visual stimulation in 'Mindful Reading'

The diagram of the experiment set up and the corresponding graph become supporting evidence of which demonstrates a concrete way to relate the information; which cannot be done by words alone. Another example of visual representation in TEL module in Mindful Reading activity is shown in Figure 3.

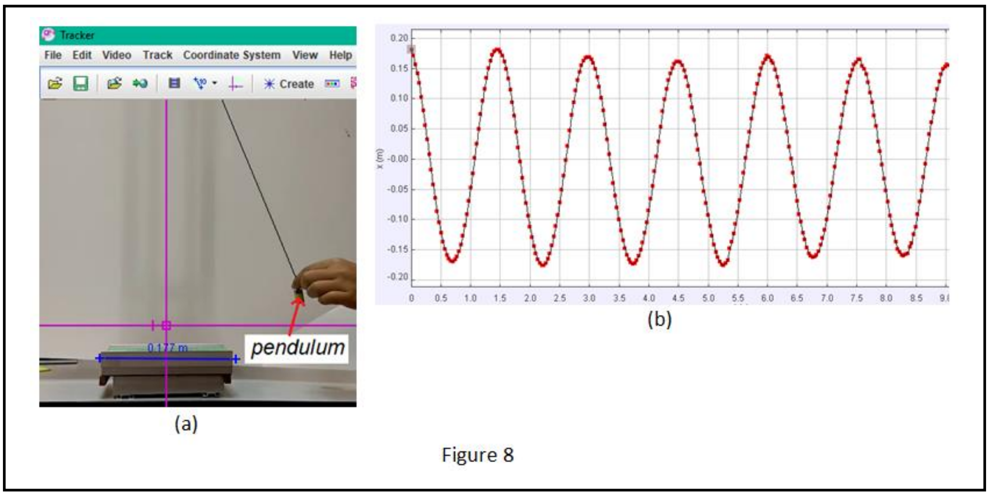



**Figure 3:** Graph display in Self-Learning module

Figure 4 shows the link to YouTube in 'Funtastic Physics' activity and the link to developer's blog for enhanced learning.

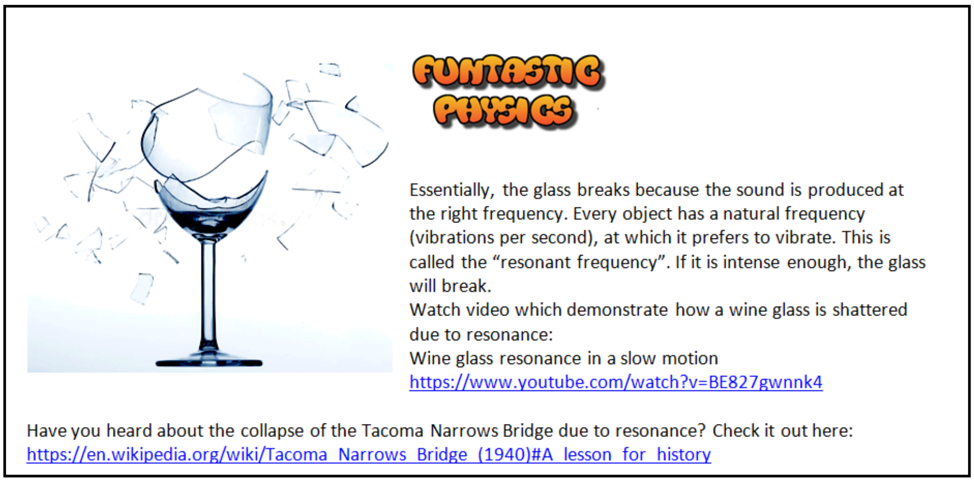



**Figure 4:** Links to YouTube in 'Funtastic Physics'

The Practical TEL Module is used as a working companion in practical session whereby the experimental instructions are given to help both teachers and students to carry out successful investigations. Teachers and students are introduced with 2 free softwares and 3 smartphones applications. The free softwares can be downloaded from the internet and are simple to use; require one to install in the path of their preference and launch the installed program.

All the TEL softwares and free apps are embedded with questions and activities at the end of every experiment which provide more time for critical thinking, hands and minds on for further analysis and construct better scientific concept. The activities in this module have been formulated to stimulate analytical and critical thinking among pupils.

As a preparation to utilise the experiment manual, students are advised to join a Telegram group where students are able to download the softwares and have Q&A sessions regarding the utilisation of the software. Figure 5 shows the arrangements of materials in one of five experiments in the Experiment Manual.

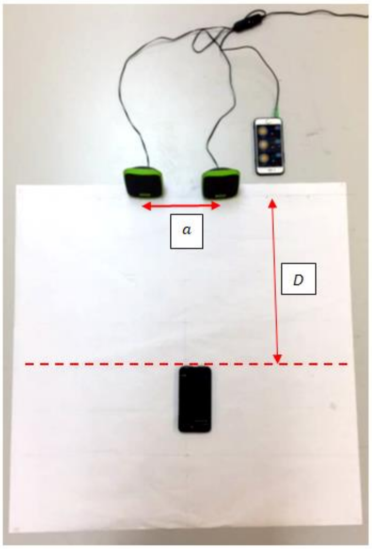
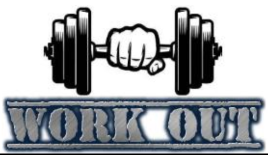



**Figure 5:** Arrangement of materials for the experiment on Interference

Other than images, drawings and diagrams, icons are also used in this self-learning module as guidance for the response to be taken to fulfill the objective of this module. Table 6 shows the icons and responses in TEL module.

**Table 6:** Icons and Responses in TEL module

| Icons | Response |
|---|---|
|   | Read the content and relate it with past knowledge. Understand the physics concept and ask for your teachers' guidance if any problem persists. |
|   | Determine the variables involved in the situation, relate with theory and study the solution of the problem. |
|   | Explore the phenomena related to physics by searching for more information from the internet— watch videos and read articles respectively. |
|   | A must-do exercise for the students in the forms of definition, conceptual question or problem-solving. |

| | |
|---|---|
| COOL PSYCHO | Implement the TEL software and smartphones app independently for inquiry learning. |
| PHYSICS LAB | Run the experiment on that topic by utilizing the TEL Experiment Manual attached to this self-learning module. |

## RESULTS AND DISCUSSION

The main objective of the study was to develop a TEL module and determine its effectiveness in promoting students' achievements. The TEL module has been developed based on Sideks' Module Development Model and results showed that it has a high value of 0.90 for content validity and 0.97 for face validity from the evaluation of three experts. After the validation process, the module was piloted on 30 Form Four coeducation Physics students in Ipoh. The researchers found that the pilot test students were technologically savvy with both software and smartphone apps and they were also cognitively prepared prior to the lesson. Learning time for the utilisation of TEL module was shorter than expected duration for the pilot test students. It was suggested that it might be because the pilot study students were from a high-performing school. They were able to use the Self-Learning Module and the Experiment Manual with minimal teacher guidance. The TEL module was also found to be reliable with a Cronbach Alpha value of 0.81. A reliable module means that the users consistently agree that the TEL module was able to achieve its objectives and users were able to follow the activities in the module.

During the experimental part of the module, the teacher facilitated the learning process to further reiterate the relevant concepts that students need to understand. Observation by the researchers showed that students were actively engaged and showed interest when the experiment was conducted based on smartphones rather than on computer softwares. Thus, the trainer strengthened the students' engagement by encouraging and facilitating the detailed step-by-step instructions on how to utilise the computer softwares. However, Zone of Proximal Development (ZPD) qualities were not specifically evaluated in this study. Kanevsky and Geake (2004) proposed that social interaction such as verbal, fleeting gestures, postures and facial expressions are among the aspects that can be evaluated qualitatively. Comparison between the students' achievements score could not provide the actual values that contributed to the ZPD episode which is one of the limitations of this study.

The result of the independent sample t-test [$t(58) = -5.531$, $p = 0.000$] showed that there was a significant difference in the posttest mean scores between the control group ($M=55.53$, $SD=10.421$) and the experimental group ($M=70.33$, $SD=10.307$). In addition, a paired-sample t-test was also conducted to compare the achievement of the experimental group before and after using the TEL module. There was a significant difference [$t(29) = -28.543$, $p = 0.000$] between the mean scores for pretest ($M=20.73$, $SD= 4.996$) and posttest ($M=70.33$, $SD=10.307$). These results suggest that the use of the TEL module does improve the achievement of students in learning about sound waves significantly. The findings are in line with Kuhn (2013) research, in which students were actively engaged and able to boost their conceptual understanding construction (Yahya et al. 2019) when the learning atmosphere is embedded with technology. The module leverages the power of technology through the integration of smartphones freeware apps and computer softwares. It also added to the novelty of the learning experiences and thus has a tendency to attract and motivate students during the learning process and subsequently increases students' achievement. According to Johnson and Johnson (2014) meta-analysis, achievement is positively correlated to motivation.

Although the findings of the experimental group indicated an improvement in terms of scores, several other factors need to be discussed which may be considered when controlling external validity. Since the research was conducted in a daily school where students' achievements were average, the results of the posttest scores were not as high as expected compared to the achievement scores of posttest during the pilot study which were much higher since it was conducted in a boarding school. Therefore, the achievements of samples were highly dependent on the population chosen by the study, thus there is also a possibility that the observed effects only hold for the population from which the experimental and control groups were selected. There are many other factors that could have an effect on students' achievements. However, the effects of these other factors were not included in this study. The results of the pilot study group to the actual experimental group shows that; students who were more technology savvy and more intrinsically motivated gained more from the learning experience afforded by the TEL module. Nevertheless, even for this sample who were selected randomly from a moderate academic achievement students population, when provided with the right and capable learning activities through the TEL module, they showed better achievement compared students learning using the traditional teaching method that consists mostly of 'teaching by telling' activity.

## IMPLICATION

The researchers had described an effort to design and develop a Physics learning process embedded with the TEL module in the Waves and Sound topic; of which it was noted that module of a similar context has yet to be developed. For interested readers, the TEL modules are freely available at https://drive.google.com/file/d/16acqQLngx1ubkEAlcnWDo5M3J64W0j3R/view?usp=sharing

The TEL module can support learning during the COVID-19 pandemic where students are 100% learning using the online platforms. Since laboratory-based classes are no longer viable, teachers can assign students to conduct experiments from the Experiment Manual via Google Classroom. The experiments can be carried out in the comfort of students respective homes. The video of the lesson and experiment can be viewed at the URL link: https://www.youtube.com/watch?v=tokgaQx7Xaw

## CONCLUSION

The TEL module contributes to a much needed validated, reliable and effective resource for use in not only a regular class but more so for 100% online classes. The development of the TEL module as an interactive module that incorporates interaction between the module and the users also creates an interactive environment with that can foster 4Cs - communication, critical thinking, collaboration and creativity which is in line with 21st century learning aspirations. The results from this study contribute to the empirical pieces of evidence in Malaysia that relate to the effectiveness of a research-based module that leverages the use of information and communication technology in an inquiry-based learning environment that when it is well-designed can promote students' achievement.

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