Exploring the Effectiveness of Interactive Simulation as Blended Learning Approach in Secondary School Physics †

Mohd Nizar Mohd Najib *, Aizan Yaacob and Ruzlan Md-Ali

School of Education, Universiti Utara Malaysia, Sintok 08000, Malaysia
* Correspondence: m.nizar_m.najib@ahsgs.uum.edu.my
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Abstract: The mastery of physics and the ability to apply this knowledge may contribute to the development of the country. However, the skills of secondary school students concerning physics are less impressive. This exploratory research aims to examine the effectiveness of interactive simulation by PhET as blended learning in physics. The results showed that there was a significant difference in the pre- and post-test mean scores for the experimental group by providing a positive impact on students’ interest, motivation, the pleasure of studying in a group or self-learning, and help to study for exams. This proved that simulation as an aspect of blended learning could improve students’ achievement in physics.

Keywords: interactive simulation; blended learning; PhET simulation

1. Introduction

The field of science that explains various phenomena and situations found in the universe is physics. Thus, all the events that occur around us in everyday life is related to physics [1]. Physics is one of the important areas to explore in this modern era, which can be applied in technology and engineering, which is certainly beneficial for developing countries [2]. However, fewer students studying physics compared to other subjects at higher education levels because this subject is considered as difficult, boring, less well-liked, and irrelevant [3]. These problems arise when students have difficulty connecting the physics concept to their scientific reasoning skills to explain a phenomenon due to the difficulty of the subject, inefficient teaching, and unclear direction, respectively [2–5]. Previous studies on physics in Malaysia has shown that a lack of understanding about physics concept has become a serious phenomenon in upper secondary school [5]. Students found that they were difficult to understand the basic concepts of physics, and tend to focus more on numerical operations [3,6]. As a result, the number of students who avoid taking physics-related courses at high level institutions is very high [3]. Also, it is found that students’ motivation to learn physics has decreased below acceptable levels [3,7,8].

There are two main contexts in learning, namely active learning and passive learning [9,10]. Passive learning is the passive acceptance of information, while active learning involves the interaction between the learners and the materials during the process of analyzing, comparing, inferencing, or critically evaluating [11]. Teaching that triggers active learning is a new format of teaching, which includes the use of simulations, lectures, and experiments directly in the curriculum [12]. The use of teaching technologies that enable active learning improves teachers’ self-efficacy and the quality of the teaching and learning process [12]. Researchers and educators have suggested that active learning is an approach where the learning process through the students’ construction of knowledge and understanding that occurs while they are in school [13]. In Malaysia, all science textbooks incorporate special features with an emphasis on science, technology, engineering and mathematics (STEM), thinking skills, scientific skills, and computational thinking (CT). The objectives are to

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equip learners with 21st century skills, and encourage scientifically minded individuals and active learning [14]. However, most secondary schools still use conventional methods with less technology in the learning processes, especially in physics. Hence, the Ministry of Education’s objective will not be achieved unless schools extensively integrate technology into their teaching and learning processes.

The term ‘blended learning’ is frequently used in the context of education today, but there is ambiguity about what it actually means [15]. There is agreement that the main content in blended learning is teaching and learning that takes place involving face-to-face meetings as well as online [16–18]. Studies involving blended learning can provide benefits in improving the academic performance of learners. Thus, it can be said that studies related to blended learning contribute to the field of teaching and learning, including learning physics [18]. For example, a study using an experimental design conducted by Hrastinski [18] related to the effect of blended learning on student performance proved that blended learning was more effective than face-to-face instruction.

1.1. Problem Statement

Students at school tend to stay away from physics, whether related to the subject, either directly or indirectly, because the students find this subject to be dreadful and difficult to study [3,19]. This problem started in the classrooms, which still practice conventional teaching techniques and lack exposure to the use of modern teaching and learning in line with the 21st century [19]. Learning physics using conventional learning invites a lot of negative feelings, such as the students finding the subject to not be interesting, difficult to understand, and irrelevant to real-life situations [20,21]. Students found difficulty understanding the basic concepts of physics and totally rely upon numerical operations [6]. To overcome this problem, changes are needed, from using teacher-centered to student-centered methods. This is in line with the education evolution in the 21st century, where STEM is being implemented [19]. Teaching and learning using simulations have been conducted by previous studies and proven to show positive results [5,22–24]. It is easier for students to understand a concept or theory and attracts students to study the subject [21]. This is because simulated learning is clearer and more efficient than conventional learning, which does not have any animation. Simulated learning proves that students are actively involved in learning [25]. However, the studies on simulations at the secondary and tertiary levels conducted in Malaysia are minimal compared to other countries [23]. As a result, the application of simulation is not fully maximized in schools, although most schools have computer labs for students to use. Previous studies on simulations are more focused on biological and chemical subjects [23,26]. Therefore, this study attempted to examine the effectiveness of learning physics through interactive simulation as blended learning and the comparison with conventional learning through the views of students at the secondary school level.

1.2. Research Questions

The research questions for this study are as follows:

1. Is there a significant difference in student achievement between pre and post-tests after using simulation as blended learning in the experimental group (EG)?
2. Is there a significant difference in student achievement between pre and post-tests after using conventional learning in the control group (CG)?
3. What are the secondary school students’ thoughts on their usual classroom learning of physics?
4. What are the secondary school students’ thoughts on the learning physics subject using simulation as blended learning?

1.3. Hypotheses

Two hypotheses were formulated based on the first and second research questions:
H1: There is no significant difference between pre and post-test results in the EG, which used simulation as blended learning for physics subjects.

H2: There is no significant difference between pre and post-test results in the CG, which used conventional learning for physics subjects.

2. Materials and Methods

2.1. Research Design

This study employed an exploratory research design by conducting quantitative and qualitative methods on 60 Form Four Pure Science students (age 16) in one of the districts in Kedah, Northern Peninsular Malaysia. The samples were randomly selected from two schools and were later divided into EG and CG, as shown in Figure 1. The pre and post-test were conducted in a quantitative method, followed by interviewing two of the participants from each group in a qualitative method [27].

![Figure 1. This is a figure of researchers’ exploratory research design in this study.](image)

2.2. Research Instruments

In this study, the EG, who underwent blended learning in physics, used the Physics Interactive Simulation Learning Module (MoPSIF) as a guide. MoPSIF was specifically designed to suit the use of the web-based interactive simulation known as Physics Education Technology (PhET). PhET was developed by experts from the University of Colorado Boulder to aid students in learning physics and other STEM subjects through simulated learning. The Simulated Daily Lesson Plan (SDLP) has also been provided to physics teachers who use the PhET interactive simulation in the teaching process. For the quantitative data collection, two sets of multiple choice type questions, pre-test (UP1) and post-test (UP1R), were used for the EG and CG. For the qualitative data collection, an interview protocol was prepared by the researchers and evaluated by a group of experts. The examples of questions in the protocol are as follows:

1. Can you tell me the learning instructions in physics that usually happen in your classroom?
2. How do you usually feel during physics lesson?
3. To what extent the textbook and the reference books helped you in learning physics?
4. Do you agree that learning in small groups in class can help you understand physics better? Why?
5. Do you always revise the physics topics at home?
6. Which do you prefer between learning physics in school or online learning at home?
7. What can you share about learning the topic of *Forces and Motion: Forces in Equilibrium* using the PhET simulation and MoPSIF module?

All of the research instruments were evaluated by experts in the field of education with at least five years of experience.
3. Results

3.1. Validity and Suitability Tests

Well-designed modules, known as MoPSIF and SDLP, were designed by researchers to aid PhET simulation via blended learning in physics. The topic covers Forces and Motion: Forces in Equilibrium. Both the module and SDLP were validated by three expert lecturers in the field of education from three different institutions. Each aspect of the validity category with the mean score value is shown in Table 1. The average mean score for all of the aspects was 3.57. Based on the validity result, the module and SDLP were categorized as very good in terms of their suitability.

Table 1. This is a table of module and SDLP evaluation by experts based on the aspects of suitability and validity.

| Validity                      | Panels | Average | Category     |
|-------------------------------|--------|---------|--------------|
| Introduction                  | P1 2.00 P2 2.75 P3 2.50 | P1 2.42 | Good         |
| Learning outcomes             | 4.00   | 4.00    | 4.00         | Very Good    |
| Materials and Technology Usage| 4.00   | 3.75    | 4.00         | Very Good    |
| Teaching Process and Procedure| 4.00   | 4.00    | 4.00         | Very Good    |
| Assessment Activities         | 4.00   | 4.00    | 4.00         | Very Good    |
| Conclusion                    | 3.00   | 4.00    | 4.00         | Very Good    |
| Professional Writing          | 3.00   | 3.00    | 3.00         | Very Good    |

3.2. Reliability Test

A survey was constructed in addition to the module validity from the experts. To determine the appropriateness of the survey, a reliability test was conducted on five (5) dimensions of the survey questionnaire, which consisted of a total of 40 items. According to Nunnaly [28] and Nunnaly and Bernstein [29], alpha reliability values above 0.70 were consistent for each dimension in this study. The reliability test results for each dimension of the survey are shown in Table 2.

Table 2. This is a table of reliability test of survey questionnaire for each dimension of the study.

| Dimensions                                      | Number of Items | Cronbach’s Alpha Value |
|-------------------------------------------------|-----------------|------------------------|
| Students’ perception of simulated learning using module | 10              | 0.77                   |
| Students’ attitude of simulated learning using module | 10              | 0.70                   |
| Teacher guidance                                | 7               | 0.71                   |
| Teacher’s knowledge of learning by simulation & module | 7               | 0.70                   |
| Group work support by teacher in the classroom  | 6               | 0.71                   |

3.3. Analysis of the Effectiveness of Simulation as Blended Learning

Based on Table 3, the paired sample t-test was significant (t (29) = −11.47, p < 0.05). A p-value of <0.05 indicates that there is a significant difference between the pre-test and post-test results [27]. The result of the study successfully rejected H1. These results proved that there was a significant difference between the pre-test and post-test results in the experimental group. The mean score (13.37) after the use of interactive simulation as blended learning was higher than the mean score (9.90) before it was conducted.

Table 3. This is a table of results using blended learning with simulation in physics of the experimental group.

| Tests | N  | Mean | Standard Deviation | df | t    | p   |
|-------|----|------|-------------------|----|------|-----|
| Pre   | 30 | 9.90 | 2.20              | 29 | −11.47 | 0.00 * |
| Post  | 30 | 13.37| 1.65              |    |      |     |

* p < 0.05.
As indicated in Table 4, the paired sample t-test was insignificant ($t (29) = 0.44, p > 0.05$). A $p$-value of $>0.05$ indicates that there is no significant difference between the pre-test and post-test results [27]. The results of the study failed to reject H2. They also proved that there was no significant difference between the pre-test and post-test results in the experimental group. The mean score (9.33) after undergoing conventional learning was almost the same as the mean score (9.47) before undergoing conventional learning in physics.

Table 4. This is a table of results using conventional learning in physics of the control group.

| Tests | N  | Mean | Standard Deviation | df  | t    | p      |
|-------|----|------|--------------------|-----|------|--------|
| Pre   | 30 | 9.47 | 2.43               | 29  | 0.44 | 0.67 * |
| Post  | 30 | 9.33 | 2.73               |     |      |        |

* $p > 0.05$.

3.4. Thematic Analysis

The thematic analysis of the interview data found that the learning experiences in classrooms were related to internal aspects, which are the assessment of self-achievement in physics and the external aspects involving the physics teacher. These students’ thoughts have provided insights into the real situation in the classroom, which should be considered as the basis for improving and enhancing the learning process of physics.

3.4.1. Students’ Thoughts on Conventional Learning in Physics

Schools preferred to use alternative references rather than using textbooks in conventional teaching and learning approaches. This finding is in line with Yap [30], who states that teachers should focus more on the content of textbooks and notes in conventional teaching. However, respondent S1 found that it was difficult to imagine a phenomenon or process related to the content of the lesson through reading. S1 states that the images in the reading materials, reference books, and textbooks were stationary. According to S1,

‘Teachers like to use various reference books in class . . . They seldom use the textbook.” (S1).

“The pictures or images in the books are all static. Not moving . . . like frozen. It is often too difficult for me to imagine how things work.” (S1).

According to S1, physics lessons in the classroom are boring. This is because of a failure to understand during the teaching and learning process, to the extent that S1 stopped paying attention to what the teacher was explaining.

“I felt bored . . . I was also confused with the teacher’s explanation . . . Sometimes my mind just shut off. That was why I became sleepy in class. When it felt hard to grasp what the teacher was trying to say, I just stopped listening . . .” (S1).

S1 preferred to study on his own than in a group when asked about group learning in physics via conventional learning because the focus was always interrupted. According to S1, group activities via conventional learning were less helpful. Participation in group work was only limited to presentations and conducting experiments during physics lessons [3,19]. According to S2, the lack of diversity in group activities was also a factor in students becoming bored and less interested in physics.

“When the teacher gave us activities to be in done in groups, usually I would not focus because there would be a lot of chatting and laughing, and less work was done. We learnt only a little from the activities . . . We only sat in groups when there was a presentation . . . I did not really contribute much . . . it was more like I did not help or contribute anything at all” (S1).

“Other than presentation, there was no other group work activity . . . for example discussion. It was always group presentation and doing experiments in the lab. That was all” (S2).
Self-learning physics at home was difficult if the reference resources were limited because they must only rely on books and notes. Explanations of any incomprehensible concept would be asked of the teacher the next day because no one can help at home. As stated by S1 and S2,

“At home, I have only the textbook and notes to refer to. I did only a bit of revision and homework . . . If I did not understand a certain point, I would ask the teacher the next day. But, sometimes I forgot to do so . . . There was nobody at home who could help me. I only relied on the text book, notes and reference books . . . I would say these resources have not helped me that much” (S1).

“At home, I did the learning alone. There was nobody whom I could ask for help. I could not have a study group outside school hours because all my friends live far away from each other. I would say that it was difficult to even organise a study group once a month outside school hours” (S2).

3.4.2. Students’ Thoughts on Interactive Simulation via Blended Learning in Physics

S3 stated that the topic taught was easy to understand and not boring because the process or phenomenon could be easily described. The simulation images moved, and the method of calculation could be performed easily. According to S3, the simulation activity carried out was a repetitive simulation similar to the characteristics of simulated learning stated by Joyce et al. [29].

“This new method made it is for me to understand . . . I have problems in this sub-topic . . . resolution of forces . . . . . . ! I am still not clear about its calculation. It is hard for me to imagine it when the teacher is explaining. When I look at the picture or the diagram, I cannot understand because it doesn’t move . . . Through simulation, I can understand it easily. I can also calculate easily because I can understand the concept. The pictures move . . . and we can repeat the process . . . It is not boring . . . This is the best way to learn!” (S3).

Learning experiences with PhET simulation via blended learning were more meaningful than conventional learning. S3 felt that it was quite difficult to digest the information provided in writing in the textbook. The use of simulation via blended learning helped the students imagine the process that occurred when the values were changed, and it was easy for the students to acquire the concept of Forces and Motion. This learning style also helped students summarize lesson content after understanding the topic. S4 repeatedly tried and observed the changes that occurred when different values were inserted.

“Through simulation learning, we can actually see how the process works compared to pictures in books. It is the same with a certain phenomenon. Explanation in words does not help us imagine or understand the process” (S3).

“It is difficult to imagine a certain phenomenon or concept. I am afraid that I might have a different imagination from others. Sometimes I could not imagine at all a certain concept . . . So, this simulation has helped me a lot” (S3).

“We could see the actual motion . . . If the horizontal plane was tilted, we could actually see its influence on the force . . . And that made me understand things easily. My friends and I could repeat the process just by changing the values and see what the results are. It was really easy to understand” (S4).

Learning using PhET Simulation as blended learning was made easier with MoPSIF in Forces and Motion: Forces in Equilibrium. The initiative to ‘play’ with the simulation even after completing all the activities in MoPSIF was demonstrated by S3 and classmates. This proved that the simulation activities encouraged self-exploration, either in a group or self-learning. MoPSIF, built by the researchers, has also supported blended learning. The students would first ask their peers, followed by referring to the MoPSIF module, before asking the teacher if the problem still persisted. According to S3,
“First, we did the experiment alone. Then, we repeated using other values . . . we also tried many different things which were not in the module just to see the result . . . If there was anything that we did not understand we referred to the module. If we still could not understand, we asked the teacher” (S3).

“I find it difficult to do it at home at first, because if I don’t understand or I’m stuck there will be no one to help. But, the module was very helpful. There was a guide on how to do the experiment . . . it was easy to follow and it was easy to understand . . . The tasks in the module also helped me how to go about doing the simulation” (S3).

The concern about learning physics at home was overcome by online support learning such as PhET web-based simulation learning, and ran smoothly with MoPSIF. This could overcome the learning problems during the pandemic because, indirectly, the effect was better compared to utilizing only one type of learning style, such as the conventional method.

“It is a very suitable learning method . . . especially during the pandemic. Simulation learning is the best way, in my opinion. The link to the website was already there. We just needed the internet. And there was also the module. The module really helped us how to do the task. It was really helpful especially when we could not attend school” (S3).

“The simulation was easy because there was the module as guide, with the pandemic; we have to observe social distancing. Our house is the only safe place. So, when teacher gave us the simulation and the module, I felt it was the suitable way of learning. It was more efficient than the previous method. This new method was also more interesting. I could easily understand the concept. I am now interested to learn more in Physics subject. It is hightime we use the new method of teaching and learning” (S4).

Learning physics using the simulation became more interesting because the students felt that it was similar to playing a game. This proved that there was an element of gamification that attracted their focus and distracted them from boredom when studying the topic [20]. These findings are in line with the research from the University of Colorado, Boulder, where their objective was to produce a game-like simulation to encourage exploration and discovery. This supports past research findings, which state that the involvement of students in learning through teaching technology, such as simulation, is active and can improve the quality of learning [12,25].

“When it comes to the part where we have to do a lot of reading, I get bored easily. However, with the simulated learning I could interact with it and understand easily the function and process of certain things. I enjoyed best when I could replace the values just to see what happens. I didn’t feel bored at all. And if I made a mistake somewhere, there was always the reset button. Just click and it would go back to normal. It was just like playing the computer games” (S3).

4. Discussion

From the analysis of the results above, students who learn Forces and Motion: Forces in Equilibrium in physics via simulation as blended learning have shown great achievement mean scores compared with the conventional learning method. The thematic analysis results indicated that the use of the conventional learning method in the CG was boring, dreadful, not interesting, and limited by references, such as textbooks and reference books, when self-learning. According to students in the CG, these factors arise when distraction in group learning occurs, the fear of being scolded by the teacher when asking questions, and a lack of diversity in teaching and learning processes, except for practical (experimental) activities in the physics laboratory. The EG students stated that the use of the simulation learning method as blended learning was interesting, easy to understand, increased their imagination, encouraged self-exploration, and had the elements of gamification. The students in the EG also stated that they were able to summarize learning content and aid their learning while revising, whether in a group or self-learning.
5. Conclusions

In conclusion, blended learning using simulation can improve students’ achievement in physics compared to conventional methods. Creativity in diversifying the teaching and learning approach of physics topics by teachers is needed to boost students’ positive attitude towards the subject of physics. The use of simulation as blended learning, together with well-designed MoPSIF and SDLP, is a new approach to learning physics in secondary schools. Simulation learning has the potential to attract students’ interest in physics and support meaningful active learning as opposed to conventional learning. Blended learning in physics with good interactive simulation by PhET, accompanied by simulation activities and guidance, such as MoPSIF and SDLP, are relevant in learning nowadays. It has been proven that misconceptions in physics can be eliminated by using PhET interactive simulations via blended learning. The repetition of PhET simulations can be performed as many times as they please until an understanding of the topic is achieved. Simulation via blended learning helps students to learn physics subjects with or without the aid of a teacher, and this encourages students to learn physics either in groups or independently. As such, future research needs to examine the impact on teachers’ motivation to teach students using simulation methods as blended learning in physics.

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