Universitas Muhammadiyah Malang, East Java, Indonesia

Journal of Community Service and Empowerment

p-ISSN 2722-4244, e-ISSN 2722-5291 // Vol. 6 No. 1 April 2025, pp. 175-185

Empowering physics educators through technology-based teaching material workshops: A teachers' perspective

Rizki Eka Shintya [a,1*], Fian Rifqi Irsalina [a,2], Beata Graceshela Muki [a,3], Ihsan Hijria Putra [a,4], Santri Ramadani [a,5], Alvin Syahrul Fauzan [a,6], Ahmad Zulkarnain Zain [a,7], Entang [a,8], Muhammad Rifky Fauzan [a,9], Andreny Dwi Nurlita [a,10]

[a] Master of Physics Education Study Program, Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia, Setiabudhi No. 229, Isola, Sukasari, Bandung, West Java, 40154, Indonesia

[1] rizkiekashintya@upi.edu, [2] fianrfq@upi.edu, [3] beatagmuki14@upi.edu, [4]ihsanhijriaputra@upi.edu, [5] santrir@upi.edu, [6] alvinsyahrulfauzan@upi.edu, [7] ahmadzzain@upi.edu, [8] entang23@upi.edu, [9] muhammadrifkyfauzan@upi.edu, [10] andrenydwin@upi.edu

Corresponding author

ARTICLE INFO

Article history
Received: 2025-01-26
Revised: 2025-04-03
Accepted: 2025-04-07
Published: 2025-04-22

Keywords
Physics Education
STEM
Technology Integration
Teaching Materials
Teacher's Workshop

ABSTRACT

Integrating technology into physics education is critical in preparing students with 21st-century skills. However, many physics teachers in Indonesia face challenges, including limited access to technological tools, insufficient training, and low confidence in using technology. This study aimed to explore the perspectives of physics teachers on a workshop designed to empower them in developing technology-based teaching materials. The workshop, held in Bandung Barat, provided hands-on training on integrating various technologies, such as Augmented Reality, Physics Mobile, Live Worksheets, and Articulate Storylines, into physics teaching. Data were collected from 51 participating teachers using a descriptive survey method through structured questionnaires. Results indicated high satisfaction across four evaluated aspects: material comprehension (mean score: 4.29), relevance and benefits (4.15), implementation and facilitation (4.17), and outcomes and impacts (4.20). Teachers perceived an increase in their confidence and readiness tp create innovative teaching materials, though some required additional time and support for mastery. This study highlights workshops' significance in bridging the gap between technology and education. It emphasizes the need for sustained training programs and collaboration among educators, policymakers, and technology developers to enhance the quality of STEM-based physics education in Indonesia.

Kata Kunci
Pendidikan fisika
STEM
Integrasi Teknologi
Bahan Pembelajaran
Workshop Guru

Memberdayakan guru fisika melalui workshop bahan pembelajaran berbasis teknologi: Perspektif guru. Mengintegrasikan teknologi dalam pendidikan fisika sangat penting untuk mempersiapkan siswa dengan keterampilan abad ke-21. Namun, banyak guru fisika di Indonesia menghadapi tantangan, termasuk keterbatasan akses terhadap alat teknologi, pelatihan yang tidak memadai, dan rendahnya kepercayaan diri dalam menggunakan teknologi. Penelitian ini bertujuan untuk mengeksplorasi perspektif guru fisika terhadap sebuah workshop yang dirancang untuk memberdayakan mereka dalam mengembangkan bahan ajar berbasis teknologi. Workshop yang diselenggarakan di Bandung Barat ini memberikan pelatihan praktis tentang integrasi berbagai teknologi, seperti Augmented Reality, Physics Mobile, Live Worksheets, dan Articulate Storylines, dalam pembelajaran fisika. Data dikumpulkan dari 51 guru yang berpartisipasi menggunakan metode survei deskriptif melalui kuesioner terstruktur. Hasil penelitian menunjukkan tingkat kepuasan yang tinggi pada empat aspek yang dievaluasi: pemahaman materi (skor rata-rata: 4,29), relevansi dan manfaat (4,15), pelaksanaan dan fasilitasi (4,17), serta hasil dan dampak (4,20). Guru merasakan peningkatan dalam kepercayaan diri dan kesiapan mereka untuk membuat materi pengajaran yang inovatif, meskipun beberapa memerlukan waktu dan dukungan tambahan untuk penguasaan. Penelitian ini menyoroti pentingnya workshop dalam menjembatani kesenjangan antara teknologi dan pendidikan. Penelitian ini juga menekankan perlunya program pelatihan berkelanjutan serta kolaborasi antara pendidik, pembuat kebijakan, dan pengembang teknologi untuk meningkatkan kualitas pendidikan fisika berbasis STEM di Indonesia.

How to cite: Shintya, R.E., Irsalina, F.R., Muki, G.b., Putra, I.H., Ramadani, S., Fauzan, A.S., Zain, A.Z., Entang, E., Fauzan, M.R., & Nurlita, A.D. (2025). Empowering physics educators through technology-based teaching material workshops: A teachers' perspective. *Journal of Community Service and Empowerment*. 6(1), 175-185. https://doi.org/10.22219/jcse.v6i1.39637

INTRODUCTION

STEM (Science, Technology, Engineering, Mathematics)-based education has become a significant focus in various countries to address the challenges of the 21st century (Akudugu & Abagale, 2024). This approach aims to integrate various disciplines in learning to equip students with critical thinking, creativity, communication, and collaboration skills. One important aspect of implementing STEM is using technology as part of the learning process (Juškevičienė et al., 2021; Nikitina & Ishchenko, 2022). In physics education, technology can be used to develop interactive learning materials that improve conceptual understanding and arouse students' interest in science and technology (Prayogi & Verawati, 2024). However, the adoption of technology in developing physics teaching materials in Indonesia still faces various obstacles, especially regarding teacher readiness.

The results of a preliminary study conducted at 10 schools in Bandung City and West Bandung Regency revealed various significant challenges related to using technology-based learning materials in physics learning. Of the total 20 physics teachers involved in the observation, 70% stated that they could not optimally utilize technology-based learning materials in the classroom. The main obstacle reported was limited access to technological devices, where 60% of teachers stated that they did not have facilities such as laptops, projectors, or stable internet connections. In addition, 50% of teachers admitted that they did not understand the techniques and steps to develop interactive technology-based learning materials, such as simulations or special applications. Furthermore, the majority of teachers, namely 80%, felt that they had not received adequate training to support mastery of technology in physics learning. Interestingly, 40% of teachers also stated that the time available in their schedules was one of the obstacles to learning and developing technology-based teaching materials independently.

These findings confirm the deep gap between teachers' needs in STEM-based learning and relevant resources and training availability. In addition to the constraints of facilities and skills, the observation results also showed that 50% of teachers felt less confident in integrating technology into learning due to minimal support from the school, such as providing a unique budget for technology procurement or further training. This condition reflects that the challenges faced are technical and related to policies and work culture in the school environment. With these challenges, it becomes increasingly clear that an innovative, comprehensive, and needs-based training approach is needed. This training must be designed to bridge the gap by providing practical guidance, strengthening teacher competencies, and creating collaboration between teachers, technology developers, and policymakers. This more systematic approach is expected to encourage broader, planned, and practical application of technology in physics education.

Although many studies have highlighted the importance of technology in physics learning, such as the use of Augmented Reality, Kahoot, and interactive multimedia (Astuti et al., 2021; Cai et al., 2021;Rahmat et al., 2023; Yulianci et al., 2021), only a few have focused on the teacher's perspective in developing technology-based learning materials. Teachers are the main actors in implementing technology-based learning and play a crucial role in learning. As mentors and facilitators, teachers not only provide feedback and support needed by students throughout the learning process but also have a great responsibility in developing technology-based learning materials, although their involvement in the process is often limited (Basilotta Gómez-Pablos et al., 2017; (Lai et al., 2016). Many teachers feel less confident or lack the technical skills to use technology effectively in learning (Anderson & Putman, 2020; Dinc, 2019; Kafyulilo et al., 2016;Winter et al., 2021). This indicates a gap in the literature on how teachers view their role in developing technology-based learning materials. This study aims to fill this gap by exploring teachers' perspectives on exhibition and workshop activities for the development of technology-based physics learning materials.

Exhibition and workshop activities can empower teachers to integrate technology into the learning process (McKnight et al., 2016). However, studies that specifically evaluate the effectiveness of such activities in the context of technology-based physics education are still minimal. Most studies focus on student learning outcomes without considering teachers' views and experiences as important components in successfully implementing technology-based learning. This study presents a new approach by exploring how teachers evaluate the benefits and impacts of the exhibition and workshop.

The uniqueness of this exhibition and workshop program lies in its collaborative and innovative approach that combines educational theory with the latest technology applications. The program focuses on improving teachers' technical skills and provides hands-on experience through an exhibition of technology-based teaching materials designed to support STEM-based physics learning. Designed by physics education master's students who deeply understand pedagogy and learning needs in the field, this program serves as an important bridge between academic research and real-world practice. In addition, this activity integrates various interactive learning tools and methods, such as the Physics Lab Mobile digital physics simulation application, Articulate Storyline, and LiveWorksheets software, as well as innovative technologies such as Google Sites, Augmented Reality (AR), and technology-based educational games. This approach provides practical experience that enriches teachers' insights and increases their readiness to adopt technology in the classroom. Since this method is rarely applied in teacher training in Indonesia, this program offers significant added value in improving the quality of physics education.

In addition to providing practical experience, this activity is designed to explore teachers' needs and views in more depth. The main questions raised in this activity cover several important aspects: (1) To what extent do physics teachers

understand the material presented in the technology-based learning materials development workshop? (2) How do teachers perceive the relevance and benefits of this workshop in supporting technology-based learning in their classrooms? (3) How do teachers evaluate the effectiveness of the implementation and facilitation of the workshop? (4) What is the real impact of the workshop on teachers' ability to integrate technology into physics learning materials in the classroom? These questions are designed to provide a comprehensive picture of teachers' experiences, needs, and challenges. With this systematic approach, this activity will provide short-term impacts in the form of increased technical skills and create long-term changes in the quality of technology-based physics learning in schools.

This activity's results are expected to significantly impact the development of a more effective and appropriate training model for physics teachers. By understanding the views and needs of teachers, training program developers can design activities that are more relevant and oriented toward improving teachers' practical abilities. In addition, this activity emphasizes the importance of collaboration between technology developers, educators, and policymakers in encouraging technology integration in education. In the long term, teacher empowerment through exhibitions and workshops is believed to improve the quality of physics learning in the classroom, creating a more dynamic and interactive learning experience for students (Mbowane et al., 2017). Teachers who are skilled in utilizing technology will be better able to encourage STEM-based learning, which is essential for building the skills of the younger generation in the digital era (Elstad & Christophersen, 2017; Fatimah & Santiana, 2017; Jääskelä et al., 2017).

Furthermore, this study addresses the main challenges that have hampered technology adoption in physics learning. Limited access to technological devices (Azlan et al., 2020; Fidan & Tuncel, 2021), lack of technical training for teachers (Falloon, 2020) and resistance to changes in teaching methods (Li & Austria, 2023; Souheyla & Nassima, 2022) are the focus of attention that can be addressed through this program. By documenting teachers' experiences, this study provides a basis for developing more inclusive and future-oriented education policies. This effort aligns with SDG 4: Quality Education, which seeks to ensure inclusive, equitable, and high-quality education and promote lifelong learning opportunities for all. Achieving this vision, particularly in physics education, calls for innovative approaches—one of which is STEM-based instruction. This approach necessitates the close integration of technology and pedagogy to foster engaging, future-oriented learning environments (AlAli, 2024; Dominguez et al., 2023). Teachers have a strategic role as the main link between technology and students, so learning success depends significantly on how much they are empowered and involved in developing technology-based learning materials (Gamage et al., 2022).

To effectively support and sustain this role, it is essential to embed technology within a broader framework of continuous professional development. Integrating information technology into lifelong education systems can provide enriched digital resources, intelligent data analysis, and adaptive online environments that enhance the effectiveness of teacher learning (Zhang et al., 2024). Moreover, establishing a lifelong learning mechanism rooted in the principles of quality education can significantly advance teachers' professional growth, improve educational quality, and nurture future-ready learners with strong innovative and practical capabilities (Qi, 2024). This is in line with one of the SDGs programs number 4, i.e. quality education, ensuring inclusive and equitable quality education and promote lifelong learning opportunities for all (sdgs.un.org).

This study contributes to developing academic literature and practical solutions to improve the quality of physics education in the digital era. By documenting teachers' experiences, this study is expected to strengthen awareness of the importance of supporting teachers in facing the challenges of technology-based learning. In addition, the findings can serve as a foundation for the formulation of more relevant, effective, and sustainable education policies and training initiatives. Through this approach, technology-based physics education can act as a catalyst for innovation in science and technology, while equipping students to thrive in an increasingly complex and competitive global landscape.

METHOD

The method used in this study is a descriptive survey research method. Descriptive survey research aims to understand the relevance of a phenomenon and describe its incidence within a population (Zheng et al., 2020). In this study, the survey method was employed to identify and describe teachers' perceptions of the “Workshop on Developing Technology-Based Physics Teaching Materials” that was held in Bandung Barat. By using this approach, the research systematically captured data on how participants perceived the workshop’s content, implementation, and outcomes.

This study employed purposive sampling to select participants, focusing on 51 physics teachers who actively participated in the workshop located in Bandung Barat. As Fowler (2014) highlights, purposive sampling is suitable for targeting individuals with specific expertise or direct experience relevant to the research objectives. This ensured that the selected participants were knowledgeable about the activities and technologies introduced during the workshop.

The primary survey instrument was a structured questionnaire, which was carefully designed in accordance with Dillman et al. (2014). Dillman emphasizes the importance of crafting survey instruments with attention to question wording, order, and response options to minimize bias and maximize response quality. The questionnaire consisted of 20 Likert-scale items (ranging from 1 = strongly disagree to 5 = strongly agree) that measured four key aspects shown by Figure 1.

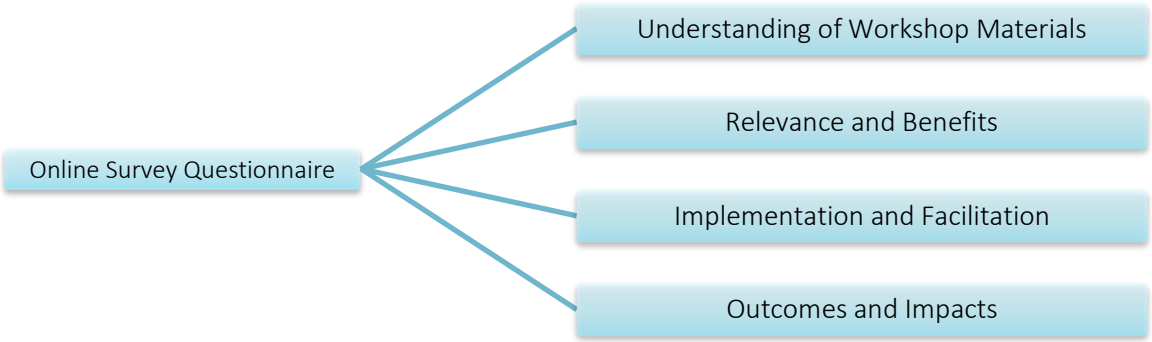

Figure 1. Key Aspects of the Questionnaire

The questionnaire aimed to evaluate both general workshop effectiveness and specific aspects, such as the integration of technologies, including Augmented Reality, Physics Mobile, Live Worksheet, Digital Games, Google Sites, and Articulate Storyline. This aligns with the principles outlined by Dubin, Malhotra, and Wacker, which emphasize the need to comprehensively capture participants' perceptions of a phenomenon's relevance.

Data analysis involved the use of descriptive statistics to calculate mean scores for each aspect, providing insights into the strengths and areas for improvement. Scoring ranges were predefined to offer a structured interpretation of the results (Creswell & Creswell, 2018), ensuring meaningful feedback for enhancing future workshops and supporting the integration of technology into physics teaching practices.

RESULTS AND DISCUSSION

A Workshop on the Development of Technology-Based Physics Learning Materials was conducted, focusing on the integration of advanced technologies such as Augmented Reality, Physics Mobile, Live Worksheets, Digital Games, Google Sites, and Articulate Storyline into physics teaching materials. The program comprised three main stages, carefully designed to ensure participants' comprehensive understanding and application of these technologies.

The first stage involved material briefings and workshops on how to develop learning materials using the specified technologies. During this stage, participants received both theoretical and practical knowledge on integrating technology into teaching practices, accompanied by in-depth demonstrations and hands-on activities. The second stage was a mentoring phase, where participants worked in groups to develop their teaching materials, present their progress, and receive feedback and guidance from assigned tutors. This stage emphasized collaboration and continuous refinement to perfect the developed teaching materials. The third stage was the presentation of the final products, where participants showcased the learning materials they had developed through an online session. This session provided an opportunity for participants to explain their designs and receive input from peers and facilitators.

After completing these three stages, a survey was conducted to gather teachers' perspectives on the workshop. The survey used a questionnaire consisting of 20 statements measured on a 5-point Likert scale, ranging from "Strongly Disagree" to "Strongly Agree." It was designed to evaluate participants' understanding of the material, the relevance and benefits of the technologies, the implementation and facilitation of the workshop, as well as its outcomes and impact on physics teaching. Based on the survey results, the average score for each aspect was analyzed using predetermined scoring guidelines to provide a more detailed interpretation of the teachers' perceptions of the workshop (as shown in Tables 1–4).

Table 1 Scoring Guidelines for the Aspect of Workshop Material Comprehension

Average Score Range	Description
1.0 - 1.4	Poor: Participants had significant difficulty understanding the workshop material. The material was either too challenging or presented unclearly.
1.5 - 2.4	Fair: Participants understood some of the material but still required intensive guidance for implementation.
2.5 - 3.4	Good: Participants understood the material well and felt reasonably confident in applying it.
3.5 - 5.0	Excellent: Participants fully comprehended the material and were able to apply it independently.

Table 2 Scoring Guidelines for the Aspect of Relevance and Benefits

Average Score Range	Description
1.0 - 1.9	Poor: The learning media were deemed irrelevant and did not adequately support the needs of physics instruction.

Average Score Range	Description
2.0 - 2.9	Fair: The learning media were moderately relevant but required adjustments to meet the needs of physics instruction.
3.0 - 4.4	Good: The learning media were relevant and significantly beneficial in enhancing the quality of instruction.
4.5 - 5.0	Excellent: The learning media were highly relevant and optimized to effectively support physics instruction in the classroom.

Table 3 Scoring Guidelines for the Aspect of Implementation and Facilitation

Average Score Range	Description
1.0 - 1.9	Poor: The workshop implementation was highly inadequate, with numerous technical issues and insufficient facilitation.
2.0 - 2.9	Fair: The implementation was moderately effective, but some challenges reduced the overall effectiveness of the activity.
3.0 - 3.9	Good: The workshop was well-executed, with adequate facilities to meet participants' needs.
4.0 - 5.0	Excellent: The workshop was executed exceptionally well, with optimal facilitation and smooth activity flow.

Table 4 Scoring Guidelines for the Aspect of Outcomes and Impact

Average Score Range	Description
1.0 - 1.4	Poor: The outcomes were inadequate, and participants were unable to produce usable learning media.
1.5 - 2.4	Fair: The outcomes were moderately satisfactory, but participants required additional guidance to achieve better results.
2.5 - 3.4	Good: The outcomes were adequate, and participants were able to produce learning media with minimal revisions.
3.5 - 5.0	Excellent: The outcomes were highly satisfactory, with participants producing high-quality learning media.

The analysis of the survey results provides a clear overview of teachers' perceptions regarding various aspects of the Technology-Based Physics Teaching Material Development Workshop. Each aspect was assessed based on the average scores of the questionnaire items. Specifically, the average scores for each statement in the questionnaire reflect a more detailed evaluation of the components being assessed. This data highlights the key strengths of the workshop while also offering insights into areas that can be improved in the future. Table 5 below presents the average scores for each questionnaire item across the evaluated aspects:

Table 5 Average Scores of Questionnaire Statements Based on Assessment Aspects

No	Questionnaire Statements	Average
	Aspect: Understanding of Workshop Materials	
1	I understand the objectives of this activity in enhancing teachers' competence in developing technology-based learning materials.	4.27
2	The materials presented in the workshop align with the needs of physics education in high schools.	4.31
3	The explanation of using Augmented Reality in physics learning greatly improved my understanding.	4.31
4	Training on the development of teaching materials using Physics Mobile was easy to understand and implement in the classroom.	4.27
5	The material on Live Worksheet provides a creative solution for creating interactive practice questions.	4.27
	Average	4.29
	Aspect: Relevance and Benefits	
6	This activity is relevant to technological advancements required in education today.	4.12
7	I found this training to provide valuable new insights for physics learning.	4.12
8	The implementation of media like Google Sites simplifies the organization of learning materials.	4.20
9	The material on Articulate Storyline is very helpful for creating engaging and interactive learning materials.	4.20

No	Questionnaire Statements	Average
10	I feel confident applying the results of this training to improve the quality of education in my school.	4.12
	Average	4.15
	Aspect: Implementation and Facilitation	
11	The workshop committee and facilitators provided adequate assistance during the activity.	4.12
12	The duration of the workshop was sufficient to learn each topic presented.	4.24
13	I felt comfortable participating in this activity due to the conducive environment.	4.24
14	Group discussions helped me understand the materials more thoroughly.	4.14
15	The tools and media used during the activities supported the training smoothly.	4.14
	Average	4.17
	Aspect: Outcomes and Impacts	
16	The results of this activity motivated me to continue developing technology-based learning materials.	4.27
17	The learning products produced during the workshop met the standards of physics education.	4.27
18	I feel confident using the teaching materials developed during this activity in my classes.	4.14
19	This workshop enhanced my skills in utilizing technology for teaching.	4.14
20	I would recommend similar activities to fellow teachers.	4.18
	Average	4.20

After reviewing the average score analysis for each item in the questionnaire, it is clear how teachers perceive various aspects of the Physics Teaching Materials Development Workshop Based on Technology. The data provides useful insights into the effectiveness and relevance of the materials presented, as well as the participants' reception of the use of technology in teaching. To gain a deeper understanding, the following discussion will explore each assessment aspect in more detail.

Understanding of Workshop Materials

The aspect of understanding workshop materials reflects the extent to which participants comprehended the concepts and technical use of the technology introduced during the event. The following documentation was obtained during the event:

(a) (b)

(c) (d)

(e) (f)

Figure 1. Workshop activities: (a) Articulate Storyline; (b) Live Worksheets; (c) Augmented Reality; (d) Google Sites; (e) Mobile Physics; and (f) Digital Games.

After the teachers participated in the workshop, a questionnaire was administered to find out how the teachers' perspectives on the workshop were, resulting in an average score of 4.29, indicating that the teachers showed a very good understanding of the training content. This average also indicates that the comprehension aspect met participants' expectations, especially in terms of their mastery of basic concepts and their ability to implement the technologies taught. This is supported by the evaluation of the five indicators, all of which received high scores ranging from 4.27 to 4.31. The highest mean scores (4.31) were obtained in indicators 2 and 3, which relate to the technical understanding of applications such as Augmented Reality and Mobile Physics. This indicates that these technologies were presented in a clear and practical manner, enabling participants to understand their effective use.

However, some indicators received slightly lower average scores, specifically 4.27 for items 1, 4, and 5. This may suggest that, although the material was well-delivered, some teachers might require additional time or training to fully master the use of these technologies independently. Time constraints could hinder users from achieving knowledgeable, accurate, and efficient use of the technology, which is crucial for genuine mastery (Gleaton et al., 2023). Thus, implementing effective time management strategies becomes essential. Adopting time management strategies can help users allocate time more efficiently to learn and master the technology. Techniques such as breaking tasks into smaller, manageable parts and setting clear timelines can alleviate feelings of time scarcity and enhance focus (Holmes, 2023; Tupchenko, 2021). Additionally, the cognitive load imposed by technology-based learning environments can also pose a barrier. High cognitive demands may overwhelm users, making it difficult to process and retain new information, thus hindering mastery (Slava & Tzu-Chien, 2015). The shift from paper-based reading to digital reading has introduced complexities that can result in cognitive overload. The non-linear nature of hypertext requires readers to navigate and integrate information from multiple sources, which can overwhelm working memory and impede comprehension (Omar Taky-eddine & Redouane Madaoui, 2024). This overload can lead to stress, anxiety, and digital fatigue, further obstructing learning and retention (Masrek & Baharuddin, 2023).

Relevance and Benefits

This aspect evaluates the relevance of the instructional technologies introduced during the workshop to the teachers' needs in managing physics learning in the classroom and the perceived benefits after participating in the workshop. With an average score of 4.15, teachers' perceptions indicate that technologies such as Google Sites, Articulate Storyline, and

Digital Games are considered good to very good in supporting learning. The highest average score, 4.20, for indicators 8 and 9, reflects that teachers recognize the tangible benefits of these technologies in enhancing the interactivity and effectiveness of physics lessons. This also suggests that these technologies align well with the demands of technology-based learning.

This relevance aligns with the STEM (Science, Technology, Engineering, and Mathematics) approach, which emphasizes the integration of technology to promote interactive, contextual, and problem-solving-based learning. Technology plays a pivotal role in STEM education by providing tools that facilitate interactive learning (Topsakal et al., 2022). By leveraging technologies such as Google Sites, Articulate Storyline, and Digital Games, teachers can integrate science and technology aspects into physics learning, increasing student interest and improving conceptual understanding. Indirectly, teachers have utilized technology to enhance student engagement and comprehension to achieve optimal learning goals (Wang et al., 2022).

On the other hand, the average scores for indicators 6, 7, and 10 are 4.12, which still indicate positive perceptions but are slightly lower than other indicators. This may be because certain technologies, such as Live Worksheets, require additional adjustments to fit the context of physics learning. Teachers may need more specific examples of application relevant to their curriculum. Nevertheless, the workshop has significantly benefited teachers by introducing them to the use of technology in teaching.

In this context, technologies like Live Worksheets or other digital tools can serve as supplementary media to create more interactive and contextual learning experiences. By integrating digital tools into contextual learning approaches, teachers can align educational content with students' daily experiences (Alfira et al., 2024; Uden et al., 2023). This alignment increases the relevance of the material, making learning more meaningful and engaging for students. Despite the challenges of adaptation, the implementation of STEM-based technologies has the potential to significantly enhance the quality of physics instruction (Martínez-Borreguero et al., 2022). The workshop's activities are expected to provide substantial relevance and benefits for teachers in developing STEM-based learning, particularly in physics, through the use of technology. STEM-based technologies offer opportunities for teachers to design learning projects that connect physics with other STEM disciplines (Tuveri et al., 2024).

Implementation and Facilitation

This aspect evaluates the implementation of the workshop, including the smoothness of the process, the preparedness of the organizing committee, and the support provided by facilitators during the workshop. With an average score of 4.17, the implementation is rated as good to very good. Indicators 12 and 13 recorded the highest scores of 4.24, indicating that technical facilitation and support during the training were perceived as highly optimal. Facilitators were deemed capable of providing adequate guidance, enabling participants to easily follow the flow of activities.

Slightly lower average scores were observed for indicators 11, 14, and 15, with scores ranging from 4.12 to 4.14. This may be attributed to minor technical issues or differences in participants' levels of understanding, which required more individualized attention. Despite this, the overall implementation of the workshop proceeded smoothly, and the facilitators successfully created a conducive environment for teachers to learn and engage in discussions. This reflects that the planning and organization of the workshop were executed effectively.

Results and Impact of the Activity

The aspect of results and impact reflects the extent to which teachers were able to produce technology-based learning media and the activity's effect on their competencies. An average score of 4.20 indicates that the outcomes of the activity were rated as very good. Indicators 16 and 17 achieved the highest scores of 4.27, suggesting that participants felt confident in implementing the learning media they developed, particularly using Augmented Reality and Articulate Storyline. This highlights that the training had a positive impact on teachers' abilities to create innovative teaching materials.

On the other hand, indicators 18, 19, and 20 received slightly lower scores, ranging from 4.14 to 4.18. This may indicate that, despite the overall excellent outcomes, some participants felt they needed more time to explore and develop their learning media further. Overall, the activity had a significant positive impact on enhancing teachers' competencies in utilizing technology, while also strengthening the implementation of technology-based learning media in the classroom.

CONCLUSION

The workshop on developing technology-based physics learning materials was perceived by participants as having a positive influence on their awareness, confidence, and understanding of using technology such as Augmented Reality, Physics Mobile, Live Worksheet, Google Sites, and Articulate Storyline in physics learning. The high level of participant satisfaction shows that this workshop is relevant to the needs of STEM-based learning and can increase teachers' confidence in integrating technology into the classroom. Although some teachers still need additional time and guidance to master the technology, this activity has been a significant initial step in empowering teachers to create learning

innovations. In the future, it is recommended that the duration of the workshop be extended or supplemented with further mentoring sessions to ensure in-depth understanding. Training materials can also be adjusted more specifically to the national physics curriculum to make their implementation more relevant. In addition, there needs to be collaboration with local governments, schools, and technology developers to support adequate facilities, such as hardware, software, and internet access. Developing a modular ongoing training program is also essential to provide more in-depth training in stages. Evaluation of the workshop's impact can be expanded by measuring the direct implementation of technology in the classroom and building a community of technology-based physics teacher practitioners to share experiences and solutions. These steps are expected to support the sustainability of technology implementation in physics learning in Indonesia and improve the quality of STEM education.

ACKNOWLEDGEMENT

The project team expresses their deepest gratitude to Physics Education Study Program, Faculty of Teacher Training and Education, Universitas Pendidikan Indonesia for the grant, funding, and steadfast support, which were pivotal in the successful implementation of this community service initiative. Led by the Master's students of Physics Education, Class of 2023, the program also greatly benefited from the collaboration and valuable contributions of the Musyawarah Guru Mata Pelajaran (MGMP) Fisika Bandung Barat Regency and our school partner, SMK Daarut Tauhiid Boarding School. We extend special thanks to the lecturer members from the Magister of Physics Physics Education Study Program, Faculty of Teacher Training and Education, Universitas Pendidikan Indonesia, for their guidance throughout the program. Lastly, we acknowledge the vital sponsorship from Majelis Telkomsel Taqwa (MTT), whose generous support significantly contributed to the success of this initiative.

REFERENCES

Akudugu, M. A., & Abagale, F. K. (2024). Building inclusive ethical cultures in STEM. In Hildt, E., Laas, K., Brey, E.M., Miller, C.Z (Eds), *Ethics education in science, technology, engineering and mathematics (STEM) in africa: A reflection on the successes, failures and the way forward in the era of a global pandemic.* Springer. https://doi.org/10.1007/978-3-031-51560-6_7

AlAli, R. (2024). Enhancing 21st century skills through integrated stem education using project-oriented problem-based learning. *GeoJournal of Tourism and Geosites*, *53*(2), 421–430. https://doi.org/10.30892/gtg.53205-1217

Alfira, A., Salmilah, S., & Suryani, L. (2024). Revolutionizing learning. *International Journal of Asian Education*, *5*(2), 141–149. https://doi.org/10.46966/ijae.v5i2.385

Anderson, S. E., & Putman, R. S. (2020). Special education teachers' experience, confidence, beliefs, and knowledge about integrating technology. *Journal of Special Education Technology*, *35*(1), 37–50. https://doi.org/10.1177/0162643419836409

Astuti, I. A. D., Bhakti, Y. B., Sumarni, R. A., Sulisworo, D., & Toifur, M. (2021). Flipped classroom and kahoot in physics learning: improving students' motivation learning. *International Journal of Educational Management and Innovation*, *2*(2), 175. https://doi.org/10.12928/ijemi.v2i2.3491

Azlan, C. A., Wong, J. H. D., Tan, L. K., A.D. Huri, M. S. N., Ung, N. M., Pallath, V., Tan, C. P. L., Yeong, C. H., & Ng, K. H. (2020). Teaching and learning of postgraduate medical physics using Internet-based e-learning during the COVID-19 pandemic – A case study from Malaysia. *Physica Medica*, *80*, 10–16. https://doi.org/10.1016/j.ejmp.2020.10.002

Basilotta Gómez-Pablos, V., Martín del Pozo, M., & García-Valcárcel Muñoz-Repiso, A. (2017). Project-based learning (PBL) through the incorporation of digital technologies: An evaluation based on the experience of serving teachers. *Computers in Human Behavior*, *68*, 501–512. https://doi.org/10.1016/j.chb.2016.11.056

Cai, S., Liu, C., Wang, T., Liu, E., & Liang, J. (2021). Effects of learning physics using augmented reality on students' self-efficacy and conceptions of learning. *British Journal of Educational Technology*, *52*(1), 235–251. https://doi.org/10.1111/bjet.13020

Creswell, J. W., & Creswell, J. D. (2018). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. Sage.

Dillman, D. A., Smyth, J. D., & Christian, L. M. (2014). *Internet, phone, mail, and mixed-mode surveys: The tailored design method.* John Wiley & Sons.

Dinc, E. (2019). Prospective teachers' perceptions of barriers to technology integration in education. *Contemporary Educational Technology*, *10*(4), 381–398. https://doi.org/10.30935/cet.634187

Dominguez, A., De la Garza, J., Quezada-Espinoza, M., & Zavala, G. (2023). integration of physics and mathematics in STEM education: use of modeling. *Education Sciences*, *14*(1), 20. https://doi.org/10.3390/educsci14010020

Elstad, E., & Christophersen, K.-A. (2017). Perceptions of digital competency among student teachers: contributing to the development of student teachers' instructional self-efficacy in technology-rich classrooms. *Education Sciences*, *7*(1), 27. https://doi.org/10.3390/educsci7010027

Falloon, G. (2020). From digital literacy to digital competence: the teacher digital competency (TDC) framework. *Educational Technology Research and Development*, *68*(5), 2449–2472. https://doi.org/10.1007/s11423-020-09767-4

Fatimah, A. S., & Santiana, S. (2017). Teaching in 21st century: students-teachers' perceptions of technology use in the classroom. *Script Journal: Journal of Linguistic and English Teaching*, *2*(2), 125. https://doi.org/10.24903/sj.v2i2.132

Fidan, M., & Tuncel, M. (2021). Developing a self-efficacy scale toward physics subjects for lower-secondary school students. *Journal of Baltic Science Education*, *20*(1), 38–49. https://doi.org/10.33225/jbse/21.20.38

Fowler, F. J. (2014). The problem with survey research. *Contemporary Sociology: A Journal of Reviews*, *43*(5), 660–662. https://doi.org/10.1177/0094306114545742f

Gamage, K. A. A., Ekanayake, S. Y., & Dehideniya, S. C. P. (2022). Embedding sustainability in learning and teaching: lessons learned and moving forward—approaches in STEM higher education programmes. *Education Sciences*, *12*(3), 225. https://doi.org/10.3390/educsci12030225

Gleaton, E., Parcell, E., Madera, M., Catrambone, R., & Walker, B. (2023). Understanding user perspectives: what is the meaning of technology mastery?. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *67*(1), 2490–2493. https://doi.org/10.1177/21695067231192628

Holmes, M. (2023). Time scarcity and student performance: instructional strategies for busy adult online students. *Canadian Journal of Learning and Technology*, *48*(3), 1–14. https://doi.org/10.21432/cjlt28357

Jääskelä, P., Häkkinen, P., & Rasku-Puttonen, H. (2017). Teacher beliefs regarding learning, pedagogy, and the use of technology in higher education. *Journal of Research on Technology in Education*, *49*(3–4), 198–211. https://doi.org/10.1080/15391523.2017.1343691

Juškevičienė, A., Dagienė, V., & Dolgopolovas, V. (2021). Integrated activities in STEM environment: Methodology and implementation practice. *Computer Applications in Engineering Education*, *29*(1), 209–228. https://doi.org/10.1002/cae.22324

Kafyulilo, A., Fisser, P., & Voogt, J. (2016). Factors affecting teachers' continuation of technology use in teaching. *Education and Information Technologies*, *21*(6), 1535–1554. https://doi.org/10.1007/s10639-015-9398-0

Lai, C., Yeung, Y., & Hu, J. (2016). University student and teacher perceptions of teacher roles in promoting autonomous language learning with technology outside the classroom. *Computer Assisted Language Learning*, *29*(4), 703–723. https://doi.org/10.1080/09588221.2015.1016441

Li, W., & Austria, R. S. (2023). Supervision and management of teaching quality of college teachers in h university. *Journal of Education, Humanities and Social Sciences*, *21*, 235–240. https://doi.org/10.54097/ehss.v21i.14010

Martínez-Borreguero, G., Naranjo-Correa, F. L., & Mateos-Núñez, M. (2022). Development of STEM instructional resources for teaching optics to teachers-in-training: influence on learning and teacher self-efficacy. *Education Sciences*, *12*(3), 186. https://doi.org/10.3390/educsci12030186

Masrek, M. N., & Baharuddin, M. F. (2023). Screens, streams, and stress: a qualitative study on how distance learning students cope with information overload. *International Journal of Membrane Science and Technology*, *10*(5), 47–58. https://doi.org/10.15379/ijmst.v10i5.2417

Mbowane, C. K., De Villiers, J. J. R., & Braun, M. W. H. (2017). Teacher participation in science fairs as professional development in South Africa. *South African Journal of Science*, *113*(7/8), 7. https://doi.org/10.17159/sajs.2017/20160364

McKnight, K., O'Malley, K., Ruzic, R., Horsley, M. K., Franey, J. J., & Bassett, K. (2016). Teaching in a digital age: how educators use technology to improve student learning. *Journal of Research on Technology in Education*, *48*(3), 194–211. https://doi.org/10.1080/15391523.2016.1175856

Nikitina, I., & Ishchenko, T. (2022). Implementation of stem education system in Ukraine. *Scientific Journal of Polonia University*, *51*(2), 108–114. https://doi.org/10.23856/5114

Omar Taky-eddine, & Redouane Madaoui. (2024). Cognitive overload in the hypertext reading environment. *International Journal of English Language Studies*, *6*(2), 94–100. https://doi.org/10.32996/ijels.2024.6.2.13

Prayogi, S., & Verawati, N. N. S. P. (2024). Physics learning technology for sustainable development goals (SDGs): a literature study. *International Journal of Ethnoscience and Technology in Education*, *1*(2), 155. https://doi.org/10.33394/ijete.v1i2.12316

Qi, J. (2024). Research on the construction of teachers' lifelong learning mechanism based on the concept of quality education. *Transactions on Comparative Education*, *6*(3). https://doi.org/10.23977/trance.2024.060304

Rahmat, A. D., Kuswanto, H., Wilujeng, I., & Perdana, R. (2023). Implementation of mobile augmented reality on physics learning in junior high school students. *Journal of Education and E-Learning Research*, *10*(2), 132–140. https://doi.org/10.20448/jeelr.v10i2.4474

Slava, K., & Tzu-Chien, L. (2015). Guest Editorial: Managing cognitive load in technology-based learning environments. Educational Technology & Society, . *Educational Technology and Society*, *18*(4), 1–8.

Souheyla, B., & Nassima, B. (2022). Taking the wave of digitalization: reflection on the psychological readiness of teachers in using information and communication technologies. *Arab World English Journal*, *8*, 121–135. https://doi.org/10.24093/awej/call8.8

Topsakal, İ., Yalçın, S. A., & Çakır, Z. (2022). The effect of problem-based STEM education on the students' critical thinking tendencies and their perceptions for problem solving skills. *Science Education International*, *33*(2), 136–145. https://doi.org/10.33828/sei.v33.i2.1

Tupchenko. (2021). Time-management as a pedagogical technology of students' educational activity. *Problemi Ìnženerno-Pedagogìčnoï Osvìti*, *73*. https://doi.org/10.32820/2074-8922-2021-73-138-144

Tuveri, M., Steri, A., Fadda, D., Stefanizzi, R., Fanti, V., & Bonivento, W. M. (2024). Fostering the interdisciplinary learning of contemporary physics through digital technologies: The "gravitas" project. *Digital*, *4*(4), 971–989. https://doi.org/10.3390/digital4040048

Uden, L., Sulaiman, F., Ching, G. S., & Rosales, J. J. (2023). Integrated science, technology, engineering, and mathematics project-based learning for physics learning from neuroscience perspectives. *Frontiers in Psychology*, *14*. https://doi.org/10.3389/fpsyg.2023.1136246

United Nations Department of Economic and Social Affairs. The 17 Goals. https://sdgs.un.org/goals

Wang, L.-H., Chen, B., Hwang, G.-J., Guan, J.-Q., & Wang, Y.-Q. (2022). Effects of digital game-based STEM education on students' learning achievement: a meta-analysis. *International Journal of STEM Education*, *9*(1), 26. https://doi.org/10.1186/s40594-022-00344-0

Winter, E., Costello, A., O'Brien, M., & Hickey, G. (2021). Teachers' use of technology and the impact of Covid-19. *Irish Educational Studies*, *40*(2), 235–246. https://doi.org/10.1080/03323315.2021.1916559

Yulianci, S., Nurjumiati, N., Asriyadin, A., & Adiansha, A. A. (2021). The effect of interactive multimedia and learning styles on students' physics creative thinking skills. *Jurnal Penelitian Pendidikan IPA*, *7*(1), 87–91. https://doi.org/10.29303/jppipa.v7i1.529

Zhang, Y., Ye, H., & Chen, H. (2024). Construction of a new lifelong education system based on vector analysis algorithms for information age services. *Computer Applications in Engineering Education*, *32*(6). https://doi.org/10.1002/cae.22774

Zheng, T., Ardolino, M., Bacchetti, A., Perona, M., & Zanardini, M. (2019). The impacts of Industry 4.0: a descriptive survey in the Italian manufacturing sector. *Journal of Manufacturing Technology Management*, *31*(5), 1085–1115. https://doi.org/10.1108/JMTM-08-2018-0269