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PAPER

The Effectiveness of Case-Based STEM Integrated with Mobile Simulation to Foster Students' Creative Thinking Skills

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ABSTRACT

This study aims to determine the effect of case-based science, technology, engineering, and mathematics (STEM) integrated with mobile simulation on fostering students' creative thinking skills. This study utilized an experimental design, specifically a pretest-posttest control group design. The research subjects were 40 students from a university in Surabaya City. The research instrument used was a test measuring creative thinking ability. The data was analyzed using the Wilcoxon non-parametric test because it was not normally distributed. The results showed that: (1) there is a statistically significant difference between the initial test and the final test; (2) there is a significant increase in the creative thinking ability of students who participate in oscillation-based STEM Embedded learning with mobile simulation; (3) there is a positive relationship between the use of mobile simulation and students' STEM Embedded creative thinking ability. The conclusion of this study is that case-based STEM embedded oscillation with mobile simulation is effective in improving students' creative thinking skills.

KEYWORDS

science, technology, engineering, and mathematics (STEM), mobile simulation, creative thinking skill

1 INTRODUCTION

Science and technology are advancing at a rapid pace, which has far-reaching effects on many aspects of human existence, including the educational system. If we want to reach our full potential as human beings, we must invest in our education [1]. Advances in science and technology can enhance education by facilitating the integration of technology into the learning process. Science and technology have a significant impact on the development of new instructional resources in the era of globalization due to the close relationship between these two fields [2]. To keep

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up with the rapid pace of scientific and technological advancement, the realms of education, employment, and other professions require individuals with advanced skills, including the capacity to learn, reason, think creatively, make decisions, and solve problems.

The fact is that it doesn't align with the present because some educators place too much emphasis on teaching students that science, especially physics, is only about formulas and questions, thus limiting their ability for creative thinking. Rather than fostering students' ability to understand topics and think creatively, traditional school-based physics curricula emphasize memorization and repetition [3]. Hence, it is critical to teach students to think creatively. Some children can simply memorize facts and figures without understanding their relevance or purpose in the real world. Therefore, there is an ongoing need to promote critical thinking and creative thinking abilities in the classroom. This manifests itself in real life as well, when pupils lack the ability to create and instead become consumers [4].

An individual's capacity to think creatively emerges from their interactions with their surroundings. It is the ability to synthesize new knowledge from existing facts, information, and elements gathered from one's home, school, and community [5]. To solve this problem creatively, one needs fluency (the capacity to generate many ideas), flexibility (the ability to generate diverse kinds or categories of ideas), originality (the capacity to generate ideas that are not already in circulation), and elaboration (the capacity to provide more specific information to existing ideas) [6]. Therefore, education should aim to foster students' creative thinking abilities so that they can meet the criteria for creative thinking.

To enhance students' creative thinking skills, particularly in physics courses such as oscillation, lecturers need to possess advanced skills. One of the key abilities is the ability to innovate in selecting learning methods that align with students' goals and needs. This can be achieved by option for science, technology, engineering, and mathematics (STEM) embedded oscillation case-based learning with computer simulations for physics education, which may appear challenging. The STEM approach is a learning approach that integrates the four disciplines in a coherent and interdisciplinary curriculum [7], [8]. The STEM approach aims to help students develop skills, especially creative thinking skills. There are several types of STEM approaches that can be applied in the classroom, one of which is STEM embedded [9]. STEM embedded is a learning approach that integrates STEM concepts into existing subject matter. Thus, students do not need to learn STEM separately; instead, they can relate it to relevant and real contexts. This approach also enables teachers to integrate various subjects into one learning activity [10].

Media investigations are essential for the implementation of the STEM embedded learning method. Using a mobile app to facilitate learning simulations is essential [11]. The goal of developing a mobile application is to create an interactive simulation that mimics the behavior of a real-world system [12]. On the other hand, virtual simulation media enables students to achieve learning objectives by utilizing modeling with web-based mobile applications. Among these, the physics education technology (PhET) simulation is a feasible choice for mobile applications. The University of Colorado's PhET simulations are a learning tool for physics, chemistry, and biology that can be used in the classroom or for individual study. The benefits of using PhET simulations include an environment that encourages creativity, constructive criticism, an emphasis on the link between real-world events and the science behind them, and support for interactive methods and constructivism [9]. One of the many benefits of using PhET simulations in the classroom is that they encourage students to think in a constructivist fashion.

This, in turn, makes learning more engaging by enabling students to draw on both their existing knowledge and the outcomes of the simulations [13]. Students can enhance their ability to think creatively about abstract phenomena and gain a better understanding of visual concepts through the use of PhET simulations. The learning process can be made more successful by utilizing STEM-embedded oscillation cases in mobile simulation.

2 LITERATURE REVIEW

2.1 Creative thinking skills

Creativity is crucial in the field of education to cultivate a superior and competitive generation. Education is aimed at developing 21st-century skills, which include the 4Cs: creativity, collaboration, critical thinking, and communication [14]. Creative thinking skills possessed by individuals can be used to generate new ideas, explore new possibilities, and make new discoveries in the process and outcomes of work [15]. To think creatively, one must utilize pre-existing mental representations in a way that generates new ideas and perspectives, while also discovering new, unexpected connections or aspects that may seem unconnected [16]. New ideas, methods, viewpoints, and perspectives are the outcomes of creative thinking. Fluency, flexibility, originality, and elaboration are indicators of creative thinking abilities [17].

1. Fluency is the ability to generate ideas, methods, input, and alternatives quickly.
2. Flexibility is the capacity to generate novel ideas and solutions by thinking innovatively and considering various perspectives.
3. Originality is the to solve problems by combining unusual or unique elements.
4. Elaboration is the ability to enhance an item, concept, or product by developing, adding, or specifying details.

2.2 Mobile simulation

With the rise of mobile devices such as smartphones and tablets, the education industry is benefiting from the expansion of information and communication technology. These devices can be used to create educational media applications. Since mobile devices offer a variety of learning methods, are ubiquitous, practical, and easy to access, they can be utilized for educational purposes [18]. Mobile simulation in learning is a technique that utilizes simulations on mobile devices to offer an interactive and immersive learning experience [19]. Mobile simulations can be used in a variety of fields, including STEM, digital communications, and health. Mobile simulations help students learn through exploration and discovery, providing learning experiences that resemble real-world situations [20].

The University of Colorado Boulder's PhET project is an example of a mobile simulation. For the purpose of teaching STEM subjects, this initiative offers online simulations in these areas. PhET is open-source, research-based, and interactive simulation software (free software). PhET simulations are designed to be user-friendly for easy navigation. PhET simulations are animated, user-friendly, and reminiscent of a game, enabling students to learn through hands-on experience. Students can easily comprehend the conceptual physical models presented in the simulations, which emphasize the user's transition between real-world events and mobile simulations [21]. Atoms, photons, electrons, and electric fields are some of the intangible elements that constitute PhET simulations. Images and simple controls such as click, drags, slide switches, and buttons enable students to interact [22]. Students can use the animations to learn about the events and how they originated. Measurement tools are available in PhET simulations for quantitative investigations, similar to actual laboratory experiments [23]. All of the current simulations have been evaluated for their usefulness and efficacy in the classroom. Visit http://www.phet.colorado.edu/new/about/index.php.

3 METHODOLOGY

This study utilized a pre-experimental approach, which involves administering a set of tests to just one group before and after treatment. The study participants were 40 students from a university in Surabaya City. Data collection was conducted using a test instrument. The test used to measure students' creative thinking ability was a descriptive test on oscillation material. Before being used in the research involved, a pre-test (O_1) was administrated followed by a treatment (X) to assess the impact of using STEM embedded case-based oscillations with mobile simulation on enhancing students' creative thinking skills. The study concluded with a post-test (O_2) after the treatment was administered. The research design is presented in Table 1.

Table 1. Research design

Pre-Test	Treatment	Post-Test
O_1	X	O_2

The results of the pre- and post-tests were analyzed using several statistical tests, including tests for normality, homogeneity, differences, and N gain. Determining whether data follows a normal or abnormal distribution is the objective of a normality test. The outcomes of parametric statistical analysis methods are applicable to data that follows a normally distributed distribution, while nonparametric methods are more suitable for data that does not. If the significance value is greater than 0.05, it indicates that the data is normally distributed; conversely, if the significance value is less than 0.05, it indicates that the data is not normally distributed [24]. As a statistical test, the homogeneity test aims to demonstrate that two or more sets of sample data represent populations with identical variances. After checking the data for normality, the difference test is conducted to ascertain whether there is a significant difference between the pre- and post-test scores. It is possible to conduct a parametric test, such as the paired sample T-test, if the data is determined to be normally distributed. If it is determined that the data does not follow a normal distribution, a non-parametric test, such as the Wilcoxon test, can be used [25]. H_0: STEM embedded oscillation case-based with mobile simulation has no effect; H_1: STEM embedded oscillation case-based with mobile simulation does have an effect are the study's statistical hypotheses. The purpose of the N-gain test is to compare pre- and post-treatment scores based on a set of criteria designed to measure various aspects of creative thinking. According to [26], a high N gain is greater than 0.70, a medium N gain is between 0.3 and 0.7, and a low N gain is between 0 and 0.3.

When the N-gain score is greater than 0.3, it is considered that creative thinking skills have improved.

4 RESULT AND DISCUSSION

Mobile simulation-assisted learning using PhET for science education, particularly for oscillation topics, is an effective approach to enhancing students' creative thinking skills. This study shows that STEM-embedded oscillation case-based learning with mobile simulation can improve students' creative thinking skills. Before learning takes place, students access the PhET simulation on their smartphones by downloading the PhET application from the Google Play Store. The mobile simulation-based PhET display can be seen in Figure 1.

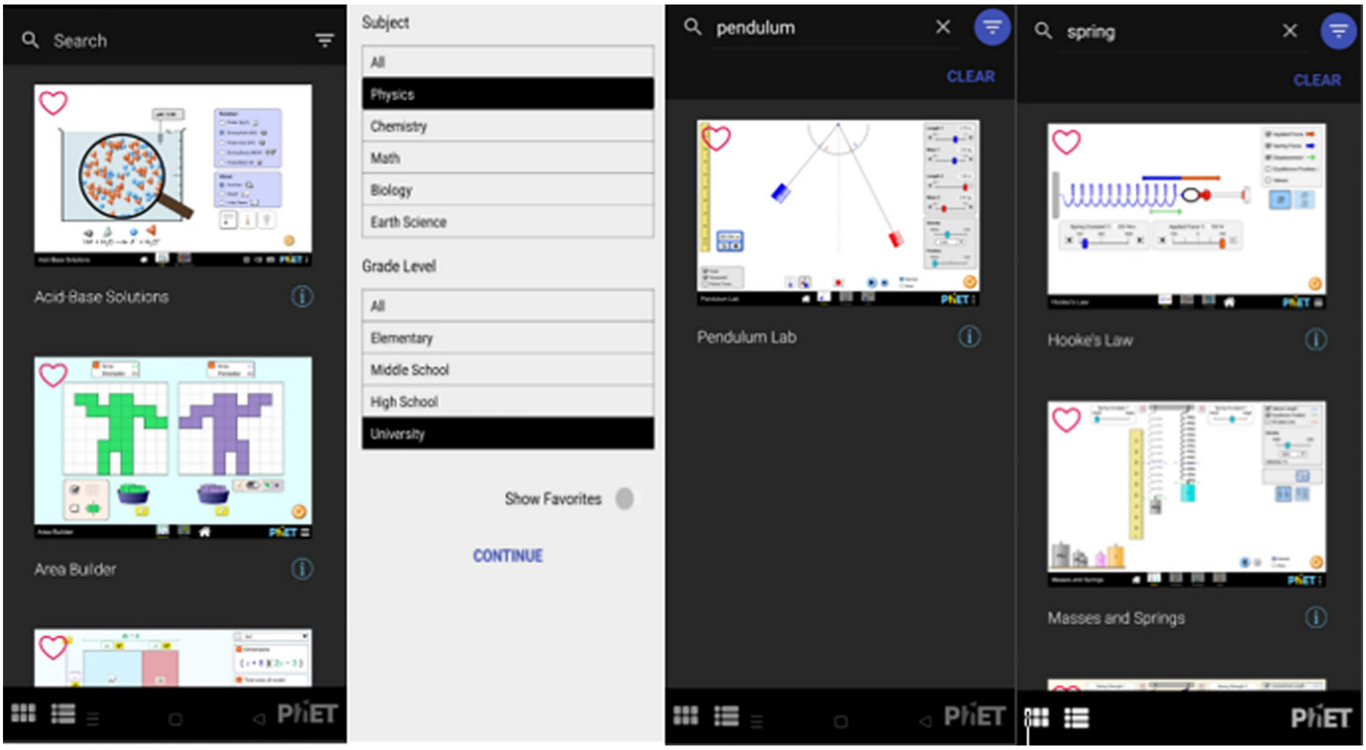

Fig. 1. PhET simulation display in mobile application (smartphone)

Students' creative thinking skills are assessed based on the pre-test and post-test scores using Minitab software. The statistical analysis is as follows:

1. Normality test

   Test the normality of the initial and final test data using the Anderson-Darling (A-D) test (see Table 2).

Table 2. Results of data normality test

Data	N	Mean	SD	AD	p-Value	Explanation
Pretest	40	52.00	8.196	1.009	0.010	Data pretest and posttest did not follow the normal distribution
Posttest	40	78.53	3.686	1.977	<0.005	

2. Homogeneity test

The homogeneity test of the initial and final test data using the Levene test results is as follows (see Table 3):

Table 3. Results of Data Homogeneity Test

Method	Test Statistic	DF1	DF2	p-Value	Explanation
Levene	15.92	1	78	0.000	Variances of data Pretest and Posttest not homogenous

3. T-test

Since the results of the homogeneity and normality tests do not indicate that the data follows a normal distribution, we can proceed to apply the non-parametric Wilcoxon test (see Table 4).

Table 4. Wilcoxon signed rank test results

Data	N	Wilcoxon Statistic	p-Value	Explanation
Posttest – Pretest	40	820.00	0.000	Difference between data Posttest and Pretest, statistically significant difference between

There is a statistically significant difference between the initial and final tests, as indicated by the Wilcoxon statistical value of 820.0. The difference in test performance between before and after treatment is not equal to zero. This result justifies the fact that the treatment was successful. This indicates that there are changes in creative thinking skills after receiving treatment with STEM-embedded oscillation case-based mobile simulation. The availability of STEM-embedded oscillation cases based on mobile simulation is one of the factors that enhance students' creative thinking skills. Students can creatively analyze the results obtained using the PhET application to solve problems [27]. Interest in the features of the PhET mobile application can strengthen students' concept of oscillation [28]. Changes made by an individual's regarding a problem can lead to improvements in their creative thinking skills [5].

4. N-gain test

See how markers of fluency, flexibility, originality, and elaboration emerged from the assessment of creative thinking skills derived from the pre- and post-test question sheets in the accompanying Figure 2.

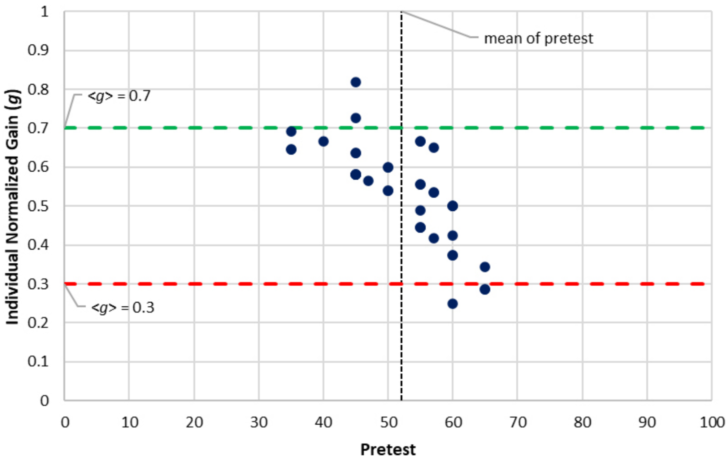

Fig. 2. The distribution of pre-test data

The distribution of post-test data is as follows (see Figure 3):

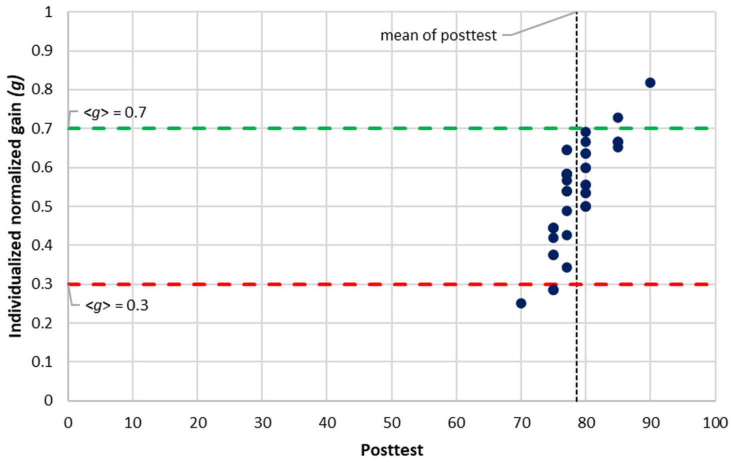

Fig. 3. The distribution of post-test data

Based on the distribution of the data from the pre- and post-tests, students' creative thinking skills fall into the medium category, as indicated by the N gain result of 0.54.

The results of research on oscillation cases embedded in STEM with mobile simulations have a very positive influence on students. The PhET mobile application simulation encourages students to learn, think creatively, and generate ideas that will be reflected in the concept of oscillations. This helps students contemplate the nature of objects during oscillations and equips them to solve problems related to oscillating materials. Mobile simulations, equipped with videos, enable students to explore ideas and engage in discussions [29]. Creative thinking skills have improved after being exposed to STEM-embedded oscillation case-based research with mobile simulation. The characteristics of STEM-embedded oscillation case-based research with mobile simulation can assist students in conducting laboratory work related to oscillation, which is abstract. Oscillation material is one of the abstract materials that require PhET simulation. PhET simulations are essential during the learning process because abstract oscillation materials can be challenging for students, especially when they need to determine parameters such as amplitude and frequency. Using PhET simulations, students conduct experiments that can make it easier to manipulate variables [30]. Teaching students how to develop creative thinking skills through PhET fosters independence in problem-solving, encourages them to take responsibility for regulating and disciplining themselves and enhances their capacity for self-directed learning.

5 CONCLUSION

STEM embedded oscillation case-based with mobile simulation using PhET offers a way for instructors to make oscillation concepts dynamic and illustrative. This study demonstrated an improvement in creative thinking skills among students who gained experience using PhET mobile simulations. The use of PhET simulations is a valuable learning experience for students. Experimentation and observation are essential aspects of the scientific method that should be introduced to students. Therefore, it is important that lectures be integrated with mobile simulation. STEM-embedded oscillation case-based mobile simulations can bridge the gap between lectures and experiments by providing a simulated and idealized exploration of scientific concepts, particularly oscillation, in a visual and dynamic manner. This allows instructors to effectively use STEM-embedded oscillation case-based mobile simulations to enhance students' creative thinking skills.

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