GUIDANCE ON DIGITAL LEARNING INNOVATIONS USING PHET INTERACTIVE SIMULATIONS TO ENHANCE TEACHERS' COMPETENCIES IN SCIENCE CURRICULUM CONTENT

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ABSTRACT

The low digital technology competency of elementary school teachers in teaching science content is a significant challenge in implementing innovative learning, particularly in Kabila District, Bone Bolango Regency. This community service activity aimed to enhance the competency of elementary school teachers by mentoring them in using PhET (Physics Education Technology) Interactive Simulations as interactive digital learning media for science instruction. The activity employed a participatory training approach consisting of four stages: an introduction to learning innovation and PhET simulations; training on integrating PhET into lesson planning; discussion and reflection on implementation; and classroom mentoring for PhET-assisted learning. The activity was conducted at SDN 10 Kabila and involved 13 elementary school teachers in Kabila District, along with 9 pre-service teacher students from Universitas Negeri Gorontalo. Results indicate that all participants successfully accessed and operated the PhET platform, selected simulations relevant to elementary science content, and directly applied them in classroom instruction. High participation and enthusiasm indicated increased motivation and digital literacy among teachers in teaching science content.

Keywords: PhET interactive simulations; elementary teacher competency; science learning; elementary school; digital innovation

ABSTRAK

Kompetensi rendah guru sekolah dasar dalam teknologi digital dalam mengajar materi sains merupakan tantangan besar dalam menerapkan pembelajaran inovatif, khususnya di Distrik Kabila, Kabupaten Bone Bolango. Kegiatan pelayanan masyarakat ini bertujuan untuk meningkatkan kompetensi guru sekolah dasar dengan membimbing mereka dalam menggunakan Simulasi Interaktif PhET (Physics Education Technology) sebagai media pembelajaran digital interaktif dalam pengajaran sains. Kegiatan ini menggunakan pendekatan pelatihan partisipatif yang terdiri dari empat tahap: pengenalan inovasi pembelajaran dan simulasi PhET; pelatihan tentang integrasi PhET ke dalam perencanaan pelajaran; diskusi dan refleksi tentang implementasi; serta mentoring di kelas untuk pembelajaran berbantuan PhET. Kegiatan ini diadakan di SDN 10 Kabila dan melibatkan 13 guru sekolah dasar di Distrik Kabila, serta 9 siswa pra-layanan dari Universitas Negeri Gorontalo. Hasil menunjukkan bahwa semua peserta berhasil mengakses dan mengoperasikan platform PhET, memilih simulasi yang relevan dengan konten sains dasar, serta langsung menerapkannya dalam pengajaran di kelas. Partisipasi dan antusiasme yang tinggi menunjukkan peningkatan motivasi dan literasi digital di antara para guru dalam mengajar konten sains.

Kata kunci: simulasi interaktif PhET; kompetensi guru dasar; pembelajaran sains; sekolah dasar; inovasi digital

1. INTRODUCTION

Innovation in learning is essential to improving the quality of education in the digital age. Teachers, as the spearhead of education, are expected to integrate technology into the learning process to meet the needs and characteristics of today's students (OECD, 2016). This also applies to elementary school (SD) teachers of natural sciences (IPA), where abstract scientific concepts require visualization and interactive learning media for elementary-aged students to understand.

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However, the reality on the ground shows that many elementary school teachers have not yet fully utilized the potential of digital technology in natural sciences instruction (Odja & Payu, 2014).

In Kabila Subdistrict, Bone Bolango Regency, Gorontalo Province, this situation is clearly evident. Most elementary school science teachers still rely on conventional methods centered on lectures and textbooks, making it difficult for them to help their students visualize abstract scientific concepts. In fact, science education requires an approach that can provide hands-on scientific exploration experiences, even in a virtual context (Kumullah et al., 2024). The still-low level of science literacy among students in Indonesia, as indicated by PISA study results, further underscores the importance of updating science teaching strategies at the elementary school level (Odja & Payu, 2014).

One innovative solution to address this challenge is the use of PhET Interactive Simulations. PhET (Physics Education Technology) is a free, interactive simulation platform developed by the University of Colorado Boulder, covering physics, chemistry, biology, and mathematics content and available at various grade levels, including elementary school (Wieman et al., 2008). PhET simulations are grounded in educational research and have been shown to enhance students' conceptual understanding and active engagement in the learning process (Santos et al., 2024). Research by Abdjul et al. (2024) shows that interactive learning media based on virtual laboratories, using a differentiated approach, is effective in improving students' science literacy, a finding that reinforces the relevance of using digital simulations in the context of science education in Indonesia.

Theoretically, the use of PhET aligns with the constructivist theory developed by Piaget and Vygotsky. This theory emphasizes that learners construct their own understanding through active engagement with the learning environment (Trianto, 2011). PhET simulations facilitate this by allowing students to conduct virtual experiments, test hypotheses, and observe the results in real time, an experience that is difficult to achieve through text-based learning alone. Furthermore, the differentiated instruction approach proposed by Tomlinson (2001, 2003) emphasizes the importance of adapting learning content, processes, and products to students' needs, a process well facilitated by the flexibility of PhET simulations. The findings of Lagarusu et al. (2023) reinforce this foundation by demonstrating that a differentiated approach combined with digital learning technology significantly improves student learning outcomes.

Previous research has shown that PhET Interactive Simulations are effective as virtual laboratories in elementary school science education, capable of visualizing difficult-to-understand concepts and promoting meaningful learning (Kumullah et al., 2024; Wulandari & Anik, 2022). Other studies reveal that interactive simulations such as PhET enhance students' motivation to learn and support the development of higher-order thinking skills (Rutten et al., 2012; Santos et al., 2024). Meanwhile, Jaapar et al. (2020) have developed a valid Android-based discovery learning model to improve conceptual understanding of physics, demonstrating that integrating digital technology in various forms is effective in science education.

However, the effectiveness of PhET in learning depends heavily on teachers' competence in integrating it into lesson plans. The situation in Kabila Subdistrict indicates that elementary school teachers have never received specialized training on using PhET to teach science. Therefore, this community service activity was designed to guide elementary school teachers in the Kabila Subdistrict in using PhET Interactive Simulations as a digital learning medium for science instruction, so that their pedagogical-technological competencies can be enhanced in a structured and sustainable manner.

2. METHODOLOGY

This community service activity was carried out at SDN 10 Kabila, Kabila Subdistrict, Bone Bolango Regency, Gorontalo Province, and lasted for 3 months. The participants in the program were 13 elementary school teachers from SDN 10 in Kabila Subdistrict, as well as 9 student teachers from the MBKM (Merdeka Belajar Kampus Merdeka) program at Gorontalo State University, who served as field mentors.

The program was implemented using the Asset-Based Community Development approach, which focuses on utilizing the existing assets and potential of the school community (Phillips &

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Pittman, 2009). The approach employed was participatory training and mentoring, in which participants did not merely receive information passively but were also actively engaged in hands-on practice. A cascading knowledge-transfer strategy reinforced this approach—that is, a tiered transfer of knowledge from faculty members to teachers and from student teachers to students in the classroom. This strategy aligns with the findings of Mamonto et al. (2020) on the effectiveness of digital technology in supporting learning.
The program's implementation consisted of four main stages.

The first phase was an Introduction to Innovative Learning and PhET Simulations. During this phase, participants were given a basic understanding through lecture sessions using an LCD projector. The material covered differentiated instruction, the benefits of digital technology in elementary school science education, and an introduction to the PhET Interactive Simulations platform.

The second stage is Training on Integrating PhET into Lesson Planning. Teachers are directly introduced to PhET's features in both the online and offline versions. The training covers the use of subject-based filters (Physics, Chemistry, Biology, Mathematics) and grade-level filters (elementary, middle, and high school), as well as how to select and open simulations relevant to the elementary school science curriculum.

The third phase was a Discussion and Reflection on PhET Implementation. This session provided an opportunity for participants to ask questions, share experiences, and discuss solutions to various implementation challenges, including limitations related to devices and internet connectivity.

The fourth stage is Mentoring on the Implementation of PhET-Assisted Learning in the Classroom. Teachers were mentored by nine pre-service teachers from Gorontalo State University in conducting hands-on classroom instruction using PhET simulations. In this stage, teachers acted as facilitators, while students actively explored the simulations.

3. RESULTS AND DISCUSSION

Result

This community service activity proceeded smoothly according to the established plan. The activity was attended by 13 elementary school science teachers from 10 public elementary schools in Kabila Subdistrict and was supported by 9 student teachers from Gorontalo State University who served as mentors. The following is a breakdown of the results for each implementation phase, along with their success indicators.

Phase 1: Introduction to Learning Innovations and PhET Simulations

All participants attended an introductory lecture on learning innovations and PhET simulations, presented via an LCD projector. Attendance totaled 22 people, including 13 elementary school teachers and 9 pre-service teachers, demonstrating strong enthusiasm for this activity. Participants gained a basic understanding of differentiated instruction and the benefits of digital technology in elementary school science education.

By the end of this session, participants were able to list at least three benefits of using PhET in science education, including: (1) visualization of abstract concepts, (2) interactive learning, and (3) independent exploration. Participants also understood differentiated instruction as the foundation for applying technology to meet students' needs.

Phase 2: Training on Integrating PhET into Lesson Planning

Teachers were given a hands-on introduction to PhET's features in both the online and offline versions. All participants successfully accessed the PhET Interactive Simulations platform on their own laptops during the training. Teachers were able to use PhET's filter features by subject and grade level, particularly in the Elementary School category.

A key achievement at this stage was that all teachers successfully selected and opened at least one simulation relevant to the elementary school science curriculum; the most frequently chosen simulation was "Force and Motion: Basics." Teachers also understood the differences between using PhET online and offline as a solution to limited internet access at school.

Phase 3: Discussion and Reflection on the Use of PhET

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The discussion session was very lively and enthusiastic. Participants raised at least four substantive questions, including: (1) strategies for using PhET with limited laptop access, (2) utilizing PhET for abstract science concepts, (3) how to access simulation guides, and (4) the availability of elementary school materials on PhET. The large number of questions raised clearly indicated the teachers' increased motivation and curiosity about digital learning innovations.

During the discussion, participants also received solutions to the challenges they faced, including alternatives for using PhET on cell phones as a substitute for laptops in schools with limited devices.

Phase 4: Classroom Implementation Mentoring

In the final phase, teachers successfully conducted at least one PhET-assisted learning session in the classroom with the guidance of nine pre-service teachers from Gorontalo State University. Teachers served as facilitators in digital simulation-based learning, while students were actively engaged in exploring PhET simulations throughout the learning process. A cascade of knowledge transfer also took place—from lecturers to teachers and from student teachers to students—activity Outcomes. Table 1 below summarizes the overall outcomes of the activity.

Table 1. Outcomes of Community Service Activities Using PhET Interactive Simulations

Indicator	Target	Achievement
Number of participants attending	≥ 15 teachers	13 teachers + 9 university students ✅
Mastery of PhET features	Basic level	Achieved ✅
PhET-based learning simulation	Enthusiastic participation	Implemented ✅
Motivation to use technology	Increased	Evidenced by active discussions ✅
Activity report	1 document	Completed ✅

Discussion

The results of this community service activity confirm that training and guidance on using PhET Interactive Simulations effectively improve the technological and pedagogical competencies of elementary school teachers in teaching science in Kabila Subdistrict. This finding aligns with research by Kumullah et al. (2024), which concluded that PhET Interactive Simulations are effective in improving elementary school students' understanding of scientific concepts and demonstrated that the key to successfully implementing technology in the classroom lies in teachers' readiness and competence.

Total attendance reached 22 participants, comprising 13 elementary school teachers and 9 pre-service teachers, reflecting the high demand for and enthusiasm for digital learning innovations. The involvement of pre-service teachers as assistants not only enhanced the effectiveness of the training but also provided a platform for them to develop professional competencies while still in school. This aligns with the findings of Syahid et al. (2022), who stated that the digital competencies of Indonesian elementary school teachers still require continuous development.

From a theoretical perspective, the successful use of PhET in this context can be explained through the constructivist theories of Piaget and Vygotsky (Trianto, 2011). PhET simulations enable students to actively construct knowledge through direct interaction with a virtual environment, which aligns with the principles of constructivism. Vygotsky adds a social dimension to this process through the concept of the Zone of Proximal Development (ZPD)—a zone where students can develop further with the guidance of others. In this activity, pre-service teachers' role as classroom mentors reinforces the social dimension of constructivism. Research by Abdjul et al. (2024) reinforces these findings by demonstrating that interactive media based on

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virtual laboratories, when used through a differentiated instruction approach, can significantly improve students' science literacy.

The emergence of many substantive questions during the discussion sessions indicated deep reflection among the participants. According to Tomlinson (2001), teachers who understand and implement differentiated instruction tend to be more responsive to students' diverse needs, and this training provided that foundation by introducing PhET as a flexible tool for various ability levels. Research by Lagarusu et al. (2023) confirms that implementing problem-based learning through a differentiated, blended-learning approach positively affects student learning outcomes, reinforcing the relevance of this training approach in this activity.

Santos et al. (2024), in their study on the impact of PhET simulations on science learning in elementary school, found that interactive simulations significantly increased student motivation and engagement, including support for the development of higher-order thinking skills during the analysis, evaluation, and creation phases. These findings align with observations from the mentoring activities, in which students appeared enthusiastic and actively explored the simulations under the guidance of trained teachers. This is also consistent with the research by Odja & Payu (2014), which emphasizes the importance of developing students' science literacy through innovative media and learning strategies.

The successful use of the offline version of PhET to address internet limitations is also a key finding. This opens up opportunities for broader implementation, including in schools with limited digital infrastructure, a common situation in Indonesia's regencies and rural areas (Wahyudi et al., 2024). Mamonto et al. (2020) have demonstrated that the use of digital platforms, such as app-assisted e-learning, can improve student learning outcomes, indicating that technology integration need not require expensive infrastructure to remain effective.

Although the results of this study are very positive, several challenges need to be addressed. First, the limited availability of laptops in schools needs to be addressed through strategies such as group use or smartphone use. Second, further training is needed to improve elementary school teachers' ability to design PhET-based lesson plans for science topics independently. Third, providing PhET guide modules in Indonesian, aligned with the current elementary school curriculum, will greatly support the sustainability of implementation.

4. CONCLUSION

A community service activity focused on guiding elementary school teachers in Kabila Subdistrict, Bone Bolango Regency, on the use of PhET Interactive Simulations for science instruction was successfully carried out. This activity involved 13 elementary school teachers and 9 pre-service teachers, all of whom were able to access, operate, and apply PhET simulations in their science lessons.

This activity demonstrated that a structured, participatory training approach—comprising four stages (introduction, training, reflection, and classroom mentoring)—is effective in enhancing elementary school teachers' technological and pedagogical competencies in teaching science. The high level of enthusiasm and participation among participants indicates increased motivation and awareness of the importance of digital learning innovations.

Theoretically, this success is underpinned by the principles of constructivism and differentiated instruction—the foundational philosophy of PhET—in which both students and teachers actively construct knowledge together. This initiative is expected to serve as a first step toward fostering a more meaningful, innovative, and student-centered transformation of science education in elementary schools across Kabila Subdistrict.

To ensure the program's sustainability, it is recommended that follow-up training be provided, Indonesian-language modules be made available, and that schools and local governments provide policy support for the development of educational technology infrastructure.

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