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Augmented Reality (AR) Based Science Learning Development Workshop to Improve ICT Literacy for Elementary School Teachers

Workshop Pengembangan Pembelajaran Sains Berbasis Augmented Reality (AR) untuk meningkatkan Literasi ICT Guru Sekolah Dasar

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Abstract

The Industrial Revolution 4.0 demands that teachers master ICT literacy, but many teachers still have difficulty integrating technology into learning. This Community Service Program addresses this gap by conducting Augmented Reality (AR)-based training for 31 primary school teachers in the Teacher Working Group (TWG) of Primary School Region 6, Gedong Tataan District, Indonesia. The training was conducted in three stages: Preparation, Training, and Post-Training. The workshop results showed that AR integration significantly improves digital literacy, creativity, and the ability of teachers to develop interactive learning media. The teachers showed increased proficiency in using, creating, and integrating ICT-based learning materials, especially AR applications for science education. This initiative highlights the potential of AR technology in improving teacher competence and promoting innovative teaching strategies. These findings emphasise the importance of AR-based training in preparing educators to face the demands of 21st-century learning.

Keywords*: ICT Literacy, Augmented Reality, Teacher Training, Educational Technology*

Abstrak

Revolusi Industri 4.0 menuntut para guru untuk menguasai literasi TIK, namun masih banyak guru yang masih kesulitan dalam mengintegrasikan teknologi ke dalam pembelajaran. Program Pengabdian Kepada Masyarakat (PkM) ini mengatasi kesenjangan ini dengan mengadakan pelatihan berbasis Augmented Reality (AR) untuk 31 guru sekolah dasar di Kelompok Kerja Guru (KKG) SD Wilayah 6, Kecamatan Gedong Tataan, Indonesia. Pelatihan ini dilakukan dalam tiga tahap: Persiapan, Pelatihan, dan Pasca Pelatihan. Hasil pelaksanaan loka karya menunjukkan bahwa integrasi AR secara signifikan meningkatkan literasi digital, kreativitas, dan kemampuan guru untuk mengembangkan media pembelajaran interaktif. Para guru menunjukkan peningkatan kemahiran dalam menggunakan, membuat, dan mengintegrasikan materi pembelajaran berbasis TIK, khususnya aplikasi AR untuk pendidikan sains. Inisiatif ini menyoroti potensi teknologi AR dalam meningkatkan kompetensi guru dan mempromosikan strategi pengajaran yang inovatif. Temuan ini menekankan pentingnya pelatihan berbasis AR dalam mempersiapkan para pendidik untuk menghadapi tuntutan pembelajaran abad ke-21.

Kata kunci*: Literasi ICT, Augmented Reality, Pelatihan Guru, Teknologi Pendidikan*

1. PENDAHULUAN

Development The development of technology in the Industrial Revolution 4.0 era has brought fundamental changes in various aspects of life, including in the education system (Rohman et al., 2023; Pratiwi et al., 2024; Rohman & Lusiyana, 2017). This transformation is often referred to as technological disruption, which has a direct impact on the skills that educators must have in facing educational challenges in the digital era (Sunyono et al., 2023; Pramudiyanti et al., 2023). Some essential skills that educators must master include digital-age literacy, inventive thinking, effective communication, and high productivity (Firdaus et al., 2024; Gürsoy, 2021). To ensure that learners can thrive in this digital ecosystem, educators must be able to facilitate

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technology-based learning, critical thinking, and collaborative work (Azzahra et al., 2023; Cakır, 2017; Griffin et al., 2015; Schwarzman & Buckley, 2019).

One of the competencies that needs to be strengthened in basic education is science literacy. Good science literacy enables learners to develop the ability to think logically, systematically, and creatively and to make decisions based on a strong understanding of science concepts (Rohman & Lusiyana, 2017; Novaristiana et al., 2019). Technology-based science education is a relevant approach to improving literacy (Rahmawati & Sulistyaningsih, 2021), given that children at the primary school level are still at the concrete operational stage in their cognitive development (Imanulhaq & Ichsan, 2022). In this case, Augmented Reality (AR) offers great opportunities to help students understand abstract science concepts with more concrete and interactive visualisations (Belmonte et al., 2019; Alamsyah et al., 2023; Eversberg et al., 2022; Fatimah et al., 2019; Rusli et al., 2023; Souza-Concilio & Pacheco, 2013).

The results of interviews with 15 teachers from the Elementary School Teacher Working Group (TWG) in Region 6, Gedong Tataan District, Pesawaran Regency, Lampung Province, revealed several main obstacles in the implementation of technology-based learning, namely: (1) lack of ICT-based teaching materials (modules, student worksheets, and interactive learning media), (2) low ICT literacy of teachers in technology-based science learning, and (3) limitations of teachers in developing innovative learning media. This finding is in line with a literature study which shows that limited access to technology and a lack of digital skills among teachers are the main obstacles to the implementation of technology-based learning (Law & Heintz, 2021; Radu, 2014; Thees et al., 2020).

In addition, interviews with 22 primary school students in the same area revealed that they had difficulty understanding complex and abstract science concepts. Some of the main challenges faced by students include (1) lack of concrete visualisation of science material, (2) difficulty in relating the concepts taught to real-life experiences, and (3) knowledge stored only in Short-Term Memory (STM) due to a lack of meaningful learning experiences. This shows that a more innovative learning approach is needed to overcome the gap between theory and practice in science learning.

Based on the background and issues above, this training aims to Develop an Augmented Reality (AR)-based science learning model to improve understanding of science concepts for elementary school students, improve teacher ICT literacy through AR-based learning innovation training, evaluate the effectiveness of using AR in science learning through classroom trials. The hypothesis proposed in the implementation of this workshop is that the application of Augmented Reality in science learning will improve students' understanding of science concepts, improve teachers' ICT literacy skills, and enrich students' learning experiences with more concrete and interactive visualisations.

The use of AR in learning has been widely studied in various global contexts. (Hariyono, 2023; Chen, S.Y. & Liu, S.Y. 2020; and Utama et al., 2024) state that AR can increase student engagement in learning, overcome the limitations of visualising abstract concepts, and improve the overall effectiveness of learning. However, challenges in its implementation also need to be considered, such as limitations in technological infrastructure, teachers' readiness to use AR, and the need for training and professional development for educators (Arici et.al 2019; Oranç & Küntay, 2019; Theodoropoulos & Lepouras, 2021).

Therefore, this workshop focuses on developing AR-based learning media and improving teachers' competence in applying this technology in the classroom. Thus, it is hoped that there will be significant changes in science learning practices at the primary school level that are more interactive and technology-based.

2. METODE

This workshop uses the practice method of training and socialisation discussion, with a descriptive quantitative approach to analyse the impact of the workshop on the development of augmented reality (AR)-based science learning on teachers‘ ICT literacy. The implementation of

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the activity is carried out in three main stages: pre-training, training (workshop), and post-training.

A descriptive quantitative approach is used to measure teachers' ICT literacy improvement based on predetermined indicators. The theoretical framework of this workshop is based on the concept of digital literacy (Gilster, 1997) and the integration of technology in learning (Mishra & Koehler, 2006 - TPACK Model), which emphasises the importance of technology skills in education. The technical implementation of the method in this service consists of three stages, namely:

1) Pre-training (preparation) stage

At this stage, the Community Service Team conducted an initial survey through interviews and questionnaires with teachers and students to identify problems in science learning in elementary schools, analyse teachers' needs for Augmented Reality (AR)-based learning media and group participants-based on literacy levels in the Elementary School Teacher Working Group in Region 6, Gedong Tataan District. Furthermore, the research team developed and divided tasks that would play a role in implementing Community Service.

2) Training Stage (Workshop)

The workshop involved 31 teachers from 10 primary schools who were members of the Teacher Working Group (TWG) in Region 6, Gedong Tataan District, Pasawaran Regency, Lampung Province. Lampung. The workshop was held for 5 days with 3 sub-themes related to (1) Introduction to Augmented Reality (AR), (2) AR development training for science learning, (3) Planning and organising science learning with AR, followed by product development. The training stage ended with teachers practising AR-based learning media products as an example of implementing science learning in schools packaged in micro-teaching. The community service team observed during the micro-teaching process to assess ICT literacy. The ICT literacy indicators assessed in the implementation of this training are presented in Table 1.

Tabel 1. Indicators of Assessment of ICT Literacy

Assessment Aspects	Indicators	Descriptors
ICT Literacy	Define	Teachers' ability to use digital devices to identify software menus and create AR visualizations.
		The ability of the teacher to convey and display the information needed for menus/tools in creating AR visualizations.
	Manage	The ability of teachers to use digital tools to apply and organize AR visualization development software.
	Integrate	The teacher's ability to translate and relay learning material information using AR visualization.
		The teacher's ability to combine information using AR visualization by the syntax of learning models.
	Create	The teacher's ability to create AR visualization for interactive learning.
		The teacher's ability to adapt and design AR visualization information in the digital sphere for interactive learning.
	Communicate	The teacher's ability to provide relevant information from AR visualization.

3) Post-Training Stage

In the Post-Training stage, the Community Service team analyses the data on teachers' ICT literacy scores obtained from observations during the micro-teaching process. In addition, the Community Service team evaluates the implementation of the training. All stages of the

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Community Service workshop on Augmented Reality (AR)-based science learning development can be seen in Figure 1.

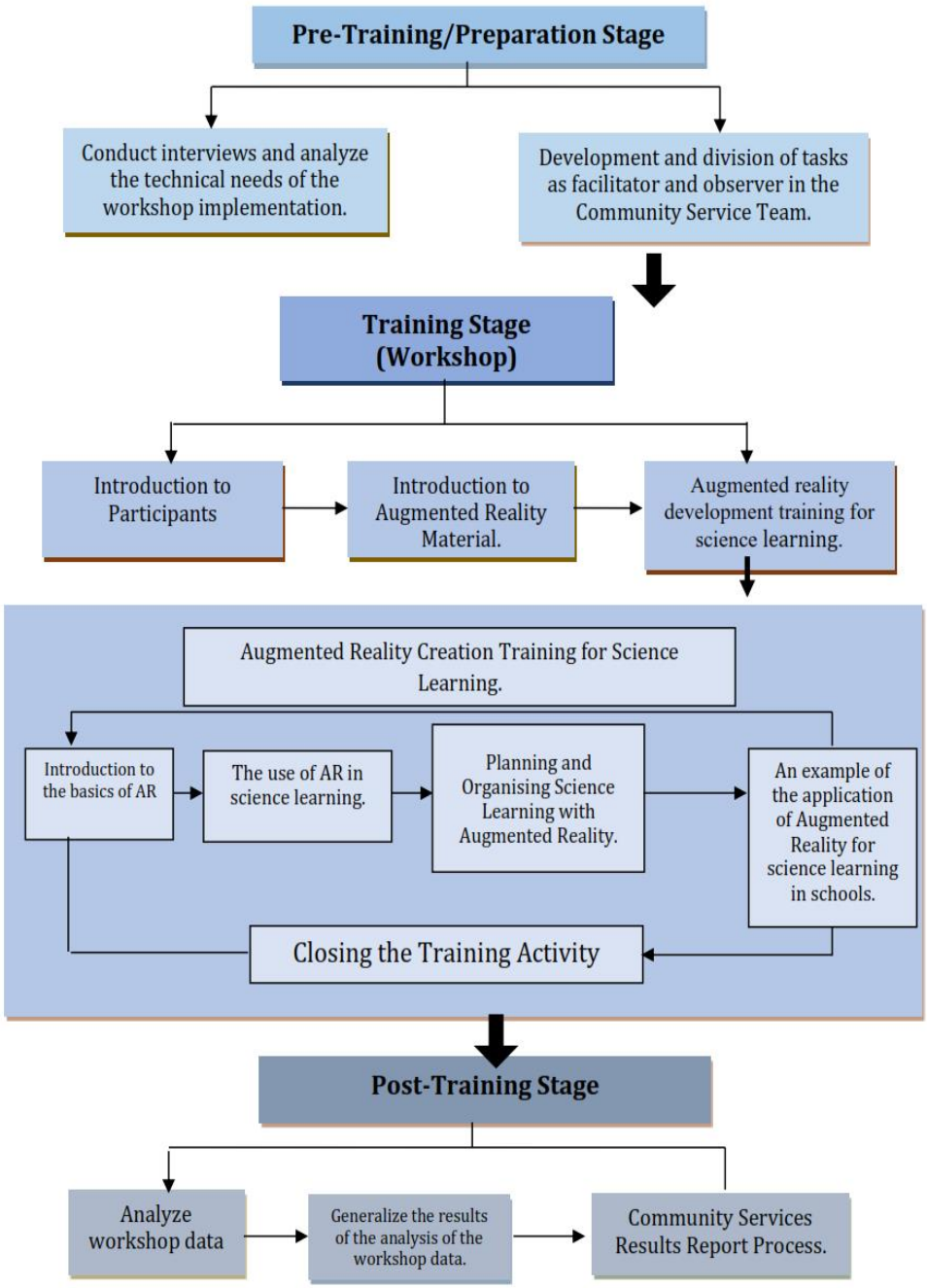

Figure 1. Community service stage of Augmented Reality (AR)-based science learning development workshop.

4) Analysis of Community Service Data

The data obtained in the implementation of the Training is analyzed quantitatively descriptively to see the average score and standard deviation of the five skills: (1) Define, (2) Manage, (3) Integrate, (4) Create, and (5) Communicate which are ICT Literacy indicators. The results of the descriptive quantitative analysis are categorized into five categories (very low, low, medium, high, and very high). The categorization is based on the assumption that the score of the subject population of participants in the Training is usually distributed, as shown in Figure 2.

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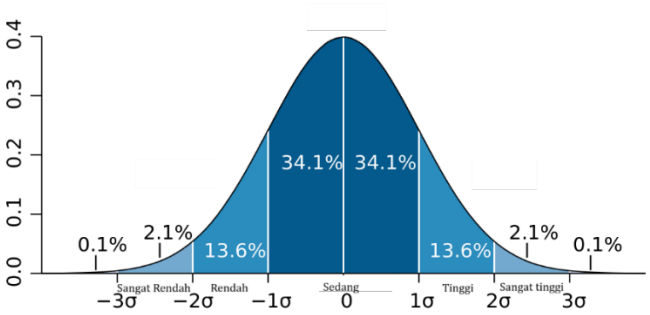

Figure 2. Normal distribution graph with a five-category scheme

According to Azwar, S. (2012), the guidelines that can be used are in Table 2 to categorise the measurement results into five categories.

Table 2. Guidelines for the five categories of ICT Literacy Indicators

No	Statistical formula	Statistical formula
1	Very Low	X < M – 1,5SD
2	Low	M – 1,5SD ≤ X < M – 0,5SD
3	Medium	M – 0,5SD ≤ X < M + 0,5SD
4	High	M + 0,5SD ≤ X < M + 1,5SD
5	Very High	M + 1,5SD ≤ X

3. RESULTS AND DISCUSSION

1) Workshop Implementation Results

The Augmented Reality (AR)-based science learning development workshop was held over five days, from 21 to 25 August 2023. The activity involved 31 teachers from 10 elementary schools (SD) who are members of the Teacher Working Group (TWG) Region 6, Gedong Tataan District, Pasawaran Regency, Lampung Province. The main focus of the workshop is 1) Introduction to Augmented Reality (AR), Participants are introduced to the basic concepts of AR and its use in learning; 2) AR development training for science learning, teachers are trained to use software in creating AR-based visualisations; 3) Planning and Organising science learning with AR, Teachers are taught how to integrate AR-based media into science learning; 4) Creation of AR-based science learning media, Teachers begin to create AR-based interactive learning media, 5) Micro teaching, Teachers apply the training results in simulation learning. During the workshop, the Community Service team observed the development of teachers' ICT literacy, which includes five leading indicators: Define, Manage, Integrate, Create, and Communicate. Workshop participants in the training process were consistently observed concerning the ICT literacy that was built, as seen in Figure 3.

Figure 3. Community Service Team Conducting an Augmented Reality (AR) Based Science Learning Development Workshop

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The Augmented Reality (AR)-based Science Learning Development Workshop was held from 21 to 25 August 2023. During the training process, members of the PkM team observed the improvement in ICT literacy obtained by teachers. The results of the observation of the ICT literacy assessment of Workshop participants can be seen in Table 3.

Table 3. ICT Literacy Indicator Assessment Results

Day to	Workshop materials/implementation	Average ICT literacy assessment of teachers				
		Define	Manage	Integrate	Create	Communicate
1	Introduction to the basics of AR	63,45	62,87	60,97	60,16	59,19
2	AR development training for science learning	70,13	69,65	66,81	66,13	64,58
3	Planning and Organising science learning with AR	75,13	74,81	72,03	71,35	69,84
4	Creation of AR-based science learning media	80,10	78,97	76,45	75,90	74,48
5	Micro teaching	85,10	83,32	81,23	80,94	80,45

Table 3 From this data, on the first day, the average ICT literacy score of the participants was still relatively low, with a score range of 59.19 to 63.45. This indicates that most teachers had difficulty understanding the basic concepts of AR and the use of supporting software. This finding aligns with previous literature studies, which show that applying new technology in education requires initial adaptation before participants can use it effectively (Azmi et al., 2024; Hwang et al., 2016).

On the second day, there was an increase in ICT literacy scores across all indicators, with the highest score of 70.13 on the Define indicator and the lowest score of 64.58 on Communicate. This increase shows that teachers are beginning to understand the basic features of AR, although they still have difficulty communicating and integrating technology into learning.

The average ICT literacy score on the third day increased from 69.84 to 75.13. This increase indicates that teachers are beginning to be able to relate the concept of AR to the learning model they use. This result is reinforced by a literature study from research by Noviansyah et al. (2022), which emphasizes that an understanding of learning syntax is essential in implementing AR technology in education.

Significant improvements were seen in all ICT literacy indicators on the fourth and fifth days. On the fourth day, the average score for the Define indicator reached 80.10, while the Communicate indicator reached 74.48. The fifth day showed the highest scores, with Define reaching 85.10 and Communicate 80.45. These results indicate that teachers have successfully used AR technology to design and deliver learning effectively. A significant increase in the achievement of ICT literacy indicators in each training session can be observed from the Curve Fitting data analysis results on the simple linear regression graph shown in Figure 3.

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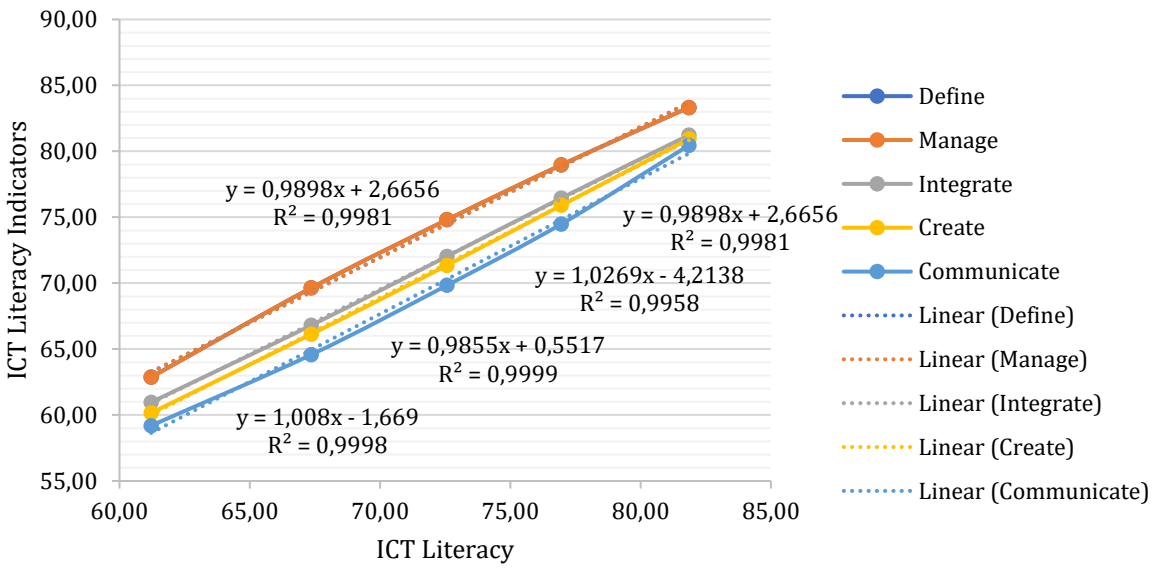

Figure 3. Results of ICT Literacy Data Fitting with Achievement Indicators in Five Days of Training

The results of the ICT literacy data fitting during the five days of training are shown in Figure 3. From a simple linear regression analysis, the R-squared value obtained is 0.999. Bevington and Robinson (1992) state that an R-squared value close to 1 indicates a very high level of consistency in the relationship between variables. Thus, these results confirm that the workshop has a significant impact on improving teachers' ICT literacy.

The distribution of ICT literacy achievement categories was also analyzed using five skill levels: very low, low, medium, high, and very high. The findings in Figure 3 show that on the first day, most teachers were in the low to medium category. The number of teachers in the high category gradually increased on the second and third days. On the fourth and fifth days, most participants had reached the high to very high category, especially in the Integrate and Create indicators.

Further analysis of the data on the achievement of the skills (1) Define, (2) Manage, (3) Integrate, (4) Create, and (5) Communicate is to determine the distribution of the five categories (very low, low, medium, high, very high). The categorization assignment refers to Table 2. The distribution results of the number of categories, very low, low, medium, high, and very high, the results of the Augmented Reality (AR) Based Science Learning Development Workshop can be seen in Figure 4.

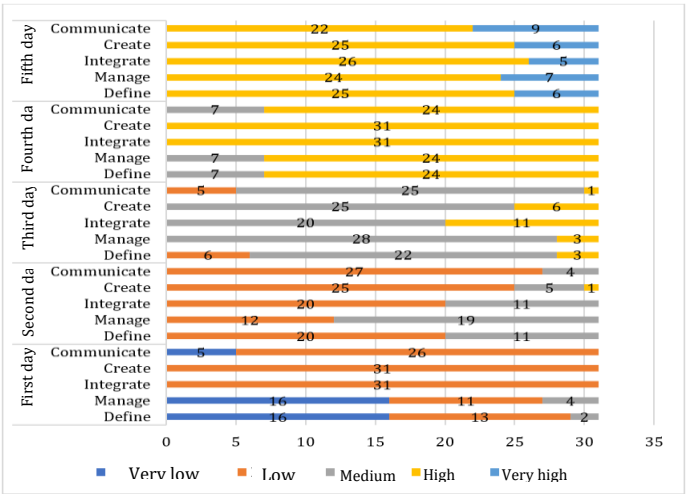

Figure 4. Distribution results of the number of categories in the ICT Literacy indicator

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Based on Figure 4, the findings show a significant distribution pattern of the five categories regarding the increase in ICT literacy indicator achievement from days 1, 2, 3, 4, and 5 of the training. The findings on the first day show that many teachers do not yet understand the basics of using AR for learning and are not yet able to create and integrate AR media for science learning. On the second day, some teachers had begun to understand the functions of the software tools used to develop AR-based visualization media for learning, but many teachers still experienced obstacles in creating AR-based learning media.

On the third day, the team presented material related to Planning and Organising science learning with AR. Figure 4 shows that for the indicator 'integrate,' 20 teachers with moderate ability and 11 teachers with high ability could translate and relay learning material information using AR visualization. The Community Service Team obtained the observation result that the teachers could combine information using AR visualization by the syntax of learning models. Noviansyah et al. (2022) mention that efforts to improve teachers' competence in designing augmented reality (AR) pedagogical abilities and a basic understanding of learning syntax must also follow media.

On the fourth day of the workshop, the community service team delivered material on creating AR-based science learning media. The workshop participants could integrate and create AR visual media for science learning; this can be seen explicitly in Figure 4 shows that on the Integrate and Create indicators, all workshop participants had a high categorization of ability. Teachers could create, adapt, and design AR visualization information for interactive learning.

The fifth day was conducted in a micro-teaching setting; the implementation of micro-teaching was aimed at implementing AR-based science learning media products in training classes. The implementation of this activity impacted the effectiveness of the Communicate indicator achievement. This can be seen from Figure 4, which shows that 22 participants had a high categorization and 9 participants had a very high categorization. The Communicate indicator achievement was higher than other ICT literacy indicators.

2) Discussion

The workshop results show that applying Augmented Reality (AR) in science learning improves teachers' ICT literacy and strengthens their skills in designing interactive learning media. Previous studies. Previous studies (Lampropoulos et al., 2022) have highlighted that using AR in education increases student engagement and understanding. However, not many studies have specifically evaluated its impact on improving teachers' ICT literacy, especially in the context of practice-based training. Therefore, this workshop contributes by quantitatively analyzing the improvement of teachers' ICT literacy in five days of AR-based training.

Teachers' ICT literacy improvement can be observed gradually over the five training days (Table 3). On the first day, the average ICT literacy indicator, as shown by the average value of the ICT literacy indicator, increased from 59,19-63,45 to 85,10-80,45 on the fifth day. This finding is in line with the Technology Content Knowledge (TCK) theory, which emphasizes that understanding technology in the context of learning materials is the main factor for successful technology integration (Fuada et al., 2020; Schmidt et al., 2009; Madanipour & Cohrssen, 2020).

The second day showed a significant improvement, with the average value of ICT literacy indicators increasing to 64.58–70.13. Teachers began to understand various software functions such as Unity 3D, Blender, Vuforia SDK, Corel Draw, Adobe Photoshop, and Android Studio. This supports the Technological Content Knowledge (TCK) theory, which states that understanding technology in the context of learning materials is a key element in the successful integration of technology (Lestari & Rahayu, 2023; Schmidt et al., 2009; Flores-Bascuñana et al., 2020; Madanipour & Cohrssen, 2020). This finding reinforces that a practice-based approach is more effective than a theory-based approach in technology training for teachers. In line with the Technological Pedagogical Content Knowledge (TPACK) model (Schmid et al., 2020), , the ability to integrate technology with pedagogy and content is essential in supporting the successful implementation of AR in learning (Mhlongo et al., 2023; Mishra & Koehler, 2006).

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On the third day, teachers' understanding of planning and organizing science learning with AR increased, with an average ICT literacy score of 69.84–75.13. This improvement shows that teachers are beginning to be able to relate AR concepts to the learning model used, which supports the findings (Jamrus & Razali, 2021 Gormally et al., 2012; and Pamorti et al., 2024) which emphasizes that teachers' pedagogical readiness is an important factor in the effectiveness of AR integration in learning. This reinforces the idea that the success of AR-based learning depends on a balance between technology, pedagogy, and content (Perifanou et al., 2023; Mishra & Koehler, 2006; Krath et al., 2021). Different from previous literature studies that focused more on the impact of AR on students, this workshop highlights how teachers' pedagogical understanding progressively develops in AR training.

The fourth day showed a significant improvement in teachers' technical skills, especially in the Create and Integrate aspects, with average scores reaching 74.48–80.10. This improvement shows that hands-on training in designing AR interactive learning media effectively improves teachers' technical skills. These findings are in line with the study by Noviansyah et al. (2022), who emphasized that teachers' competence in designing AR media must be accompanied by pedagogical understanding in order to create an interactive and practical learning experience (Efendi et al., 2023; Meletiou-Mavrotheris et al., 2020).

ICT literacy indicators peaked on the fifth day, with the highest scores of 85.10 for Define and 80,45 for Communicate. The micro-teaching conducted on the last day showed that teachers could create AR-based learning media and use them effectively in learning. This success confirms the Technological Pedagogical Content Knowledge (TPACK) model, which emphasises the balance between technology, pedagogy, and content in improving learning effectiveness (Mishra & Koehler, 2006; Schmid et al., 2020). Unlike previous literature studies that only measured teachers‘ technical competencies, the implementation of this workshop shows that micro-teaching can be an effective method for measuring teachers’ readiness to integrate technology into learning.

Overall, the results of this workshop show that practice-based training with a constructivist approach can gradually improve teachers' ICT literacy skills. This improvement is relevant to UNESCO's ICT literacy competency model (2018), which emphasizes that teachers must have the skills to define, manage, integrate, create, and communicate information using digital technology. In addition, these findings also reinforce the results of studies by (Rizki et al., 2024; Adedokun-Shittu et al. 2020 and Roopa, et al. 2021), which show that AR can improve teachers' digital skills and critical thinking in learning.

In the broader context of education, the results of this workshop show that the integration of AR in science learning can be a model that can be applied at various levels of education. Teachers with good ICT literacy skills can create more engaging, digitally interactive learning experiences, which have been shown to improve students' understanding of science concepts (Dutta et al., 2023; Arslan et al., 2020; Chen et al., 2017).

Although the results of the workshop show a significant improvement in teachers' ICT literacy, several limitations need to be considered: 1) The duration of the training, five days, may not be enough to provide in-depth understanding for all participants, especially those with low initial ICT skills (Mishra & Koehler, 2006). The Mishra & Koehler (2006) study suggests that technology training should be combined with long-term mentoring to make the results more sustainable. 2) Variation in participants' initial competencies: Some teachers understand AR technology faster than those new to ICT. A study by Madanipour & Cohrssen (2020) shows that training that accommodates differences in initial competencies is more effective in improving technology literacy; 3) Access to technology, further implementation of AR in learning requires better access to adequate hardware and software. The Almenara and Vila (2019) study emphasizes that the continued use of technology in education is highly dependent on the availability of adequate infrastructure. To overcome these limitations, it is recommended that similar training be extended with a post-training mentoring program and additional resources such as digital tutorials and communities for sharing experiences. In addition, further workshops are needed to measure the long-term impact of this training on teachers' teaching practices and

students' learning outcomes. Integrating AR in science learning can be more optimal and sustainable with this strategy.

4. KESIMPULAN

The Augmented Reality (AR)-based science learning development workshop is a beneficial community service activity to improve ICT literacy in learning. The workshop helps teachers to fulfil the availability of ICT-based teaching materials (modules, LKPD, and learning media) produced by teachers as an output in community service activities carried out by a team of lecturers from the Faculty of Teacher Training and Education, University of Lampung. The results of this community service collaboration help teachers overcome the problem of low ICT literacy skills and teach partner teachers to innovate by developing interactive Augmented Reality (AR)-based learning media. The workshop activities have implications for strengthening teachers' ICT literacy in science learning. The strengthening of teachers' ICT literacy after the training is characterised by the proficiency of partner teachers in using, creating and integrating ICT products in Augmented Reality (AR)-based learning.

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