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Building Science Teachers' Conceptual Understanding with PhET Simulation

David Tuhurima[1]*, John Rafafy Batlolona[1]

[1]Physics Education Study Program, Faculty of Teacher Training and Education, Pattimura University, Ambon, Indonesia

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Corresponding Author:
David Tuhurima
davidtuhurima@gmail.com

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Abstract: This community service activity aims to improve the knowledge and skills of science teachers in creating practical simulation media using the PhET application. Involving 12 teachers, this training focused on creating practical simulation media that can be implemented in the learning process. The main results of this activity showed a significant increase in teachers' understanding and skills in managing learning media, as reflected in the positive response of participants to the use of PhET Simulation. In addition, teachers succeeded in producing simulation media that were relevant to the teaching material, increasing students' creativity and interest in science lessons. The main conclusion of this activity is that the integration of PhET Simulation in learning can deepen students' conceptual understanding and improve the quality of education at SMP Kristen 1 Dobo as a whole. This program also opens opportunities for further development in the use of educational technology in remote areas such as the Aru Islands.

Keywords: Conceptual Understanding; PhET Simulation; Science Teacher

Introduction

Science, particularly physics, is a subject often considered difficult by many students, leading to low interest in learning it. This subject involves many mathematical formulas and abstract concepts, making some elements invisible and difficult to visualize (Wattimena & Batlolona, 2024). Therefore, teaching concepts to students without appropriate visual cues can hinder their conceptual understanding. This indicates a gap between the material students learn and the application of that knowledge, reflecting a lack of conceptual understanding of those concepts (de Jong et al., 2023). To teach these concepts well, teachers need to use interactive and creative computer-based software in the form of simulations, because traditional teaching methods are not yet effective enough to meet this need (Özcan et al., 2020). Interactive computer simulations give students the opportunity to analyze problems, make decisions, manage real situations, control projects, and experience the impact of their actions (McLaughlin & Farris, 2025).

The use of computer simulations is one of the best methods for concretizing abstract concepts to achieve better understanding. Furthermore, virtual laboratories include simulations and games that immerse students in a digital environment where they can conduct experiments, interact with tools, and manipulate variables, providing hands-on experience and risk-free learning (Govender & Brás, 2025). Many researchers have studied the impact of interactive computer simulations in helping students solve various problems in physics concepts (Victor et al., 2023). As an example,Kunnath & Kriek, (2018)found that students performed better when using computer simulations to teach the photoelectric effect. In addition, for example, Zacharia (2007) found that using interactive simulations in a science laboratory to teach electrical topics improved students' conceptual knowledge of electrical circuits more than conducting real-world experiments. Gelbart et al. (2009) created a web-based simulation that allows high school students to engage in genetic research using bioinformatics tools, resulting in significant improvements in their understanding of genetics. Luo et al. (2016) used a web-based interactive simulation tool, WILSIM-GC, to improve students' understanding of landform evolution, showing that students preferred the simulation method and

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performed better on higher-order thinking tasks. Almasri (2022) applied simulations to teach basic concepts to younger children, and found that simulations could enhance their conceptual understanding of basic physics principles as well as encourage participation in more complex cognitive processes. Correia et al., (2019) integrating simulation into a science learning system to help students understand the behavior of gases, with results showing that this approach can facilitate changes in students' understanding of science learning.

More than 25% of participants reported finding physics boring. Approximately 39% of them believed that physics was irrelevant to everyday experiences. Many individuals expressed negative views of physics due to the large amount of homework required. This also indicates that participants' ability to solve physics problems is generally low (Mbonyiryivuze et al., 2021). In the context of student- and teacher-led activities, students perceived collaborative functions as the most beneficial. More specifically, male students' physics learning performance was positively related to their perceptions of collaborative functions, while female students' views of student-led functions also showed a positive relationship. However, Zhai & Shi (2020) noted that students' perceptions of teacher-led learning can negatively impact their success in physics learning. Students demonstrated moderate technological readiness, but also high levels of scientific knowledge. Furthermore, this study identified a significant relationship between students' technological readiness and specific abilities in group projects and creative thinking.

Furthermore, a study in Maluku showed that students' creative thinking skills are still relatively low, necessitating comprehensive learning improvements to improve these skills. It is hoped that students' improved creative thinking skills will contribute to better regional development in the future (Leasa et al., 2021). In addition, the results of the study Rumatiga et al. (2023)This indicates that education in the Aru Islands, which falls within the 3T (Underdeveloped, Frontier, and Outermost) category, also faces challenges such as a lack of learning facilities and infrastructure, low teacher professionalism, low student achievement, and a lack of equal educational opportunities, particularly in remote areas. Therefore, support from various parties is needed to address these issues (Kempa et al., 2019). One of the activities carried out is training in the use of the application. PhET simulation as a science learning media for science and mathematics teachers inDobo 1 Christian Middle School. This is becauseInnovative teaching methods involving group projects can encourage critical thinking that can be integrated into all curriculum areas and activities (Leasa & Batlolona, 2023). However, there appears to be a gap in practical knowledge in previous studies.

Modern technological devices have contributed to identifying significant changes in the educational process, which in turn influence the methods and tools for acquiring and presenting information to students. This plays a role in demonstrating student success rates, with interactive simulation methods becoming a contemporary teaching technique. The integration of information and communication technology (ICT) into education is crucial and effective for designing, developing, using, and evaluating learning processes. Intellectual and practical interaction between teachers and the educational environment is now a hallmark of IT-based education. With the inherent characteristics of modern devices, technology has made their use a necessity, providing learners with specific knowledge and skills, as well as helping develop their thinking abilities and increasing success rates (Mirzajani et al., 2016). One of the interactive simulations available is PhET, developed by the University of Colorado with support from the William and Flora Hewlett Foundation and the National Science Foundation. This site offers free learning simulations in physics, mathematics, biology, and chemistry, which can be downloaded for classroom teaching or used for independent learning (Ben Ouahi et al., 2020).

Findings Dy et al. (2024)showed a significant increase in overall student performance after the use of interactive PhET simulations in science learning. Thus, interactive PhET simulations proved to be an effective tool for improving student performance in science. These findings support the suggestion that the integration of PhET simulations can be effective in deepening students' understanding of science concepts (Taibu et al., 2021). Various studies on the application of PhET simulations in teaching have shown positive results. It significantly impacts students' performance and retention during the learning process, enhances their creativity, and fosters positive attitudes and interest in Physics, while encouraging exploration and inquiry (Sarı et al., 2017). For example, in the Philippines, the implementation of PhET in the classroom has shown satisfactory results. It contributes to good academic achievement, is very useful in developing content knowledge and process skills, and helps achieve more complex objectives and effective learning materials (Almadrones, 2024). Although the idea of integrating and utilizing computer simulations in classroom learning is not new, there are still limited activities that validate the impact of using PhET simulations on mastery of learning competencies. The physics education technology (PhET) project develops simulations useful for teaching and learning physics, which are freely accessible through the PhET website (http://phet.colorado.edu). This simulation provides an interactive, animated, and game-like environment where students can learn through exploration. It emphasizes the connection between real-world phenomena and the underlying scientific principles, and attempts to make the visual and conceptual models typically used by physicists more accessible to students. PhET simulations are highly effective tools for enhancing cognitive skills, demonstrating significant progress in understanding complex concepts, fostering curiosity and exploration, and adding game-based elements. While challenges such as limited access to technology, the use of outdated versions of device operating systems, difficulty navigating the simulation, and the need for background knowledge can be addressed, addressing these issues can maximize the simulation's potential, making it a highly effective tool for fostering deeper learning (Tusoy & Baraquia, 2025). With the advantages of PhET simulation, this training program was conducted for science teachers in the Aru Islands, specifically at Dobo 1 Christian Middle School. The goal of this activity was to improve science teachers' knowledge and skills in creating simulation media for practical work using the PhET application.

Method

The target of this community service activity is the teachers who teach science and mathematics subjects at SMP Kristen 1 Dobo. The location of the community service activity can be seen in Figure 1. This activity was carried out in November 2022. The distance from Pattimura University to SMP Kristen 1 Dobo is 830 km by plane or ship from Ambon City. This school has an accreditation status of A with the Principal being Daniel Petrus Ruben Dasmasela. Other information regarding the condition of the school can be seen at the following link:https://sekolah.data.kemendikdasmen.go.id/index.php/chome/profil/1011e3fb-30f5-e011-bd89-21551876579e.

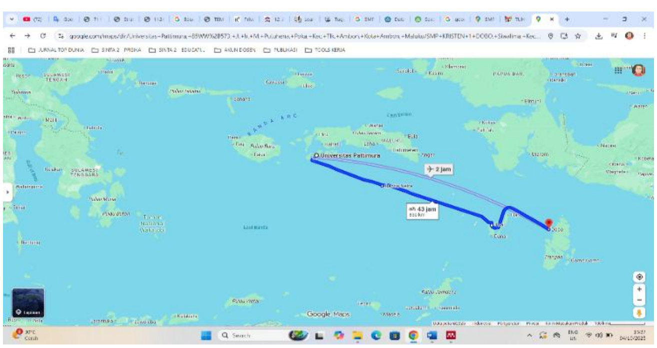

Figure 1. Location of Community Service Activities at Dobo 1 Christian Middle School

Another goal of the activity is for teachers to develop themselves individually and in groups in using this interactive software-based learning media. This development is expected to be realized in the form of lesson plans, teaching materials, and more comprehensive assessment sheets. Most importantly, the teachers' ability to apply the use of this interactive software in the classroom in a realistic manner, so that the learning process becomes more engaging and effective. As a first step in the activity, a pretest was conducted to measure the teachers' initial level of understanding regarding the use of technology-based learning media. This pretest aims to obtain an overview of the teachers' knowledge and skills, so that training can be tailored to their needs. This is in line with the perspective of Berry (2008)Pretests are non-graded assessment tools used to determine the prior knowledge of science teachers before participating in Phet simulation training. Typically, pretests are administered before a training session to evaluate participants' knowledge base. In this context, the test is used to gauge teachers' understanding before the topic is covered during the training. While perhaps unexpected, the pretest includes material that participants are not expected to know but serves as a motivational tool and roadmap for teachers, which can improve their performance during the training.

Another impact of this community service program is the emergence of creativity among science and mathematics teachers to explore and research more advanced and relevant learning media software that can support quality learning processes. The material presented in this activity focused on the use of the PhET Simulation application as an innovative and interactive learning medium. The number of teachers involved in this activity reached 12 people, all of whom came from SMP Kristen 1 Dobo. The community service activity method was carried out through training specifically designed to facilitate teachers in using learning media with PhET Simulation. This training consisted of an introduction to PhET Simulation and direct practice in using the media. The training material was tailored to each teacher's subject according to their field of study, so it is hoped that each teacher can feel the direct benefits of this activity.

As part of the ongoing learning process, several teachers will be assigned to present their work after the training. These presentations aim not only to share their experiences and knowledge but also to encourage collaboration and discussion among teachers. This is expected to create a supportive environment where teachers can learn from each other and inspire their colleagues to implement more innovative and effective teaching methods. To support this activity, we will also collaborate with the school and the Aru Islands

Education Office to provide several laptops. These laptops will be used by the teachers to create simulations based on the assignments given by the instructors during the training. This facility will allow teachers easier access to learning software and more optimal application of the knowledge they have learned.

After the training, a posttest was conducted to evaluate the improvement in teachers' knowledge and skills. The benefit of the posttest was to measure the knowledge gained from participating in the training (Shivaraju et al., 2017). The results showed that: 1) Most participants showed significant improvement in their understanding of the use of PhET Simulation. They felt more confident in integrating this technology into their teaching; 2) Participants successfully produced simulation media that were relevant to the teaching material, which resulted in increased creativity and student interest in learning science; 3) Teachers provided positive feedback on the training, stating that they felt better prepared to apply simulation media in the learning process. Thus, this program not only improved teacher competency, but also contributed to improving the overall quality of education at SMP Kristen 1 Dobo, as well as having a positive impact on the students they teach.

Results and Discussion

Participants had limited knowledge about using PhET Simulation media, but showed great interest in it. Their enthusiasm was evident when they demonstrated PhET Simulation as a learning management tool. The training began with opening PhET, which was very easy because it didn't require downloading from the App Store or Play Store. Next, participants could choose their preferred difficulty level, as shown in Figure 2.

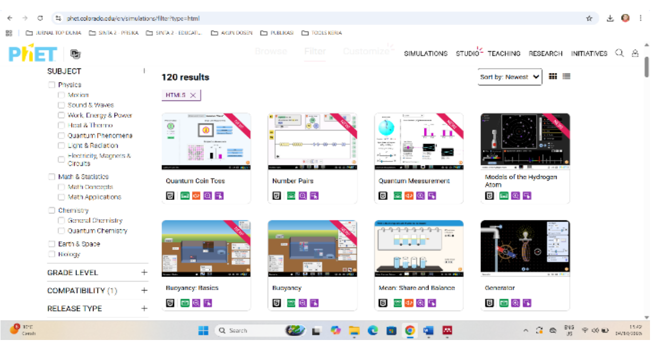

Figure 2. PhET simulation page view

The levels available in the PhET application cover a wide range of educational levels, from elementary school to college. In the context of this training, the focus is on junior high school teachers and ensuring that the simulated material is relevant to the curriculum they teach. After determining the level, the next step is to select various lab exercises that can be simulated through PhET. One example of an accessible lab exercise is about the forms and transformations of energy, as seen in Figure 3. According to Wieman & Adams, (2008)Interactive simulations can enhance students' conceptual understanding by providing a more immersive and engaging learning experience. This suggests that the PhET simulation environment significantly enhances students' learning of selected concepts.

This suggests that selecting appropriate lab work can significantly contribute to student understanding. By focusing on relevant and engaging content, teachers can not only develop their skills in using educational technology but also improve the effectiveness of their teaching. This aligns with previous studies showing that the use of PhET simulations offers teachers a variety of opportunities to develop rich learning activities. PhET simulations can replace experiments that are difficult to control, dangerous, or impossible to conduct in the laboratory, such as working with the nervous system, lightning, or dynamite (Ndihokubwayo, 2017). The advantages of this simulation are that it provides students with the opportunity to interact with dynamic visuals, focuses on inquiry exploration, provides rapid feedback, and provides experience using various representations (Moore et al., 2013). Thus, selecting the right lab through PhET not only supports better teaching but also creates a more meaningful learning experience for students.

Figure 3. Practical work on the state of particles when the two materials are heated

The training activity for creating practical simulation media using the PhET simulation program has several main objectives. First, the training aims to improve the knowledge and skills of science teachers at SMP Kristen 1 Dobo in creating interactive and engaging simulation media. This aligns with previous studies that found that the use of interactive simulations can improve students' conceptual understanding by providing a more in-depth learning experience (Ouahi et al., 2022). Second, it is hoped that science teachers at SMP Kristen 1 Dobo can implement PhET simulation media effectively in the science practicum learning process in the classroom. The use of this media aims to enrich students' learning experiences while facilitating a deeper understanding of scientific concepts. Digital simulations not only increase student motivation but also strengthen their understanding of the subject matter (Kefalis et al., 2025). Thus, this training not only focuses on developing teachers' technical skills, but also on improving the quality of classroom learning. Through the application of PhET simulation media, it is hoped that the science practicum learning process will become more engaging and effective, which in turn can improve overall student learning outcomes. The integration of interactive media in education can create a more dynamic learning environment, encourage collaboration, and increase student engagement in the learning process. The presentation of activity materials to teachers is shown in Figure 4.

Figure 4. Provision of materials for science and mathematics teachers at Dobo 1 Christian Middle School by David Tuhurima, S.Pd., M.Pd.

The training method, the participants were provided with the initial concept of simulation with PhET, given examples of how to make it, and continued with independent practice. The results of the training on making practical simulation media with the PhET simulation program, such as pendulum swings, series circuits, parallel circuits, light reflection, light refraction, and simulation of particles that make up matter. The main results of the training on making simulation media with the PhET program are as in Figure 5.In the training process for creating simulation media with PhET, the procedure followed was that, in the initial stage, participants were provided with the basic concepts of simulations with the PhET program, then participants were given examples of how to create them. Next, participants were given the opportunity to create their own media according to the existing guidelines, and for those who were already able to create simulations, they were invited to develop them by searching the internet for various types of related simulations. The training system also used a peer tutoring system to speed up the process of achieving results. The results of the teacher's work can be seen in Figure 5.

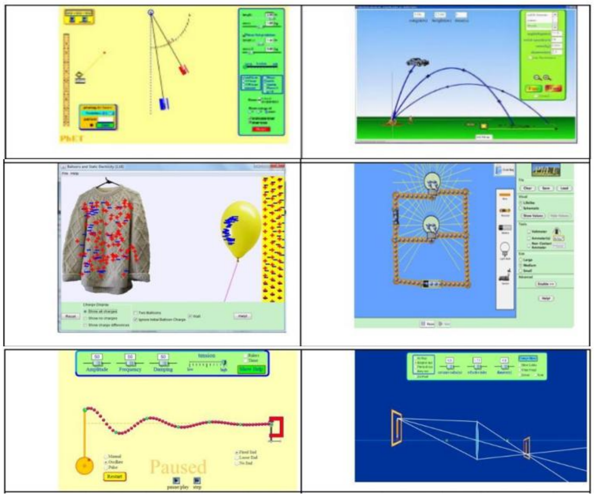

Figure 5. Teachers' work results during training with PhET Simulation

In addition, participants were given time to design, create, and refine animated media using PhET. These designs were then implemented during the learning process. PhET simulation media is practical, meaning it is easy to create and apply in learning. Based on the results of the PhET simulation media that have been implemented by teachers, for the initial stage, the participants have produced good PhET simulation media. However, for the next stage, it is hoped that it will be applied to other material topics, and further research is needed on the effectiveness of using PhET simulation media in junior high school science learning. In general, all participants gave a very positive response to the community service activity that discussed the introduction of PhET simulation as an effective learning medium. Several meaningful inputs related to the technical aspects of the activity will be used as evaluation and improvement materials for similar activities that will be carried out in the future for the community or other communities. Teachers' conceptual improvements during training with PhET simulation showed the same performance as the study. Mutende, (2025)which showed that 63% of teachers used PhET simulations in at least three lessons each week, while 77% of students were actively engaged during instruction using PhET. Students showed an average 28-point increase in test scores, and 84% of them reported that their conceptual understanding improved.

In this regard, PhET simulations offer dynamic access to multiple representations, making the invisible visible, supporting inquiry, and enabling secure and rapid access to multiple entry points while simultaneously engaging and engaging for both teachers and learners. They are based on the premise that laboratory experiments can be taught online in a cost-effective and efficient manner. These simulations help students compete with their more prepared peers and are a step toward bridging the digital divide. Teachers presenting their work are shown in Figure 6.

Figure 6. Teachers present their work with PhET simulation

Conclusion

The conclusion of this community service activity shows that training on the use of the PhET Simulation application has successfully improved the knowledge and skills of science teachers at SMP Kristen 1 Dobo. Involving 12 teachers, this program aims to facilitate them in creating interactive learning media that can improve students' understanding of science concepts. The training results showed a positive response from participants, who felt more confident in using modern technology for teaching. From this activity, the teachers not only learned how to use PhET Simulation but also were able to develop more engaging lesson plans and teaching materials. Furthermore, this activity encouraged teachers to collaborate and share experiences, creating a more inclusive and innovative learning environment. Despite challenges such as limited access to technology, this training provided practical solutions to maximize the potential of using simulation in learning. Overall, this program contributed to improving the quality of education at SMP Kristen 1 Dobo, as well as having a positive impact on the students they teach. It is hoped that the use of PhET Simulation can continue to be integrated into science learning to achieve better results in the future.

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