Optimizing STEM Learning In SDN Bringinan With Interactive PhET Technology

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Abstract.

This program aimed to enhance STEM education at SDN Bringinan, Jambon, Ponorogo, by integrating PhET Interactive Simulations. The program focused on two main topics: energy transfer and energy transformations. Students from grades 4, 5, and 6 were divided into groups and guided by facilitators to explore these concepts using PhET. The program began with problem identification through discussions with the school's Principal and teachers, followed by careful planning and execution over two sessions in August 2024. The first session introduced students to heat transfer, while the second focused on energy transformations. Post-session evaluations showed that students successfully understood and applied these concepts, identifying energy sources, converters, and users, and explaining the process of energy transformations. The success of the program suggests the effectiveness of interactive technology like PhET in improving students' comprehension of complex scientific concepts, highlighting a valuable approach for future educational initiatives.

Keywords: *STEM education, SDN Bringinan, PhET simulations, energy and student comprehension.*

I. INTRODUCTION

SDN Bringinan is a public elementary school situated in the Bringinan Village of Jambon District, Ponorogo Regency, East Java, Indonesia [1]. SDN Bringinan offers primary education for students in grades 1 to 6, similar to other public elementary schools in Indonesia. This educational institution caters to young students residing in Bringinan Village and the neighboring areas. The school's facilities are comprehensive, providing ample computer and internet access to facilitate the learning process.Utilizing information technology in science, technology, engineering, and mathematics (STEM) education at the elementary school level is crucial for enhancing the quality of education and fostering student engagement. In the realm of modern education, teachers and students alike must possess information technology skills as a necessary competency. Research has shown that incorporating technology into education has numerous benefits for students. It enhances their engagement and fosters their creativity, while also promoting the development of important cognitive skills such as critical thinking and metacognition [2], [3]. Studies indicate that the utilization of information technology has the potential to enhance information processing and reflective thinking abilities, both of which hold significant value in the realm of science education, where abstract concepts are frequently encountered [2]. An important advantage of information technology in science education is its capacity to visually represent complex concepts. Using interactive applications and media can enhance students' comprehension of natural phenomena, leading to improved motivation and learning outcomes [4], [5].

Furthermore, information technology facilitates enhanced and productive learning, particularly in the realm of distance education, which is becoming more prevalent in today's digital age. Thanks to the availability of e-learning platforms and learning applications, students now have the convenience of accessing learning materials at their own convenience, regardless of time and location. This has greatly facilitated flexible learning opportunities [6].In addition, the incorporation of information technology in science education has been found to enhance students' motivation to learn. According to a study conducted by Nursyam [7], the incorporation of technology-based media has been found to enhance students' enthusiasm and drive for learning. Integrating technology into the learning process enables teachers to

establish a dynamic and participatory learning atmosphere, particularly for elementary school students who typically have limited attention spans [8]. In elementary schools, the integration of information technology into science learning has been found to enhance the quality of education and equip students with the necessary skills to tackle future challenges. Early development of information technology skills equips students to actively engage in a technology-dependent society [9].

Hence, it is crucial for educational institutions to persist in their support and advancement of initiatives that promote the integration of information technology in the learning process.Utilizing PhET (Physics Education Technology) in elementary school education holds significant value in enhancing students' comprehension of scientific and physics principles. PhET offers interactive simulations that enable students to visually and practically explore physics phenomena, aiding their comprehension of concepts that can be abstract and challenging to grasp. Studies have demonstrated that incorporating interactive simulations, like PhET, can enhance students' learning and conceptual understanding [10], [11], [12]. Through the use of simulations, students can gain a deeper understanding of how physics concepts relate to real-life applications. This connection between theory and practice enhances their comprehension and appreciation of the subject [12], [13]. Furthermore, PhET also contributes to enhancing students' enthusiasm for education. In the realm of education, where technology plays an ever-growing role, the incorporation of interactive media like PhET has proven to be effective in capturing students' interest and fostering greater engagement in the learning journey [14], [15].

Studies have indicated that students who utilize PhET as a learning tool exhibit favorable reactions, such as heightened enthusiasm and improved problem-solving abilities [16], [17]. It is crucial to emphasize the significance of this matter, particularly in elementary education, as it lays the groundwork for future learning at more advanced levels. In addition, PhET can assist in fostering students' critical thinking abilities and science process skills. Simulations promote student engagement in exploration, observation, and discussion, which are essential components of inquiry-based learning [18], [19]. This approach enhances conceptual understanding and fosters the development of critical thinking skills necessary for science learning [20], [21]. Hence, it is highly recommended to incorporate PhET into the elementary education curriculum in order to enhance the learning experience by making it more interactive and effective.In elementary school learning, the utilization of PhET has been found to enhance comprehension of science and mathematics concepts. Additionally, it fosters a greater interest in learning, boosts student engagement, and cultivates critical thinking skills. PhET is an invaluable tool for enhancing science education at the elementary level.

II. METHODS

The objective of the community service program at SDN Bringinan, Jambon, Ponorogo, was to improve the quality of STEM education by utilizing PhET Interactive Simulations. The program was implemented in a multi-stage process, including the identification of problems, the planning of activities, the execution of the activities, and the assessment of the outcomes.

2.1 Problem Identification

The initial stage in this technique involved recognizing the obstacles present in STEM education at SDN Bringinan through talks with the school's Principal and relevant educators. The community service team held a direct meeting with the Principal, as depicted in Figure 1 (left side), to attain a comprehensive comprehension of the prevailing concerns. This exchange was intended to identify areas where additional support and technological advancements, such as the utilization of PhET, could yield considerable advantages. The discussion encompassed the constraints of existing educational resources, the efficiency of current teaching strategies, and the students' comprehension and curiosity levels in STEM topics. We also held a discussion with UTM representatives to plan the activities, as shown in Figure 1 on the right.

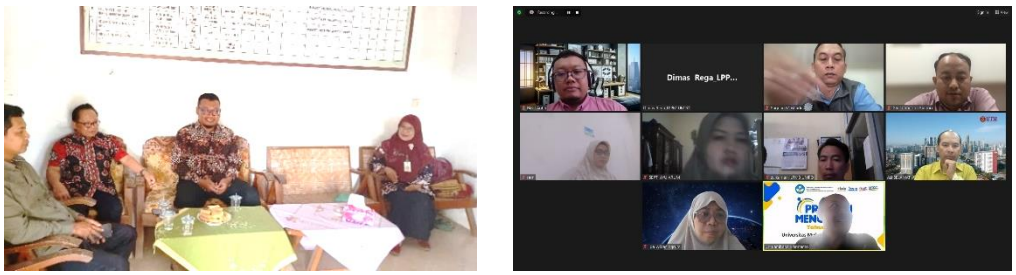

Fig 1. Discussion with the Principal of SDN Bringinan (left)
and with UTM Representatives (right) to Identify Challenges in STEM Education.

2.2 Activity Planning

After identifying the problem, the community service team devised a comprehensive plan of activities to address the identified needs. This planning process involved scheduling training sessions, selecting appropriate content to be delivered, and preparing necessary resources, such as computers and access to the PhET Interactive Simulations. Furthermore, the team made adjustments to the existing STEM curriculum to ensure that the integration of PhET into the teaching process was effective and aligned with the educational objectives of SDN Bringinan.

2.3 Implementation

The activities were carried out over two sessions during the third and fourth weeks of August 2024. The implementation phase commenced with the introduction of PhET to students in grades 4, 5, and 6. This introduction comprised live demonstrations of PhET by the community service team, during which students were urged to interact directly with simulations pertaining to concepts such as energy forms, energy transformations, and other pertinent applications. Each student was provided with the chance to experiment independently with PhET, with assistance offered by the team and trained educators.

2.4 Evaluation

The culmination of the implementation process entailed evaluating the program's efficacy through posttests administered to the participating students. These posttests were specifically designed to gauge the students' comprehension of the concepts taught using PhET and to assess the efficacy of these simulations in enhancing learning outcomes. The data garnered from the posttests were analyzed to discern any notable improvements in students' comprehension when compared to the pretest results, which had been conducted earlier. Apart from the posttest results, the evaluation encompassed feedback from both teachers and students regarding their experiences with PhET, providing invaluable insights for further refinements to the program and future advancements.The implementation strategy deployed by the community service program at SDN Bringinan is designed to attain its primary objective of enhancing the quality of STEM education and sparking student interest in science by leveraging cutting-edge interactive technology.

III. RESULTS AND DISCUSSION

The introduction of PhET Interactive Simulations was initiated by the team in conjunction with the students of grades 4, 5, and 6 at SDN Bringinan. A total of 24 students were involved in this activity, which was conducted with six groups. Each group was accompanied by a member of the team, including lecturers and student facilitators, to guide them in operating the PhET program. The groups were facilitated with computers or laptops that were connected to the internet, which allowed them to access and explore the simulations with efficiency.During the session, each group participated in hands-on activities using the PhET simulations, focusing on concepts related to energy forms and transformations. The simulations enabled the students to interactively experiment with various variables and observe the resulting changes in real-time, thereby making abstract concepts more concrete and comprehensible. The team members facilitated the learning process by offering guidance and responding to questions, ensuring that the students fully grasped the educational content. This group-based approach not only enhanced the students' understanding of STEM concepts but also encouraged collaborative learning and critical thinking. The incorporation of technology in the classroom, particularly through the PhET simulations, provided an engaging and dynamic learning

environment that was well-received by the students. The activity culminated in a group discussion where students shared their observations and insights, reinforcing the learning outcomes.

Fig 2. Students actively engage with PhET simulations in group learning sessions, guided by facilitators using internet-connected computers.

Figure 2 depicts the collaborative learning atmosphere during the launch of PhET, with students actively engaging in group activities and interacting with the simulations under the supervision of facilitators. This teaching approach demonstrated effectiveness in promoting a more profound comprehension of the subject matter while simultaneously nurturing teamwork and problem-solving abilities in the students.The primary subject covered in the training session was energy and its transfer. This topic introduced students to the fundamental principles of energy and the diverse ways it can be transferred between different objects or systems. The concept of energy was specifically chosen because it is an abstract physical quantity that can be challenging for elementary school students to comprehend. Grasping energy and its transfer is crucial because these concepts are foundational in the study of physics and other scientific disciplines. To assist students in overcoming the difficulties they might encounter when trying to understand these abstract concepts, PhET Interactive Simulations were utilized. The visualizations provided by PhET play a critical role in making the invisible processes of energy transfer more palpable and accessible. Through these simulations, students could observe how energy changes form and moves between objects in real-time, offering a hands-on learning experience that goes beyond conventional teaching methods. By visualizing energy and its transfer, students could better understand how energy operates in various scenarios, such as in heating, mechanical work, or electrical circuits. This interactive approach was designed to ensure that students could more easily grasp the concept and retain it better than they might through conventional instruction.

Fig 3. PhET visualization used to help students understand energy concepts and energy transfer through interactive simulations [22].

Figure 3 depicts the PhET visualization of energy, which was employed during the session to facilitate students' comprehension of energy's functioning in diverse situations, thereby rendering the learning process both captivating and fruitful.The second session emphasized the principles of energy transformation, where students examined the process by which energy can change from one form to another through the use of PhET Interactive Simulations. Through the simulation, students observed that energy, while conserved, can take on various forms. For instance, as illustrated in Figure 4, students saw energy transition from chemical energy to mechanical energy, then to electrical energy, and finally to thermal energy. This visual representation demonstrated that energy is not lost, but rather changes its form as it moves through different systems. To illustrate, chemical energy from the food can be converted into mechanical energy to power a generator, which in turn generates electricity, and ultimately, this electrical energy can be converted as heat.

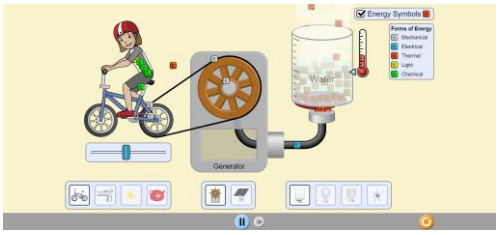

Fig 5. PhET visualization used to help students understand the concepts of energy conversion [22].

Through these interactive simulations, students were able to see these abstract concepts come to life, helping them understand the practical applications of energy transformations in everyday life. The hands-on experience provided by PhET allowed students to visualize and grasp the concept of energy transformations more easily than through traditional teaching methods, enhancing their understanding and retention of the material.Following each session, students were assessed on their comprehension of the material covered. The initial posttest assessed their understanding of heat energy transfer and its impact on temperature changes. All students demonstrated a strong grasp of this concept, indicating their ability to effectively apply heat transfer processes. In the subsequent session, the evaluation focused on energy transformation processes. Students were required to identify energy sources, converters, and users, as well as explain how energy changes form in various scenarios. The evaluation results showed that all students were able to accurately complete these tasks, suggesting a thorough understanding of energy transformation processes. These assessment outcomes underscore the efficacy of PhET visualizations in enhancing students' comprehension of complex scientific concepts. The interactive and visual nature of PhET simulations significantly improved the students' ability to quickly and accurately understand and apply the knowledge acquired during the sessions.

IV. CONCLUSION

The community service program implemented at SDN Bringinan utilized PhET Interactive Simulations effectively to improve students' understanding of energy concepts and transformations. By employing structured sessions and interactive learning, students in grades 4, 5, and 6 were able to easily comprehend complex scientific ideas. The evaluations conducted at the end of each session demonstrated significant improvements in the students' understanding, and all participants were able to accurately explain heat transfer, identify energy sources, and describe energy transformations. These outcomes serve to highlight the effectiveness of PhET simulations as an educational tool, as it not only accelerated learning but also deepened students' understanding of abstract concepts. The success of this program suggests that incorporating technology into STEM education can be highly advantageous, particularly in helping students visualize and comprehend scientific principles.

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