Indonesian Society for Science Educators

Journal of Science Learning

journal homepage: ejournal.upi.edu/index.php/jslearning

# Using Physics Education Technology as Virtual Laboratory in Learning Waves and Sounds

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**ABSTRACT** This research was intended to analyze the use of Physics Education Technology (PhET) as a virtual laboratory in learning waves and sounds. The analysis was in terms of the implementation of waves on a string student activity as a lesson plan, the profile of students' cognitive, and the profile of science laboratory environment. The method which is used in this research was a descriptive method with methodological triangulation as the research design. The sample was taken on the convenient situation at grade 8 in an international school in Bandung. According to the analysis of the result, the waves on a string student activity can be adopted as the lesson plan with several recommendation to be improved such as in part A, changing some sentences in the data table, changing some settings in obtaining data activity, and adding clear example in determining the base and peak point in measuring the height of wave at start and at the end. Moreover in part B, adding clear instruction on how to use the ruler to measure the wavelength, and changing the picture to obtain the data of wavelength with the picture of simulation with the instructed setting are important. In part C, it needs to add the instruction to do the practice session together with the teacher and to add the instruction to make the starting point in counting the wave similar in each trial. The use of Physics Education Technology (PhET) as a virtual laboratory in learning waves and sounds shows the favorable result on both the cognitive aspect and science laboratory environment.

**Keywords** Virtual Laboratory, Physics Education Technology (PhET), Waves and Sounds, Students' Cognitive, Science Laboratory Environment

## 1. INTRODUCTION

Practical work is an essential feature of science education (Abraham & Millar, 2008). It can not be separated from the learning process of science. Nieh & Vaill (2005) stated that practical work is one of the ways to enhance students' understanding. In addition, Frewer & Salter (2002) stated that practical work helps students in appreciating evidence as basic of science and acquiring hands-on skills. Abraham & Millar (2008) stated that practical work can be defined as activities in which the students manipulate and observe real objects and materials. To do this practical work, students have to deal with hands-on activities. It is clearly known that hands-on activity in learning science is usually done in the laboratory, although it may be held in the classroom and field as well. In this context, laboratories are an essential component of education to make students gain experience (Tüysüz, 2010).

Physical laboratory is very useful to promote the learning process of science, yet provides several problems for both students and teacher. Pyatt & Sims (2012) stated that physical laboratory experiences may not always promote conceptual change. In the real world situation, students have no such experiences in conducting laboratory activity. Based on Tüysüz (2010), there are several problems faced in conducting laboratory activity in the physical laboratories such as limitation of facilities, limited time allocation, and insufficient laboratory condition. Those problems sometimes force the teachers to perform laboratory activities in crowded groups. Moreover, related to a safety concern, Tatli & Ayas (2013) stated that perform laboratory activities in the physical laboratory involve risks due to poisonous and unsavory gas releases. Considering the problem faced by using the physics laboratory to conduct laboratory activities, a virtual laboratory may be a preferable alternative to overcome those problems (Tatli & Ayas, 2013). Virtual laboratories simulate a real laboratory environment and processes and are defined as a learning environment in which students

**Received:** 29 June 2018
**Revised:** 2 August 2018
**Published:** 15 August 2018





DOI: 10.17509/jsl.v1i3.11797

convert their theoretical knowledge into practical knowledge by conducting experiments (Woodfield, 2005). Tiwari & Singh (2011) added that it is designed and sequenced in such a manner as to give a real feel of performing the experiment. A virtual laboratory may sometimes be a preferable alternative, or simply a supportive learning environment to physical laboratories (Tatli & Ayas, 2013).

According to Candelas, et. al. (2003), in this era, educators have got the accesses to use various kind of technology to enhance the effectiveness of the instruction process. It supports the use of Virtual laboratory in the instruction process. The use of virtual laboratory as an alternative to overcome the problems faced in the physical laboratory is in line with 21st-century demands. In the 21st century, technologies have become commonplace in improving and advancing the practice of science education because of its potentials of bringing about change in ways of teaching practice and learning process (Srisawasdi, 2012).

One of the examples of the virtual laboratory is Physics Education Technology abbreviated as PhET (Finkelstein et al., 2005). PhET is developed by the University of Colorado, it is freely available on its website (www.phet.colorado.edu). This website consists of more than 50 simulations related to physics subject, it can be accessed both offline and online. These simulations are designed to be highly interactive, engaging, and open learning environments that provide animated feedback to the user. The simulations model physically accurate, highly visual, dynamic representations of physics principles (Finkelstein et al., 2005). PhET simulation is equipped with its student activity, teacher guidance, and worksheet.

Many researchers in science have determined that carrying out virtual laboratory in the instruction process significantly increase students' achievement (Tüysüz, 2010; Tatli & Ayas 2013; Candelas, et. al. 2003) and have positive effect on students' attitudes (Tuysuz, 2010; Candelas, et. al. 2003; Pyatt &Sims, 2012). In the process of increasing students' achievement and having a positive attitude in learning, students experience an environment which can support them to gain the knowledge and have a positive attitude. Luketic & Dolan (2013) stated that a student's perception of their learning environment influence how and to what extent they learn and retain knowledge. Hence, the researcher decided to analyze the students' cognitive and their perception about their science laboratory environment in learning waves and sounds using Physics Education Technology (PhET) as a virtual laboratory. Prima, Putri, & Rustaman (2018) have implemented a PhET simulation to improve students' understanding and motivation in learning the solar system. Prima, Oktaviani, & Sholihin (2018) conducted the learning about electricity using Arduino-PhETto exercise STEM literacy. This research was conducted to analyze the implementation of waves on a string student activity by Esler (2011) a lesson plan, to analyze the profile of students' cognitive and science laboratory environment in learning waves and sounds using Physics Education Technology (PhET) as Virtual Laboratory. The result of this research is expected to be used by the teacher as an information to guide attempts to improve their classroom.

## 2. METHOD

The method that is used in this research was descriptive. The term descriptive research refers to studies which are known to describe and to interpret what is (Cohen, Manion & Morrison, 2007). The location of this research was International Junior High School in Bandung. The population in this research were 8th-grade students in School A. The samples were one class in eighth grade. The sampling technique that is used was Convenience Sampling. This technique sampling means taking a group of individuals who (conveniently) are available for study (Fraenkel, Wallen & Hyun, 1993). The Instructional tools which was used in this research were Waves on a String.swf, it is one of the simulations from PhET which can be used to learn transverse wave and it's properties.

To obtain the data, the researcher used various kind of instruments such as students' worksheet, cognitive test, and SLEI questionnaire. First, to analyze the implementation of waves on a string student activity as lesson plan, the analysis was in terms of the implementation of the initial lesson plan based on field notes and the result show up as the impact of the activity done by the students such as the data result, and the answer to the question in the worksheet. As the result of this analysis, the recommendation in revising the lesson plan will be elaborated. Second, to analyze the profile of students' cognitive, the researcher used cognitive test consist of 22 questions related to waves properties concept. The result of students' cognitive test is analyzed by relating it to the learning process, and then it is being calculated until the average of each level of cognitive is obtained, after that interpret the average of each cognitive level by referring to the criteria described in Table 1.

The interpretation of the result shows the students cognitive in learning waves and sounds with Physics Education Technology (PhET). Third, to analyze the profile of science laboratory environment, the researcher distributed Science Laboratory Environment Inventory (SLEI) questionnaire to the sample of this research. This questionnaire was developed by Fraser, Giddings &

**Table 1** The criteria for the average of the cognitive aspect

| Percentage of Average (%) | Interpretation |
|---|---|
| 80-100 | Very Good |
| 66-79 | Good |
| 56-65 | Fair |
| 40-55 | Poor |
| 30-39 | Failed |

(Arikunto, 2013: 281)

McRobbie (1992). This questionnaire was field tested and validated simultaneously with a sample of 5447 students in 269 classes in six different countries including USA, Canada, England, Israel, Australia, and Nigeria. It also has been cross-validated with 1594 Australian students in 92 classes (Fraser & McRobbie, 1995), 489 senior high school biology students in Australia (Fraser & McRobbie, 1995) and 1592 Grade 10 chemistry students in Singapore (Wong & Fraser, 1994). The data of students' perception about their science laboratory environment which was obtained through questionnaire distribution were processed by calculating the average score of each item. The interpretation of the result shows the science laboratory environment in learning waves and sound with Physics Education Technology (PhET) as a virtual laboratory.

## 3. RESULT AND DISCUSSION

The data obtained will be analyzed in accordance with the research objectives. The first analysis is about the implementation of waves on a string student activity as a lesson plan. According to waves on a string student activity, there were three main parts of the lesson, in each part of the lesson, part of the worksheet which was recommended to be revised will be elaborated as follows. In Part A, the students had to change the scale of amplitude and measure the height of wave at the beginning and the end of the string. Since the students used similar simulation and setting, the data result of each group was supposed to be similar. In fact, the data result of each group in this part was different each other but lead to the similar tendency, means the higher the scale of amplitude, the higher the height of wave at the start and at the end of the string. It was happened because of parallax error that caused by the error in determining the base and peak point of the wave, and the wave setting that is used by each group. It is found that oscillate setting is more suitable to be used in obtaining the data in investigating amplitude instead of pulse setting. In this activity, the students also found another difficulty namely did not understand some sentences in the data table. To sum up the previous explanation, it was found that students did not understand some sentences in the worksheet, had difficulties in determining base and peak point, and Oscillate setting is more suitable to be used in this activity. Hence it is recommended to change the sentence by easily understood sentence, give students example on how to determine base and peak point in measuring the height, and use Oscillate setting instead of Pulse.

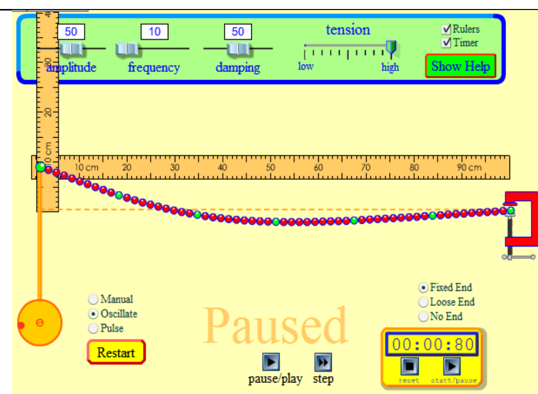
In Part B, the students had to measure the length of the wave at the beginning & the end of the string. The data result of each group in this activity was also various because each group has a different way to determine the half point of the crest in measuring the wavelength. It was found that the picture in the worksheet was different from the real simulation of the instructed setting. Therefore, It confused the students to determine which crest that was being the wavelength 2 because the gap between the crest and the trough near to the end of the string could not be seen clearly. To sum up the previous explanation, it was found that students had difficulties in determining half point of the crest to be measured as wavelength and the picture in the worksheet was different from a real condition one. Hence. it is recommended to give clear instruction on how to use the ruler to measure the wavelength and change the picture in the worksheet with real condition one.

In Part C, in this part the Students had to change the scale of frequency 3 times, in each scale, they had to measure the waves passing the certain point at ruler within interval time. In this activity, the students did not find any meaningful difficulties. Each group data result was slightly different from each other because each group has a different way to obtain the data. Group 1 obtained the data by directly counting the wave as the timer start without pause the simulation first, meanwhile, group 2 obtained the data by pause the simulation first, and then start the timer, after that count the wave by clicking step button. Besides that, the determination of the starting point in counting the wave was also influenced by their data result, it can be seen in Table 2.

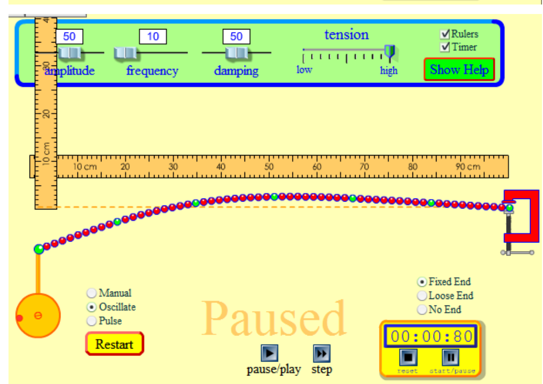
Table 2 shows the display of different starting point within the similar time. The wave is counted when it is passing the 10 cm point at the ruler. As can be seen in Table 2, before 1 second the display of starting point 1 has been

**Table 2** Comparison of different starting point in counting the waves

**Starting point 1**




**Starting point 2**



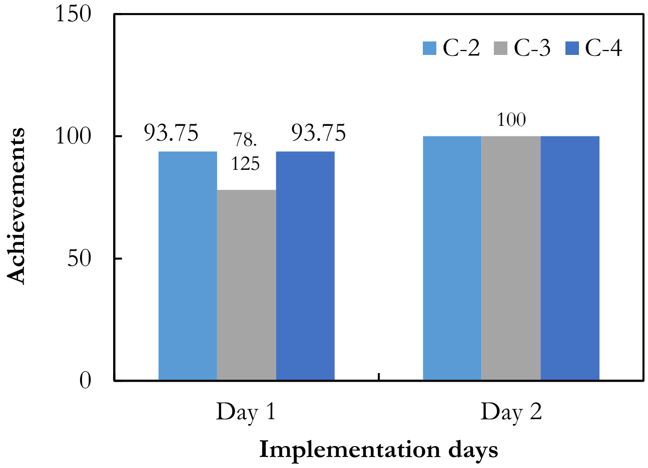



**Figure 1** Recapitulation of the cognitive test result

able to be counted as one wave passing the ruler, meanwhile in starting point 2, at a similar time the user has not started to count the wave. It has been proved that when the user using the starting point 1, the data result would be 4 waves counted. Meanwhile, when the user using the starting point 2, the data result would not be 4. To sum up a previous explanation, it was found that group 2 has a more homogenous data result than group 1 and the determination of the starting point influenced the data result. Hence it is recommended to do the practice session together with the teacher, since this session was intended to make the students understand about the way to obtain the data, and it is also recommended to give instruction to make the starting point in counting the wave similar in each trial.

The second analysis is about students' cognitive. The data on students' cognitive was obtained through objective which consists of 22 questions. This test was conducted within two days at the same time as the research implementation. The recapitulation of students' cognitive test result can be seen in Figure 1. The average score of each level of cognitive in each day shown by Figure 1 was obtained by dividing the average correct answer of each level by the number of the question of each level times 100 %. According to the table 1 about the criteria of cognitive test average by Arikunto (2013), the students cognitive result (can be seen in figure 1) in level of C-2 (understanding) and C-4 (analyzing) were considered in the criteria of very good both in day 1 and day 2 of research implementation. Meanwhile, the student's cognitive result in a level of C-3 (applying) was considered in the criteria of good on day 1, and very good on day 2 of research implementation.

This favorable result of cognitive aspect was supported by the previous research which stated that the use of virtual laboratory increased students' achievement levels (Tüysüz, 2010). The previous research also suggested that virtual laboratories are at least as effective as real laboratories in terms of introducing the students with the experiment process (Yu et al.; Tatli & Ayas, 2013).

**Table 3** The average score for each scale of SLEI

| No | Attitude Scale | Max Item Score | Average Item Score |
|---|---|---|---|
| 1 | Students' Cohesiveness | 5 | 4.75 |
| 2 | Open-Endedness | 5 | 3.73 |
| 3 | Integration | 5 | 4.77 |
| 4 | Rule Clarity | 5 | 4.56 |
| 5 | Material Environment | 5 | 4.74 |

The third analysis is about science laboratory environment. The data of science laboratory environment is obtained through the Science Laboratory Environment Inventory (SLEI) questionnaire which was distributed to each sample of this research. The average score of each scale as the result can be seen in Table 3.

Table 3 shows the result of the SLEI questionnaire distributed to the sample of this research. It shows the average item score of each scale. The first scale is Students Cohesiveness, this scale means the extent to which students know, help, and are supportive of one another (Fraser, Giddings & McRobbie, 1992). The average score obtained for this scale is 4.75 with the interpretation of often happened. It means the learning process using Physics Education Technology (PhET) as virtual laboratory supported the students' cohesiveness. This virtual laboratory activity demanded the students be able to know, help, and support one another since they had to work within the group. For example, in one of the activities using this virtual lab, the students helping one another by dividing the job-desk.

The second scale is Open-Mindedness. This scale has the meaning of the extent to which the laboratory activities emphasize an open-ended divergent approach to experimentation (Fraser, Giddings & McRobbie, 1992). The average score on this scale is as much as 3.73, with the interpretation of sometimes happened. This scale is related with students' exploration in conducting the virtual laboratory activity. In this virtual laboratory activity there was instruction given to the students in conducting the virtual laboratory activity, hence sometimes the teacher decide the best way to carry out the virtual laboratory activity and sometimes the teacher asks the students to explore the simulation by themselves. This result is in line with the previous research which stated that the students were given the opportunity to explore and manipulate experimental variables by virtual experiences (Pyatt & Sims, 2012).

The third scale in the SLEI questionnaire is Integration. This scale has the meaning of the extent to which the laboratory activities are integrated with non-laboratory and theory classes (Fraser, Giddings & McRobbie, 1992). The average score of this scale is as much as 4.77, it was the highest average score compared to the other scale. It has an interpretation of often happened. It means the students often used a theory which has been learned in regular science class to conduct virtual laboratory activity. Even, this virtual laboratory activity helped them to understand the theory covered in regular science class as described in one of the statements in the questionnaire.

The fourth scale is Rule Clarity, with the meaning of the extent to which behavior in the laboratory is guided by formal rules (Fraser, Giddings & McRobbie, 1992). The average score on this scale is as much as 4.56, with the interpretation of often happened. The students were given the rule before they conducted the virtual laboratory activity. Since they would not deal with dangerous materials, hence they were only given rule about using the laptop as the instructional tools in conducting virtual laboratory activity. The rule forbids them to open any other application besides adobe flash player within the learning process. It made them focus on the virtual laboratory activity.

The last scale is Material Environment which asks the students about the adequacy of laboratory equipment and materials (Fraser, Giddings & McRobbie, 1992). Since this virtual laboratory activity only used laptop and PhET simulation as the equipment, the average score of this scale is 4.74 with the interpretation of often happen. Means, the equipment used in this virtual laboratory activity was adequate enough to support the learning process using Physics Education Technology (PhET) as a virtual laboratory.

## 4. CONCLUSION

Based on the result and discussion elaborated, it can be concluded that Waves on string student activity by Esler (2011) can be adopted as a lesson plan with several aspects which are recommended to be improved as follows. In Part A, changing some sentences in the data table is required in order to make it easier to be understood by the students, changing some settings in obtaining data activity is required, and adding a clear example is required on how to determine the base and peak point in measuring the height of wave at the start and at the end. In Part B, adding clear instruction is required on how to use the ruler to measure the wavelength, and changing the picture is required to obtain the data of wavelength with the picture of simulation with the instructed setting. In Part C, adding instruction is required to do the practice session together with the teacher, and adding instruction to make the starting point in counting the wave similar in each trial. To sum up, the use of Physics Education Technology (PhET) as a virtual laboratory in learning waves and sounds shows the favorable result on both the cognitive aspect and science laboratory environment.

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