

Strengthening Teachers' Competencies in Utilising ICT in Physics Experiment Activities and Developing Student Worksheets

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Abstract: The development of ICT brings new innovations in physics learning. Thus, the application of ICT needs to be trained to be mastered by teachers in physics education. The community service aimed to strengthen teachers' competencies in utilising ICT and training in developing student worksheets for physics experiments. The software includes PhET, Physical Phone Experiment, and Physics Toolbox. The implementation method included preparation, implementation, and evaluation stages. The activities on the first day (online) included introducing technology-based software as laboratory support and designing student worksheets to train students' skills. The activities on the second day (offline) involved direct training on software usage and student worksheet creation. On the third day (online), there were presentations of the student worksheets created by teachers. There were 110 participants in this community service, consisting of physics and science teachers from various Sumatera, Java, Kalimantan, and Sulawesi schools. The implementation of the community service utilised lectures, Q&A sessions, discussions, and demonstrations. The achievements of the community service included providing teachers with new knowledge and experiences in developing student worksheets. The validity results of the student worksheets created by teachers obtained an average percentage of 95.5%. This indicated that the community service activities positively impacted teachers and were highly effective.

Keywords: ICT; physics experiment; student worksheets; teacher competency

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Received: 22 November 2023

Accepted: 1 April 2024

Published: 12 July 2024

DOI : <https://doi.org/10.20527/btjpm.v6i3.10937>

How to cite: Achmad, G. P., Aini, N., Anwar, M.A., Mardian, V., Aryani, S. D., Sari, I. M., & Suhandi, A. (2024). Strengthening teachers' competencies in utilising ict in physics experiment activities and developing student worksheets. *Bubungan Tinggi: Jurnal Pengabdian Masyarakat*, 6(3), 505-519.

INTRODUCTION

Physics is a discipline built upon the interaction of theory and practice (Wilcox & Lewandowski, 2017). Therefore, physics learning in schools should not be limited to transferring theories to students but should also

include experiments to strengthen students' understanding of concepts. Experiment activities conducted by students include following, observing, analysing, and drawing conclusions about a particular object, situation, or process (Maknun, 2020; Nugraha et al.,

2023). Thus, teachers must prepare student worksheets before using experimental methods.

Student worksheets are crucial for laboratory activities as they help to make learning more focused and organised. Student worksheets also assist students in discovering new ideas (Bakri et al., 2020). According to Purwasi & Fitriyana (2020), student worksheets are the learning resources for students at school and at home. Student worksheets contain instructions or descriptions regarding the steps that students should take during experiments. Teachers can evaluate the progress of students' mastery of physics concepts based on their student worksheets (Choo et al., 2011). Thus, it can be concluded that student worksheets serve as learning material for students at school and at home, especially for conducting experiments.

Teachers should ideally be able to develop student worksheets that can enhance students' competencies. Teachers competent in conducting experiments can maximise facilities optimally, design suitable experiment activities, and even create simple experimental tools for learning (Nugraha et al., 2023). However, the laboratory conditions in some schools are still inadequate. The management of these facilities at one high school in Samarinda City has not been optimal due to a lack of resources, facilities, and professionalism (Annisa et al., 2023). A similar situation occurred at one high school in Kutai Barat Regency, marked by a lack of initiative among teachers to carry out experimental activities in teaching (Istinganah et al., 2021). Furthermore, the quality of experimental activities at one high school in Pangkajene and Kepulauan Regency remains low, there is a lack of laboratory manuals and student worksheets, and laboratory facilities as well as equipment are still used manually (Anggereni et al., 2021). Yet, choosing and using the right tools is crucial for

successful physics practice (Gunawan et al., 2019). Therefore, activities are needed to enhance teachers' abilities in designing experimental activities.

In connection with the above matters, a survey was conducted by distributing questionnaires to representative physics teachers from several regions in Indonesia. The questionnaire contained information regarding the need for training on experimental activities in physics learning. Seventy-seven respondents responded to representatives of various regions in Indonesia. Among the nine types of teacher needs mentioned based on literature studies, laboratory equipment training based on digital platforms is needed. More specifically, the required training includes Virtual Reality (VR) and Augmented Reality (AR) training, robotics and instrumentation training, physics laboratory management training, and training on experiments based on digital applications. The input from teachers is relevant, given the number of teachers who require training on laboratory equipment.

In response to the issues and needs of physics teachers mentioned above, alternative solutions are proposed to help teachers improve their competencies as well as the competencies of students, namely by utilising Information and Communication Technology (ICT) in physics education. Currently, ICT development brings new learning innovations, especially in physics (Bhakti et al., 2019). Research concludes that ICT-based learning can simplify abstract content and create student interest, thereby improving the quality of education (Ndihokubwayo et al., 2020). Compared to traditional methods that are teacher-centred, ICT is a very important tool to make learning in schools more engaging, interactive, and student-centred (Samaila et al., 2021).

Furthermore, the ICT utilisation discussed here involves virtual

laboratories, which can be used to support physics experiment activities and facilitate teachers and students in conducting practical work. Virtual laboratories are computer simulations that offer displays and functionalities similar to real-life experiments used as learning activities for students (El Kharki et al., 2021). This form of virtual practical work helps overcome the limitations of physical face-to-face experiments, such as equipment accessibility, location, and other economic issues. Additionally, implementing virtual practical work can create active learning, be used repeatedly, and apply preliminary experiments before actual experimentation (Rani et al., 2019). Studies have shown that virtual practical work can improve students' scientific literacy (Putri et al., 2021), bridge difficult and abstract concepts, and improve scientific inquiry self-efficacy (Husnaini & Chen, 2019) as well as enhance students' learning achievement (Masril et al., 2019; Verawati et al., 2022). Furthermore, several community engagement studies have trained the utilisation of virtual laboratory-based practical work for teachers and have yielded very positive responses as an alternative solution in physics education (Adam et al., 2021; Putri et al., 2021; Saputro et al., 2023; Tiandho et al., 2020; Wahyuni et al., 2022).

With the development of smartphones as part of technology, the use of mobile sensors in physics laboratory activities has also increased, and there are also virtual laboratories based on computer simulations (such as PhET simulations) that enable essential laboratory functions (Klein et al., 2021). An analysis of software usage in learning found three types of platforms that support physics experiments: PhET simulations, Physical Phone Experiment (later referred to as Phyphox), and Physics Toolbox. PhET Simulation is a simulation developed by

the University of Colorado. This simulation emphasises the relationship between real-world phenomena and the underlying science, supports interactive and constructivist approaches, provides feedback, and offers a creative workspace (Finkelstein et al., 2005). Meanwhile, Phyphox is an open-source application that utilises sensors already present in smartphones and produces real-time data and graphs (Yasaroh et al., 2021). Finally, Physics Toolbox is an application that utilises smartphone sensors to help students conduct experiments. The collected data can be accessed and shared for further analysis (Putri & Wahyudi, 2022).

Based on the need to strengthen teachers' competencies and the development of ICT, the next step is to conduct Community Service Activities (PKM) in the field of physics to enhance the competence of physics teachers in optimising physics experiments with the assistance of software and improve their proficiency in using relevant software to support experimental-based physics learning for high school physics teachers. Additionally, teachers need to be trained in designing student worksheets effectively.

METHOD

The Community Service Activity (PKM) implementation mechanism proceeded through three stages: preparation, implementation, and evaluation. The activity stages are outlined in Figure 1. The training activities utilised blended learning techniques. Blended learning was a learning strategy that integrated online activities with face-to-face classroom activities in a planned and pedagogically valuable manner, where some face-to-face time was replaced by online activities (Kaur, 2013). Training was conducted synchronously via Zoom Meeting and asynchronously through video recordings of software usage, where training participants could watch

the videos repeatedly and ask questions through a WhatsApp group between the facilitator and participants. The training

implementation method is shown in Figure 1.

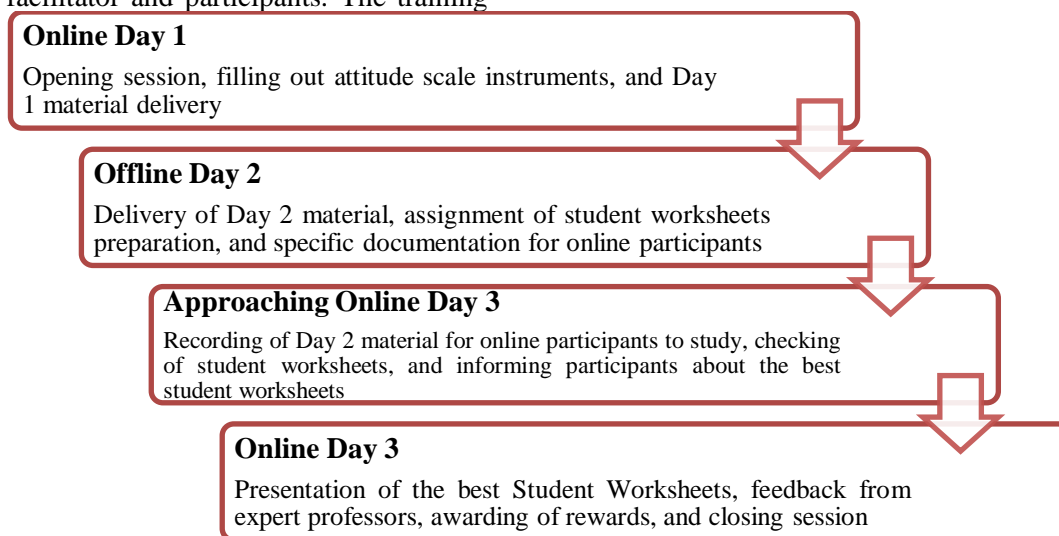


Figure 1 Training implementation methods

The activities of each stage are shown in the following details.

Preparation Stage

During this stage, coordination was carried out with the Bandung City Physics Teachers Forum (*Musyawah Guru Mata Pelajaran* or *MGMP*) and *SEAMEO QTIP* West Java. 110 participants attended the online training, consisting of physics teachers, science teachers, and students, while 26 participants attended the offline training, consisting of teachers from the Bandung Raya area. Figure 2 shows the distribution of training participants based on their domicile.

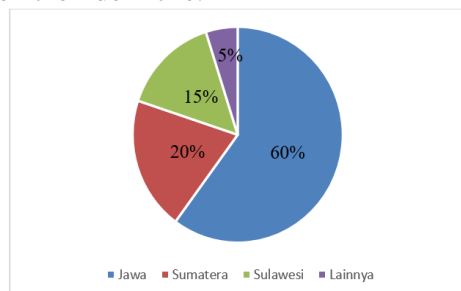


Figure 2 Distribution of training participants based on domicile

Implementation Stage

The training was conducted for three days starting from Friday, September 29, 2023, from 7:30 AM to 11:15 AM WIB via Zoom Meeting. Subsequently, the training was conducted offline on Saturday, September 30, 2023, from 8:00 AM to 12:00 PM WIB at the BBGP 2 Building in West Java for physics teachers residing in Bandung and Cimahi. Only participants from the Bandung Raya area attended the offline training. This was because the committee did not facilitate accommodation and transportation costs. However, all participants were provided with comprehensive guidelines and were included in a WhatsApp group with the committee so that the committee could respond quickly to participants' difficulties. Finally, the training was conducted again on Saturday, October 7, 2023, online via Zoom Meeting.

Evaluation Stage

The evaluation of the activities was measured through attitude scale instruments and assessment rubrics. Two types of attitude scales were used: open-ended and closed-ended scales. The

closed-ended attitude scale distributed on the first day aimed to explore difficulties and initial perceptions of using ICT in physics education using Likert scales, while the open-ended attitude scale aimed to determine teachers' expectations after the training. Then, attitude scales were also distributed on the third day to assess participants' responses to the presented material and their ability to create student worksheets, while the open-ended attitude scale was used to assess participants' responses to new knowledge and their impressions after the training. Additionally, assessment rubrics were used to evaluate the Student Worksheets produced by training participants after the activities on the second day, adjusted to the indicators of science process skills.

The instruments were distributed through Google Form before and after the training activities. The attitude scale data were analysed through descriptive qualitative analysis. Furthermore, the training facilitators assessed the results of participants designing student worksheets to train students' science process skills. These results represented the achievement of teachers' abilities in designing student worksheets. The achievement of teachers' abilities in composing student worksheets was processed into percentage scores based

on the assessment rubric. The percentage scores and their categories were based on Table 1.

Table 1 Criteria for the ability to compile student worksheets based on percentages

No.	Percentage	Criteria
1.	0% - 20%	Very Poor
2.	21% - 40%	Poor
3.	41% - 60%	Fair
4.	61% - 80%	Good
5.	81% - 100%	Excellent

RESULTS AND DISCUSSION

Teacher Perceptions

Before the training activities commenced, teachers were provided with an attitude scale regarding their initial perceptions of software and student worksheets. This attitude scale was filled out by 110 teachers via Google Forms initially. The distributed attitude scale aimed to identify teachers' difficulties and initial perceptions of using virtual laboratories in physics education. The attitude scale contained three statements about teachers' difficulties and five statements about teachers' initial perceptions, which could be answered using four levels of the scale: strongly disagree, disagree, agree, and strongly agree. The attitude scale response results are listed in Table 2.

Table 2 Attitude scale response results

No.	Statement	Sclae (%)			
		1	2	3	4
1.	I have difficulty determining the appropriate virtual lab to support physics learning.	12.7	21.8	52.7	12.7
2.	I have difficulty designing virtual lab student worksheets.	5.5	25.5	57.3	11.8
3.	I have difficulty designing virtual lab student worksheets to train various skills in physics learning.	5.5	20.0	60.0	14.5
4.	I have used PhET/Phyphox/Physics Toolbox as supporting software for physics learning in class less than three times.	15.5	27.3	41.8	15.5
5.	I have used PhET/Phyphox/Physics Toolbox as supporting software for physics learning in class more than three times.	13.6	32.7	35.5	18.2
6.	I believe using the PhET/Phyphox/Physics Toolbox can increase student motivation to engage in experiments.	1.8	6.4	46.4	45.5
7.	I believe PhET/Phyphox/Physics Toolbox can be a supportive solution in overcoming the limitations of real experiments.	0.9	7.3	37.3	54.5

No.	Statement	Scale (%)			
		1	2	3	4
8.	I believe using the PhET/Phyphox/Physics Toolbox can facilitate students in understanding physics concepts.	0.9	5.5	44.5	49.1

The results in Table 2 show that several findings were obtained from teachers' responses. Firstly, most teachers experienced difficulty in determining the appropriate virtual lab to support physics learning. Secondly, most teachers had difficulty designing virtual lab Student Worksheets. Thirdly, most teachers faced challenges in designing virtual lab Student Worksheets to train various skills in physics learning. Fourthly, most teachers who used the PhET/Phyphox/Physics Toolbox as support for physics experiments had done so less than 3 times in class. Fifthly, the frequency of teachers who had used all three software in class was almost the same as the frequency of teachers who had used them less than 3 times. Sixthly, teachers believed students would be more motivated to conduct experiments using PhET/Phyphox/Physics Toolbox. Seventhly, most teachers believed that these three applications served as solutions to support experiments when limitations of real experiments were encountered. Lastly, teachers generally agreed that all three software could facilitate students in understanding physics concepts.

The three components of disparity analysis included in needs analysis in the context of performance consisted of (a) determining the gap by comparing individual capabilities with previously established competency models, (b) analysing the causes of disparities by examining environmental and personal factors of individuals; and (c) determining the necessary training to reduce differences (Fu et al., 2013). Based on needs analysis and attitude scale instrument analysis, the appropriate training for teachers was to enhance their

abilities in using ICT in physics experiments and developing student worksheets. The aim of this training was to address the limitations of real experiments, increase students' motivation to learn and facilitate a comprehensive understanding of physics content.

The Process of Implementing Community Service Activities

Community service activities were one of the implementations of the three pillars of higher education. This activity was conducted for 48 credit hours for offline participants and 36 credit hours for online participants. Online activities were carried out nationally, while offline activities were more focused on teachers in the Bandung Raya area. The implementation of the first day's activities is shown in Figure 1.



Figure 3 Implementation of day one activities

Through this first activity, it was found that the participants already had insights into designing virtual lab Student Worksheets by training various skills, and most of them even had previous experience in applying various applications that would be trained during the training activities. The enthusiasm and curiosity of the participants to explore the existing tools in the applications were very high. This was evidenced when the speakers provided

material as an initial overview of the software to be trained directly in the offline session, which could be done interactively and bidirectionally even though it was conducted online. Based on the first training session, it became apparent that the training participants were eager to explore directly and receive intensive assistance regarding using the three applications. In various cases, the use of software has its allure to be learned, supported by the human need that cannot be separated from the use of various digital tools such as gadgets and

PCs (Johnson et al., 2022; Mejia-Puig et al., 2022).

On the second day of the training session, participants explored using software (PhET, Phyphox, and Physics Toolbox) offline. All training participants were divided into three classes, and each class was assigned one software to learn and apply. This session aimed to provide new knowledge to teachers, and it was expected that they could learn all three applications provided. The implementation of the second day's activities is shown in Figure 4.



Figure 4 (a) Implementation of day two activities (PhET simulation teaching), (b) Implementation of day two activities (phyphox teaching), and (c) Implementation of day two activities (physics toolbox teaching)

This session aimed to provide new knowledge and training to the participants with the hope that they could thoroughly explore the software they learned so that they could apply it in teaching at school to provide quality education to students. The PhET Simulation training session explored physics material related to building electrical analysis using provided devices such as PCs and PhET user guides. Meanwhile, in the Phyphox training session, participants learned about spring oscillations using software guides and real-life experiments that integrated the application as a data processing tool. Additionally, in the Physics Toolbox training session, participants delved into the concept of sound waves, further exploring the use of mobile sensors within it.

The activities in the third session were conducted on October 7, 2023, aiming to provide feedback to the training participants who had designed student worksheets to train students' science process skills. The training participants had the opportunity to present the results of the student worksheets they had worked on for approximately one week during this session, as shown in Figure 5.

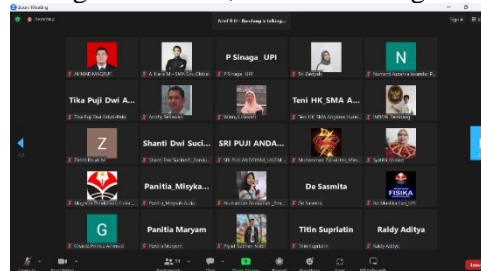


Figure 5 Implementation of activities on day 3

The Physics Toolbox Student Worksheet product is shown in Figure 6.



Figure 6 The physics toolbox student worksheet product

Figure 6 showed the results of participants' "Student worksheets on sound waves based on the physics toolbox application" by applying science process skills indicators. Overall, the developed product met the assessment criteria. Some emphasised points according to the evaluators, in this case, the physics lecturers, included the need to present brief questions that guided the progress of the experiment with the aim of not causing misunderstandings among students during the data collection process. Additionally, providing examples of correct data collection was necessary before students collected data independently or in groups. In the hypothesis section, teachers could add numbers, such as the distance between objects and measurement tools, to help students recognise the relationship between physics phenomena more easily. The PhET simulation student worksheet product is shown in Figure 7.

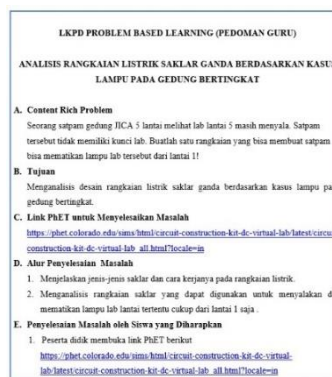


Figure 7 The PhET simulation student worksheet product

The participants' next work was titled "student worksheets on problem-based learning," as shown in Figure 7. The developed student worksheets were intended for application at the junior high school level, where students were accustomed to using computer simulations, including PhET. Teachers were advised to add other media, such as Arduino Uno, to demonstrate how to switch lights in multi-story buildings. Additionally, teachers could have introduced the working principle of batteries at the beginning of the lesson before using the developed student worksheets. This way, students could have understood the basic concepts of Ohm's Law and Kirchhoff's Law. The Phyphox student worksheets product is shown in Figure 8.

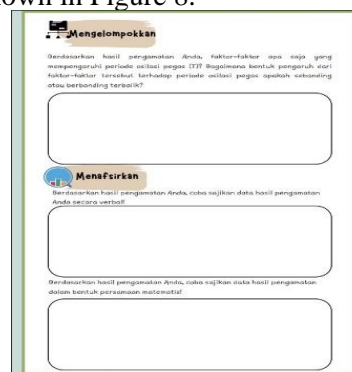


Figure 8 The Phyphox student worksheets product

The participants' other product was a student worksheet on vibrations assisted

by the Phyphox application (part of the student worksheet, as shown in Figure 8). The developed student worksheet applied science process skills indicators. Feedback from lecturers included the need for teachers to change the images that served as problem orientation, such as shock absorbers on the motor. This could have been addressed through problems presented in the student worksheet that were more realistic and had been experienced by students. Student worksheets for training science process skills meant that students were more independent in conducting experiments without direct guidance from the teacher, including making graphs. Teachers should have written down the requirements for using this student worksheet so that other teachers who would use the student worksheet would have an idea of what prerequisites needed to be fulfilled.

The main outcome of the participants was the student worksheets that would be used in physics learning. In working on the student worksheet products, teachers were given the freedom to choose the material to be applied in the student worksheets, with the note of integrating the software that had been learned.

Teachers who developed the Physics Toolbox Student Worksheet and the PhET Simulation student worksheet aimed to train students' science process skills, while teachers who developed the Phyphox student worksheet aimed to train students' problem-solving skills. The presented student worksheets received several responses from expert content and media lecturers. The training participants were very responsive following this session because they gained new insights about various content learned in school, especially in abstract physics concepts.

Achievements of Teachers' Ability in Compiling Student Worksheets

One of the outputs of this training was teachers' design of student worksheets. Overall, 32 student worksheets were designed by teachers from the three software. However, in this discussion, only seven of the best student worksheets were analysed. The analysis referred to was the analysis of the validity of student worksheets based on the assessment rubric by the expert team. The validation results of the participating students' worksheets are shown in Table 3.

Table 3 The validation results of participants' student worksheets

Student Worksheets				
No.	Supported by Software	Title of the Student Worksheet	%	Criteria
1.	Physics Toolbox	Sound Wave Worksheet	100	Excellent
2.	Physics Toolbox	Sound Intensity Level Worksheet Using Physics Toolbox	82	Excellent
3.	Phyphox	Spring Oscillation Science Process Skills-Worksheet Using Phyphox Application	100	Excellent
4.	Phyphox	Skill-Based Science Process Practicum Learning (<i>KPS</i>) Worksheet Using Phyphox Application	100	Excellent
5.	*PhET	Left-Behind Lamp Worksheet (Analysis of Building Electrical Circuit)	93.3	Excellent
6.	*PhET	Analysis of Double Switch Electrical Circuits based on the case of lamps in multi-story buildings	93.3	Excellent
7.	*PhET	Problem-Based Learning (Teacher's Guide) Worksheet	100	Excellent

Note: * science process skills problem-based laboratory

Table 3 shows the titles of the student worksheets designed by teachers and their validity results. The average validity percentage of the teacher's student worksheet products was 95.5%, placing them in the excellent category. This indicated that the teachers had understood the techniques of creating good student worksheets, especially for improving students' science process skills. The science process skills indicators included observation, prediction, hypothesis formulation, experiment design, experimentation, data interpretation, and drawing conclusions. There were two parts to the teacher-designed student worksheet products. First, student worksheets assisted by Physics Toolbox and Phyphox were created to train students' SPS. Second, student worksheets assisted by PhET

simulations were designed to train problem-based laboratory science process skills.

At the end of the activity, teachers were given a perception survey after receiving this training. A summary of teachers' responses, impressions, and feedback can be seen in Table 4. The responses provided by teachers were then identified into three aspects of training benefits: physics content, learning media, and pedagogical knowledge. Teachers gained ideas for developing more authentic physics content. With this training, teachers acquired new experiences and knowledge to design student worksheets with the help of supporting software. Additionally, teachers were also trained to develop student worksheets that could enhance students' science process skills. Participant responses after training are listed in Table 4.

Table 4 Participant responses after training

Participant Responses/Impressions	Training Benefits Aspect
The new thing I got from this workshop is about developing physics learning materials.	Physics content
Cool; hopefully, I can apply and develop learning activities at school.	Instructional media
I learned many new learning media and their usage.	Instructional media
Using software to aid physics learning is very interesting and can be applied to students, motivating them.	Instructional media + pedagogical knowledge
Alhamdulillah, I gained more knowledge to maximise the simulations available in PhET, especially for real problems or rich problem cases.	Instructional media + physics content
Physics Toolbox can be very useful for conducting experiments with a wider coverage area because almost all students have a smartphone. Even students can measure magnetic fields and noise levels, which I find extraordinary.	Instructional media + physics content + pedagogical knowledge
I am very happy to receive advice and input from the lecturers, I am now able to create student worksheets with a sharper context. Thank you very much.	Instructional media
It turns out that in PhET, there is curve fitting, so it can be used to create experimental graphs.	Instructional media
I am very lucky to have the opportunity to participate in this workshop and gain new knowledge from the great professors and master's students at UPI. Thank you, hopefully we can apply it well to the students in our schools.	Instructional media
I got a lot of inspiration and various adaptations of PhET in 21st-century skills and problem-solving.	Instructional media + pedagogical knowledge

Participant Responses/Impressions	Training Benefits Aspect
The Phyphox application is something new for me, and it provides innovation for school laboratory activities. I hope I can implement it in school so that students don't get bored with the usual laboratory activities, thus increasing their enthusiasm for learning and improving learning outcomes.	Instructional media + pedagogical knowledge
Suggestions/Input	
<p>It would be better for those not attending in person to join offline activities via <i>Zoom Live</i> or broadcast on <i>YouTube</i>. This was because it was difficult to imagine how to prepare the student worksheets task during the preparation.</p> <p>It is fun, just a bit short, and hopefully, more teachers will be involved in the offline activities. The workshop was very interesting. Unfortunately, I only had the opportunity to learn one, PhET, while Phyphox and Physics Toolbox were not understood yet. Hopefully, this workshop will be held again with a longer duration in the future.</p> <p>Please carry out this workshop every month.</p> <p>Please increase the number of physics workshops like this so that we, physics teachers wherever we are, can connect, update information, and gain additional knowledge in its application in the classroom. Hopefully the <i>WhatsApp</i> group can also become a place for sharing among the physics teachers.</p>	

Based on the feedback from participants who attended the training both online and offline, as shown in Table 4, overall, the participants gave positive responses to the implementation of the training activities because they gained a lot of new knowledge and experiences related to the use of digital or virtual-based experimental tools. According to (Ma'ruf et al., 2019), research, content, media, and pedagogy are inseparable components of learning that greatly influence students' learning outcomes. Participants acknowledged that the software (PhET, Physics Toolbox, and Phyphox) helped students understand physics concepts deeply when applied directly in classroom learning. Additionally, participants realised that the three trained software applications could support ICT-based experiments and overcome the limitations of experimental tools, making the use of software one of the options and solutions for the continuity of experiment implementation. Consistent with the review findings (Flegr et al., 2023), it was argued that real experiments in the laboratory and virtual ones using various software could be integrated

simultaneously and had been proven to train students' skills.

Implementing this training had several shortcomings, including the lack of facilities for conducting Zoom Live on the second day of the training. This affected the suboptimal completion of the teachers' student worksheet designs. Additionally, each participant's opportunity was limited to exploring only one application during the offline training session, based on the teams assigned directly by the training committee. However, this impacted participants' curiosity and the formation of cooperation to share information related to the applications they learned. Participants hoped for the continuity of training to be held periodically to enhance skills and knowledge related to using various software in experiments. From the feedback received, it could be seen that the demand for training on various software was significant in the field, influenced by the changing demands of education in each period. Teachers realised the need to sharpen their skills in using technology in learning, especially in physics. Physics was not only about various formula

derivations, leading to the perception that physics was a difficult and abstract subject. By integrating various software, interest in learning among students could be increased, and diverse learning opportunities could be provided (Banda & Nzabahimana, 2023).

CONCLUSION

Based on the results of the teacher competency strengthening training on ICT in physics experiments and the development of student worksheets for physics teachers in schools, several conclusions were drawn: (a) teachers needed training in using virtual labs; (b) teachers needed training on how to design a student worksheet to measure a student's skill; (c) the validity of the student worksheets produced by teachers was very good with an average score percentage of 95.5%; and (d) teachers felt the benefits of using software (PhET Simulation, Phyphox, and Physics Toolbox) as supports for physics experiments in schools. Subsequent community service activities were expected to include training on creating supporting physics learning media such as AR, VR, robotics, and instrumentation.

ACKNOWLEDGEMENT

Appreciation and gratitude are extended to all lecturers and students of the Physics Education Graduate Program, Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia, as both the organisers and participants of the training, who are high school teachers from various provinces in Indonesia. Gratefulness is also expressed to the Physics Education Graduate Program, Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia, through the community service as the funding source. Appreciation is extended to the Bandung City Physics Teachers Forum (MGMP) and SEAMEO QTIP West Java for their

cooperation, as well as to other parties who contributed to the success of this Community Service activity.

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