Hindawi
Education Research International
Volume 2021, Article ID 7264230, 9 pages
https://doi.org/10.1155/2021/7264230

Research Article

The Science Teachers' Optimism Response to the Use of Marker-Based Augmented Reality in the Global Warming Issue

Dwi Sulisworo,[1] Ratnawati Drusmin,[1] Dian Artha Kusumaningtyas,[1] Trikinasih Handayani,[2] Wahyuningsih Wahyuningsih,[3] Adi Jufriansah,[4] Azmi Khusnani,[4] and Erwin Prasetyo[4]

[1]*Physics Education Department, Universitas Ahmad Dahlan, Yogyakarta, Indonesia*
[2]*Biology Education Department, Universitas Ahmad Dahlan, Yogyakarta, Indonesia*
[3]*Mathematics Education Department, IKIP Muhammadiyah Maumere, Sikka, Indonesia*
[4]*Physics Education Department, IKIP Muhammadiyah Maumere, Sikka, Indonesia*

Correspondence should be addressed to Dwi Sulisworo; sulisworo@gmail.com

Received 21 October 2021; Revised 19 November 2021; Accepted 27 November 2021; Published 11 December 2021

Academic Editor: Ehsan Namaziandost

During the COVID-19 pandemic, almost all regions of Indonesia, including Sikka, East Nusa Tenggara, and Indonesia, have implemented e-learning. However, this method has not been conducted in all schools due to the problem of uneven Internet access. Disconnection from the Internet makes it difficult to conduct this process effectively even though students have smartphones. Furthermore, the expectation of education quality improvement in sciences also gets higher with the development of today's world technology, and this cannot be avoided. Augmented reality (AR) gives a variety of opportunities to be utilized as science learning media embedded on smartphones even without an Internet connection. Therefore, this study aims at conducting an intervention towards the teachers through the training and workshops on the use of augmented reality for science learning on the topic of Global Warming. This research was an action research approach. While considering this problem, the intervention of teachers' behavior and perception was conducted through training and workshops on the use of augmented reality for science learning using a one-shot case study research design. This program had four stages: need identification, strengthening the understanding of using AR, training and workshop implementation, and evaluation. The participants of this program were 24 science teachers from 10 schools at junior high schools in Sikka Regency, Indonesia (17 females, 7 males). The marker-based AR was developed based on learning media need assessment provided by teachers. Teacher optimism was measured using a questionnaire with a Likert scale. The program's implementation led teachers to understand the use of AR in learning, significantly to develop HOTs (higher-order thinking skills) in science learning. After experiencing training and workshops, the teachers showed high optimism to use AR in science learning. The results of this study imply for the development of school policies to establish digital learning media used without the Internet on various learning issues in rural areas.

1. Introduction

The COVID-19 pandemic is having a different impact on learning practices in Indonesia. Besides, the need to improve their reaction in the teaching and learning process-related factors is also essential. In rural areas with little Internet access, a conducive situation for online learning is relatively limited [1]. Furthermore, the demands for competence development that meet the needs of living in the era of Industrial Revolution 4.0 cannot be simply ignored in learning.

Industrial Revolution 4.0 may help to overcome the obstacles related to online learning in pandemic to limit the direct interaction. The themes of artificial intelligence, robotics, cloud computing, big data, Internet of Things (IoT), augmented reality (AR), and virtual reality (VR) give a lot of opportunities for learning following the goals of new skills in this era. The use of a variety of learning media based on

competence requirements will support innovative and creative learning as a part of HOTs (higher-order thinking skills) [2, 3]. This expectation corresponds to the educational objectives set in the 2013 curriculum.

AR is one of the newest technologies in the era of Industrial Revolution 4.0 and has offered various possibilities to bridge the gap in the quality of education [4–6]. It is used as a science learning medium to support a variety of performances in the sciences [7, 8]. Furthermore, it can also be embedded on smartphones without an Internet connection; therefore, the utilization can be a solution in learning including in Sikka, particularly when there is no Internet access.

Global learning development has also been anticipated by the government through the Curriculum 2013. The provision mentions a variety of learning models and strategies used to achieve learning goals. Meanwhile, the three models used are project-based, problem-solving, and discovery learning, and they can also be used by utilizing AR in science learning. These can be supporting factors in the implementation of AR to improve the quality of education in rural areas. However, in particular rural areas including Sikka, many teachers experience obstacles in the teaching and learning process. Developing the skills of the teacher in the era of the industrial revolution is an essential element for successful learning [9]. The characteristics of learners related to the ability to learn independently should also be considered to optimize the use of the media [10].

During the initial discussion with the chief of the Science Teacher Association and two junior high school science teachers in Sikka, several obstacles in science learning for adaptation in the pandemic era were discussed. Generally, learners have gadgets that enable the use of digital materials, and this is related to students' perception in electronic-based learning [11, 12], including students in Sikka, Indonesia [13]. However, in online learning, there are several obstacles in terms of Internet network availability. One of the alternative solutions is providing digital learning sources accessed without the Internet (embedded on the gadget). The partner problem in this situation is that junior high school science teachers have no adequate skills in using digital learning media with particular strategies. This problem encouraged the implementation of a behavior and perception intervention focusing on science learning at junior high schools in Sikka, East Nusa Tenggara. This is conducted as a solution in partnership between the Department of Education, Culture and Sports, Science Teacher Association, Institute of Teacher Training and Education, Muhammadiyah Maumere, and Ahmad Dahlan University to improve the quality of science learning at junior high schools. The program implementation resulted in the teachers with AR understanding, developing HOTs in science learning as the output as well as several copyrights in the form of videos and the AR-based application.

2. Literature Review

2.1. Online Learning Obstacles and Opportunities during Pandemic. During the pandemic, almost all schools have implemented online learning either on their consciousness or because of government policies. However, not all schools can implement this policy well due to various obstacles. The results of the study stated three obstacles to online learning during the pandemic: the lack of capabilities to communicate remotely, weak Internet speed, and the difficulty of students' understanding of some subjects in the absence of classroom interaction [14]. In comparison, the study conducted by Reference [15] stated that limited quotas and Internet networks caused inefficiencies during online learning. It can be understood that it becomes an obstacle in mitigating learning during a pandemic in areas where Internet networks are limited. Likewise, quotas are relatively expensive for people with limited economic levels. In Indonesia, there is a tendency for teachers not to implement learning strategies following the concept of good online learning. The platform and the learning activities mainly use WhatsApp [15]; it indicates a lack of teacher skill to arrange online learning. Research Reference [16] adds that a critical constraint in online learning in Indonesia is teachers' skill in implementing appropriate strategies and low learning motivation. Other studies corroborate the findings regarding the obstacles to online learning during the pandemic. It is in terms of both technical aspects and the skills of teachers and students. There are at least three main obstacles to good online learning: limited Internet access, not all students having gadgets, and teaching skills in managing online learning. The aspect of teacher limitations in managing learning includes skills in using online learning platforms, developing learning media, and managing online interactions.

Educational policymakers and school administrators have been trying to find various solutions so that online learning can run smoothly. This effort cannot immediately solve problems, especially those related to sudden changes in learning, and these problems cannot be resolved quickly. Some of the efforts made are providing learning platforms, training and workshops for teachers, and digital learning content, and increasing Internet access [17–19]. The Indonesian government also applies these policies to schools [20]. The participation of higher education in supporting government policies is significant for teachers, especially for rural areas and islands, which are relatively limited in resources [21, 22].

This pandemic situation has provided vast opportunities for the penetration of information and communication technology in rural schools. The awareness of education managers so that learning continues to run well has become a driving force for teachers to increase competence in managing digital-based learning both online and offline [23–25]. Internet access constraints need to be anticipated and resolved by providing various digital learning contents accessed through gadgets owned by students. This effort was to continue implementing social distancing and because of the reduction in direct interaction at schools. In line with the issue of Industrial Revolution 4.0, augmented reality is one alternative to digital-based learning [3, 5, 26]. It does not have to use the Internet. Adjusting this technology in education can also be related to various global issues that are important to students.

2.2. The Used AR for Learning. As mentioned before, in the environment of students who cannot get Internet access, providing learning resources that can improve learning performance with independent and group learning becomes very important [10, 13, 27]. However, the media in science learning, especially about Global Warming, have limitations in explaining a phenomenon [6, 7, 28]. Augmented reality can enrich existing media by adding various deeper and more complete activities available on smartphones [29]. This feature will be activated when obtaining a trigger from the material contained in the AR marker [30]. With these advantages, these learning media are more practical and effective for developing new competencies in this era [31–33]. The learning material embedded, for example, module by augmented reality, can be designed to improve students' competencies. However, research developing this module is still relatively little developed as an alternative learning medium during the pandemic, especially in areas where Internet access is not covered.

The research results [1, 34] show that Indonesian people are among those with a high level of mobile technology-based social media use. With the COVID-19 pandemic that demands the strengthening of online learning, not all students can take advantage of the potential of this technology in education. This benefit is especially true in areas that do not have good Internet access. One technology that can bridge this is the use of AR.

Recent studies on Technology-Enhanced Learning have placed AR as necessary in increasing learning effectiveness. AR is a technique in informatics that combines two-dimensional or three-dimensional virtual objects into three-dimensional real space and projects these virtual objects in real time [6, 7]. AR can stimulate the user's perception and senses. This technique combines modules (two dimensional) with additional three-dimensional virtual information in learning. This combined information can be displayed with the help of mobile devices such as webcams, computers, smartphones, or Google [7]. With this technique, the user can see virtual objects with the intermediary of mobile technology. These advantages are used in science learning to explain various phenomena more fully. It is impossible to write in a book to increase the immersion when understanding phenomena [35, 36]. Studies on AR in science learning show promising results for improving competence in critical thinking and collaboration skills.

3. Materials and Methods

3.1. Context of Program. The participants of this program were 24 science teachers at junior high schools in Sikka Regency, where 17 were females and 7 were males; 16 teachers were 20–35 years old. Meanwhile, 7 teachers were 35–50 years old and 1 teacher was older than 50; they were all from 10 schools. The method used was training and workshops on the use of AR for science learning, and the topic used was Global Warming. The program was conducted from 10 April to 20 September 2021. Furthermore, the implementation of activities was blended and some activities were conducted offline at the Institute of Teacher Training and Education, Muhammadiyah Maumere, (participants attended the event with the health protocols following the provision of the COVID-19 Task Force) and online by using the Zoom meeting application. Questionnaires were distributed through Google Forms to collect data on the participants' responses.

3.2. Instrumentation and Analysis Techniques. There are two kinds of research instruments: a needs analysis instrument and an application optimism instrument. The needs analysis instrument was a questionnaire with open-ended questions covering the obstacles encountered, the alternative solutions' implementation, and the implementation results' effectiveness. Questionnaires were shared using Google Forms distributed before participants took part in the training and workshops. The results were analyzed using affinity diagram and Pareto techniques. The optimism-level questionnaire adapted from [37] included five statements: the usefulness of AR media that can be accessed by the Internet, experience using AR media, belief that AR media is practical for learning, confidence in learning media with manuals, and belief in increasing independent skills. This questionnaire was shared using Google Forms too. The results were processed qualitatively based on the proportions.

3.3. Stages of Program. The stages to achieve the goals of the teacher's behavior and perception intervention program related to AR-assisted learning are shown in Figure 1.

1st Phase: Need Identification of Learning Media. This stage was conducted by delivering questionnaires through Google Forms to determine a variety of obstacles in science learning amidst the pandemic era. The questionnaires were in the form of open questions, and the results were analyzed by using the techniques of affinity diagram and Pareto to determine the aspects of the learning obstacles. The results were also supported with statements from two resources (the chief of Science Teacher Association and the principal of the junior high school) and became fundamental for the next stage in determining the training materials.

2nd Phase: Strengthening the Understanding of Using AR for Developing HOTs. Following the learning obstacles identified in stage I, participants attended an online training with three speakers in this stage. The first speaker delivered materials about AR-based media to develop HOTs in science learning at junior high schools. The second speaker explained the government's policy of school quality improvement in the era of Industrial Revolution 4.0. Meanwhile, the third speaker delivered the role of higher education institutions in the partnership of the online learning implementation in Sikka. After this training, the participants were given questionnaires to measure the rate of teachers' beliefs in the use of AR for learning.

3rd Phase: Training on Using AR in Learning. Based on the data analysis onstage II, AR-based learning media were developed to be embedded into gadgets on the

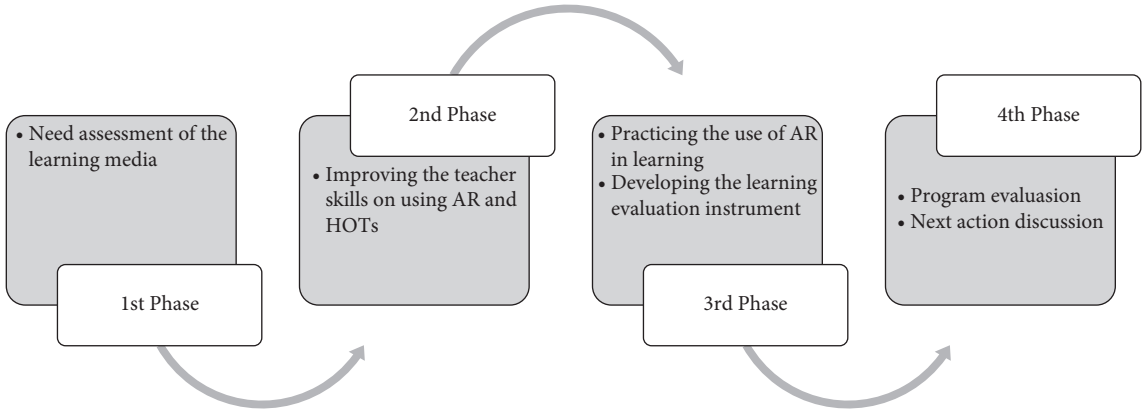

Figure 1: Stages of program implementation.

topic of Global Warming. Therefore, teachers and students do not need to have Internet access when using this application. In this stage, teachers were given training and workshops to use an AR-based application in science learning, and the implementation was blended. The participants attended the event in the Institute of Teacher Training and Education, Muhammadiyah Maumere, whereas the trainers interacted through online platforms. The first trainer explained a variety of instruments to measure the success of science learning assisted with AR. The second trainer, as an expert in AR development, gave training on how to use KOFIN, an AR-based application, related to the topic of Global Warming. In addition, the third trainer explained how to arrange questions for science learning evaluation on the topic of Global Warming. The participants collected questionnaires related to the follow-up plans and the success rate of the program through Google Forms.

4th Phase: Program Evaluation. This stage was conducted to obtain the success rate of the teacher's behavior and perception intervention program in using AR for learning and follow-up plans after training in the form of classroom action. The results of this stage will be a recommendation for the next teachers' competence development program.

4. Results

4.1. Science Learning Obstacles. The required identification of learning media collected through Google Forms disclosed a variety of science learning obstacles amidst the pandemic era in Sikka. The questionnaires were in the form of three open questions. The results were analyzed by using the techniques of affinity diagram and Pareto. Figures 2 to 4 show the results.

4.2. Optimism Level of Using AR. With the training, the teachers gave responses in terms of their optimism for implementation at their schools. The results of questionnaires collected using Google Forms are shown in Figures 5 to 8.

4.3. AR on the Topic of Global Warming. Considering the teachers' responses, AR-based learning media was then developed to be embedded on the gadgets for the topic of Global Warming. It uses markers to bring out the Global Warming phenomena. The results of the media development were three marker-based ARs. In the activities of the teachers during the workshop, they creatively provided several alternatives to the use of marker-based AR. Teachers can use this media as part of either a worksheet or comic or standalone as a direct media. Figure 9 shows AR markers that have been printed and used for learning. Figure 10 is the AR marker pinned in the tree as an alternative learning media.

5. Discussion

Affinity diagram and Pareto showed that the significant obstacles are low Internet access, teachers' skills in implementing online learning strategies, and variation of learning media. During the pandemic, teachers tried to run science learning online following the policies of the local education office. The two main challenges are not having a quota for Internet access and no Internet network. These two things are essential requirements to conduct online learning. Many other studies related to online education in various countries also show that these two issues are obstacles that need attention [14, 15]. Teachers try to apply digital-based learning online, but Internet access is limited. Increasing access is undoubtedly an ideal solution, but this solution requires a relatively long time because it is related to various policies at a higher level from several ministries. The fastest solution while still paying attention to the learning objectives is to develop digital learning media used without the Internet. Many studies have shown the effectiveness of this kind of media.

Furthermore, there should be alternative learning that does not require Internet access but still uses technology. Digital media installed on gadgets also provides opportunities to encourage various learning skills and student competencies. The use of technology in the current era is critical to master science materials at this secondary school level [38–40]. Teachers can improve various competencies relevant to the 21st century by utilizing technologies such as critical thinking skills [41–43], creativity [44, 45], and collaboration [46, 47].

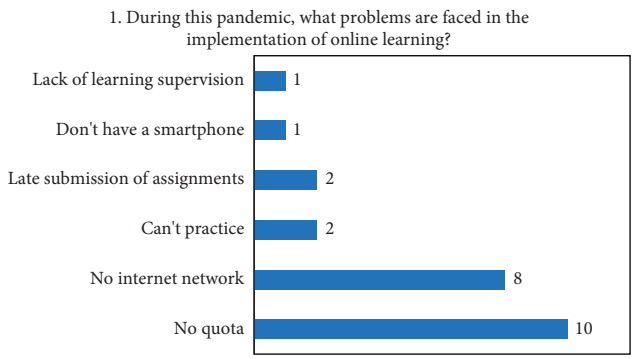

Figure 2: The online learning problem.

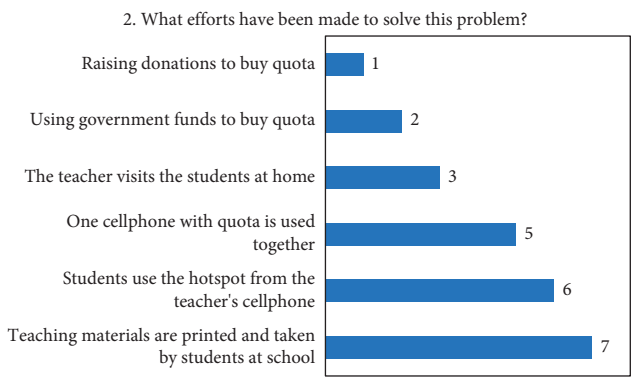

Figure 3: Teachers' initiative to solve the learning problem.

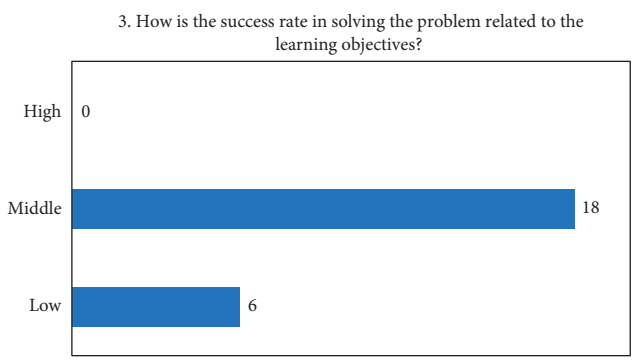

Figure 4: The effectiveness of the initiative implementation.

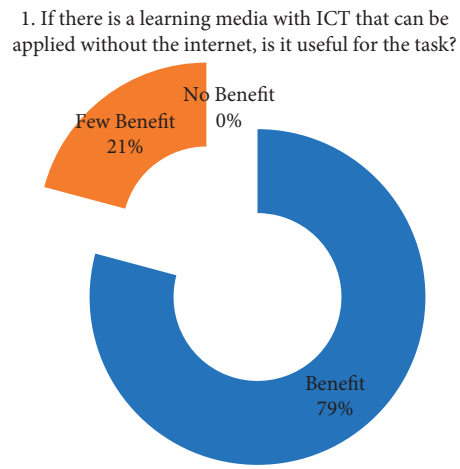

Figure 5: The intention of ICT-based media without Internet.

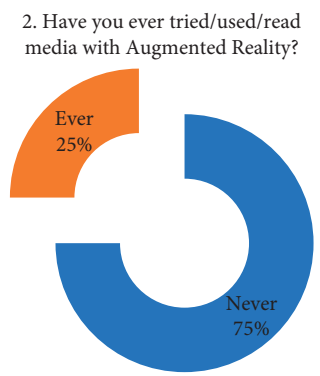

Figure 6: Teachers' experiences with using AR.

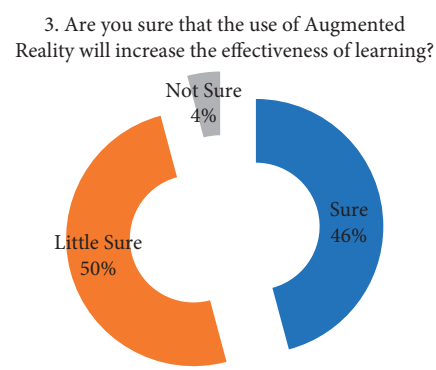

Figure 7: Teachers' optimism on using AR.

The data obtained show that almost all efforts are activities to provide an Internet quota. Seven respondents changed online learning by providing printed materials. This result is undoubtedly beyond expectations for the development of various alternative digital learning solutions. There are relatively no teachers who have tried to develop or use digital learning media installed on gadgets. Applications that can be accessed offline and embedded in devices have not been set. This situation will undoubtedly affect the level of efficiency and effectiveness of learning. Several possibilities need to be revealed further why teachers have not tried this alternative. Several opportunities are due to the skills of teachers in rural areas in developing digital learning media. Several other researchers have studied this indication. This situation leads to the need to improve the skills of teachers to use digital media installed on gadgets and develop relevant learning stages using these media [48, 49].

Meanwhile, the development of applications directly on the device becomes a new opportunity to provide learning resources [50, 51]. Several teacher responses in dealing with obstacles showed negative results for the alternatives. This finding is an opportunity for the application of AR embedded in gadgets as a learning alternative. The observation reported by the chief of the Science Teacher Association also

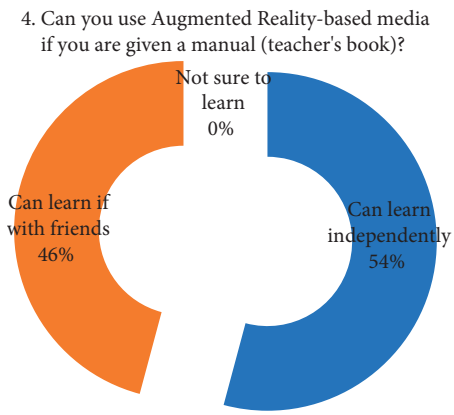

Figure 8: Teachers' responses to their skills to use AR.

Figure 9: Products of AR card markers.

Figure 10: AR pinned on the tree.

showed similar findings of science learning obstacles. It is also supported by the principal of junior high school SMP Negeri I, who mentioned the science learning and the barriers of online learning implementation. The obstacles in terms of supporting facilities for online learning influence the learning performance [10, 11]. The follow-up to this result is to provide learning media installed on the gadget and provide training and workshops on its use in learning.

In the needs analysis, the teacher explains that the provision of digital learning media installed on gadgets can encourage better learning during this pandemic. AR was also responded positively as an alternative in teaching science following current technological developments. The teachers were given training on using AR to develop HOTs to transform the good perceptions of technology-based science learning (AR). This understanding also refers to educational policies from the government and the partnership with other stakeholders. With the training, the teachers gave responses in terms of their optimism for implementation at their schools. The actual findings showed a high opportunity in the use of AR in science learning. After training on AR, teachers (79%) stated that ICT-based applications running without Internet access could complete understanding during this pandemic. The teacher uses an AR-based application embedded in smartphones during the training.

Furthermore, this experience is their reason for opening up opportunities for AR in science learning. The expected result of this utilization is an increase in students' competence following the needs as in other studies. Teachers' optimism to apply AR in learning certainly needs to be supported by good skills. Other studies related to education in Indonesia, especially in rural areas, indicate the teachers' feeling. Many teachers do not have the opportunity to improve their skills in using digital technology. These results are the same as the results in this research, which shows that teachers need training and workshops on using this technology. These results form the basis for the development of AR and provide related training to teachers.

The development of AR and interventions for teachers in the form of training and workshops responded to the condition of teacher skills. The majority of teachers (75%) have never used AR, and their experience using and integrating with learning strategies is valuable. This media is engaging for teachers to organize more varied learning. Training is given to teachers to master three critical competencies: the operation of AR-based learning media, development of learning strategies, and measurement of HOTs-oriented learning outcomes. While at the workshop, the teacher experienced project-based group learning with the output of learning strategies for the issue of Global Warming using AR media and HOTs-based learning outcomes measurement instruments.

Furthermore, AR media that provide a high level of immersion with suitable learning strategies can increase students' competence. This result can be explained by motivation theory, and a good learning environment (media, methods, materials) will encourage better learning motivation. The impact of good motivation is to ask for high learning and boost good performance [29, 52]. Teachers practice using marker-based AR as an appropriate learning strategy. In terms of optimism, some feel unsure about applying it in their learning (4%), and this optimism is essential to ensure the success of its implementation. Several other studies support this finding that teacher optimism will increase the chances of success in applying both technology strategies and learning media [27, 53–55]. Therefore, it is necessary to examine the factors that make teachers feel optimistic about their application. AR-assisted learning media have several formats that can be used flexibly, such as cards, worksheets, and comics. The creativity in using these various forms is an indication of their optimism.

Part of this teachers' optimism is shown in the level of independence to learn AR-assisted media. All teachers stated that they can learn to use AR and apply it either manually (54%) or studying with friends (46%). These results showed

high opportunities to apply an AR-based application to support science learning due to several benefits and do not need Internet access to use. The immersion aspect of AR also becomes the excellence of this technology [38, 43]. Besides, teachers also tend to have a strong belief in its utilization, even though some do not believe in the media effectiveness. The results of the analysis recommend the use of AR for science learning. Following the analysis on the characteristics of science learning and the broader interest, an AR-based application on the topic of Global Warming was agreed to be developed. This application is directly embedded in the gadget and does not need Internet access.

Considering the teachers' responses, AR-based learning media were then developed to be embedded on the gadgets for the topic of Global Warming. It uses markers to bring out the global warming phenomena. To make sure teachers' ability to use AR is developed, the teachers, as a group or individual task, have created learning strategies assisted with AR test items to find out the learning effectiveness, and questionnaires to measure the students' responses. Furthermore, it was disclosed that AR products can be used in a variety of learning strategies and developing HOTs following the results of a study by References [51, 52]. The combination of virtual and real objects is the benefit of this digital media to increase motivation and learning outcomes [56, 57]. There are several techniques of using AR for learning developed by the teachers in this training and workshop. The teachers' ideas of using AR in various strategies are believed to increase some students' skills, such as the results of other studies. This belief is also in line with similar research related to the use of AR in various forms [43, 58].

This study implies that there is a need for policies from schools to facilitate teachers in their implementation. This policy is mainly because not all teachers have sufficient skills in the use of these media. The continuous training reaching all teachers using AR that integrates various learning strategies enables more engaging and effective learning. In addition, AR media with the theme of Global Warming can be used in science learning and other knowledge. The global warming phenomenon impacts various sectors of life, so studies from multiple scientific perspectives will provide good insights for students. Success in this broader study requires support from school administrators and the ministry of education.

6. Conclusion

The training conducted with participants of science teachers at junior high schools in Sikka gives a positive impact on the implementation of digital technology-based learning. Meanwhile, the AR-based application on the topic of Global Warming can be used with a variety of strategies. The instruments to measure the learning outcomes that meet the expected competencies in the era of Industrial Revolution 4.0 can also be developed. Furthermore, the AR applications should be implemented in a variety of formats to support more meaningful learning. This will broaden the benefits and strengthen the partnership that has been built during the training. The partnership is particularly for the implementation of the classroom action study as the follow-up of the program. Mentoring from higher education institutions in the implementation of classroom action is also required to improve the quality of the output.

Data Availability

The participants' response data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

Authors' Contributions

Dwi Sulisworo conceived the study; Adi Jufriansah, Azmi Khusnani, and Erwin Prasetyo curated the data; Dwi Sulisworo did the formal analysis and helped with funding acquisition; Erwin Prasetyo investigated the study; Dwi Sulisworo and Dian Artha Kusumaningtyas helped with methodology; Dwi Sulisworo provided the resources and supervised the study; Dwi Sulisworo, Dian Artha Kusumaningtyas, and Trikinasih Handayani validated the study; Azmi Khusnani helped with visualization; Dwi Sulisworo wrote the original draft of the manuscript and reviewed and edited the manuscript.

Acknowledgments

The authors are grateful to the Research and Community Service Institute of Ahmad Dahlan University, Teacher Science Association of Sikka. This study was funded by the Ministry of Education, Culture, and Higher Education of Indonesia, under Grant no. 1897.7/LL5/PG/2021, and the APC was funded by the same institution.

References

[1] D. Sulisworo, D. A. Kusumaningtyas, and T. Handayani, "The utilization of mobile learning in junior high school physics science learning in rural area of Sikka, East Nusa Tenggara, Indonesia," in *Proceedings of the 3rd International Conference on Learning Innovation and Quality Education (ICLIQE 2019)*, pp. 454–461, Surakarta, Indonesia, January 2020.

[2] D. Sulisworo, W. Winarti, Y. A. Amalia, S. H. Larekeng, I. Maryani, and D. Demitra, *Model Lingkungan Pembelajaran Era New Normal*, Pascasarjana UAD, Yogyakarta, Indonesia, 2020.

[3] A. A. Ismail and R. Hassan, "Technical competencies in digital technology towards industrial revolution 4.0," *Journal of Technical Education and Training*, vol. 11, pp. 55–62, 2019.

[4] C. Lindner, A. Rienow, and C. Jürgens, "Augmented Reality applications as digital experiments for education-an example in the Earth-Moon System," *Acta Astronautica*, vol. 161, pp. 66–74, 2019.

[5] I. C. Stanica, A. Moldoveanu, I. Dascalu, F. Moldoveanu, M. Radoi, and I. V. Nemoianu, "Emergent technologies to enrich reading outcomes through augmented reality," *Revue Roumaine des Sciences Techniques-Serie Électrotechnique et Énergétique*, vol. 64, pp. 95–100, 2019.

[6] H.-K. Wu, S. W.-Y. Lee, H.-Y. Chang, and J.-C. Liang, "Current status, opportunities and challenges of augmented reality in education," *Computers & Education*, vol. 62, pp. 41–49, 2013.

[7] J. Carmigniani and B. Furht, "Augmented reality: an overview," in *Handbook of Augmented Reality,* Springer, New York, NY, USA, 2011.

[8] M. Selisne, Y. S. Sari, and R. Ramli, "Role of learning module in STEM approach to achieve competence of physics learning," *Journal of Physics: Conference Series*, vol. 1185, Article ID 012100, 2019.

[9] E. W. M. Indira, A. Hermanto, and S. E. Pramono, "Improvement of teacher competence in the industrial revolution era 4.0," in *Proceedings of the International Conference on Science and Education and Technology (ISET 2019)*, pp. 350–352, Semarang, Indonesia, January 2020.

[10] D. Sulisworo, N. Fatimah, S. S. Sunaryati, and S. Sanidi, "A quick study on srl profiles of online learning participants during the anticipation of the spread of COVID-19," *International Journal of Evaluation and Research in Education*, vol. 9, no. 3, pp. 723–730, 2020.

[11] D. Darmaji, D. A. Kurniawan, A. Astalini, W. Kurniawan, K. Anwar, and A. Lumbantoruan, "Students' perceptions of electronic's module in physics practicum," *Journal of Education and Learning*, vol. 13, no. 2, pp. 288–294, 2019.

[12] R. Sujanem, I. N. P. Suwindra, and I. Suswandi, "The effectiveness of problem-based interactive physics E-module on high school students' critical thinking," *Journal of Physics: Conference Series*, vol. 1503, Article ID 012025, 2020.

[13] D. Sulisworo, D. A. Kusumaningtyas, A. A. Bergita, Wahyuningsih, and W. Rahmadhani, "Perceptions of online learning experiences between students in urban and remote areas: case study in Indonesia," *International Journal of Scientific & Technology Research*, vol. 9, pp. 4850–4854, 2020.

[14] Z. Lassoued, M. Alhendawi, and R. Bashitialshaaer, "An exploratory study of the obstacles for achieving quality in distance learning during the COVID-19 pandemic," *Education Sciences*, vol. 10, no. 9, Article ID 232, 2020.

[15] A. N. Bahasoan, W. Wulan Ayuandiani, M. Muhammad Mukhram, and A. Rahmat, "Effectiveness of online learning in pandemic COVID-19," *International Journal of Services Technology and Management*, vol. 1, no. 2, pp. 100–106, 2020.

[16] R. P. Rahayu and Y. Wirza, "Teachers' perception of online learning during pandemic covid-19," *Jurnal Penelitian Pendidikan*, vol. 20, no. 3, pp. 392–406, 2020.

[17] C. M. Toquero and K. J. Talidong, "Webinar technology: developing teacher training programs for emergency remote teaching amid COVID-19," *Interdisciplinary Journal of Virtual Learning in Medical Sciences*, vol. 11, pp. 200–203, 2020.

[18] S. Pokhrel and R. Chhetri, "A literature review on impact of COVID-19 pandemic on teaching and learning," *Higher Education for the Future*, vol. 8, no. 1, pp. 133–141, 2021.

[19] T. Shamir-Inbal and I. Blau, "Facilitating emergency remote K-12 teaching in computing-enhanced virtual learning environments during COVID-19 pandemic-blessing or curse?" *Journal of Educational Computing Research*, vol. 59, no. 7, 2021.

[20] M. Churiyah, S. Sholikhan, F. Filianti, and D. A. Sakdiyyah, "Indonesia education readiness conducting distance learning in Covid-19 pandemic situation," *International Journal of Multicultural and Multireligious Understanding*, vol. 7, no. 6, pp. 491–507, 2020.

[21] J. Crawford, K. Butler-Henderson, J. Rudolph et al., "COVID-19: 20 countries' higher education intra-period digital pedagogy responses," *Journal of Applied Learning & Teaching*, vol. 3, pp. 1–20, 2020.

[22] S. Slamet, A. M. K. Amrullah, S. Sutiah, and A. Ridho, "Differences in the experience of lecturers and students on distance learning in higher education in Indonesia: case study in the pandemic of Covid-19," *Systematic Reviews in Pharmacy*, vol. 12, pp. 742–747, 2021.

[23] N. Pather, P. Blyth, J. A. Chapman et al., "Forced disruption of anatomy education in Australia and New Zealand: an acute response to the covid-19 pandemic," *Anatomical Sciences Education*, vol. 13, no. 3, pp. 284–300, 2020.

[24] F. Bento, A. Giglio Bottino, F. Cerchiareto Pereira, J. Forastieri de Almeida, and F. Gomes Rodrigues, "Resilience in higher education: a complex perspective to lecturers' adaptive processes in response to the COVID-19 pandemic," *Education Sciences*, vol. 11, Article ID 492, 2021.

[25] B. Dube, "Rural online learning in the context of COVID 19 in South Africa: evoking an inclusive education approach," *Multidisciplinary Journal of Educational Research*, vol. 10, no. 2, pp. 135–157, 2020.

[26] A. A. Shahroom and N. Hussin, "Industrial revolution 4.0 and education," *International Journal of Academic Research in Business and Social Sciences*, vol. 8, pp. 314–319, 2018.

[27] C.-H. Chen, Y.-Y. Chou, and C.-Y. Huang, "An augmented-reality-based concept map to support mobile learning for science," *The Asia-Pacific Education Researcher*, vol. 25, no. 4, pp. 567–578, 2016.

[28] J. Fischer, D. Bartz, and W. Straber, "Stylized augmented reality for improved immersion," in *Proceedings of the VR 2005, Virtual Reality, 2005*, pp. 195–202, Bonn, Germany, March 2005.

[29] Y. Georgiou and E. A. Kyza, "Relations between student motivation, immersion and learning outcomes in location-based augmented reality settings," *Computers in Human Behavior*, vol. 89, pp. 173–181, 2018.

[30] L. Pombo and M. M. Marques, "Marker-based augmented reality application for mobile learning in an urban park: steps to make it real under the EduPARK project," in *Proceedings of the 2017 International Symposium on Computers in Education (SIIE)*, pp. 1–5, Lisbon, Portugal, November 2017.

[31] K. Martin Sagayam, C. C. Ho, L. Henesey, and B. Robert, "3D scenery learning on solar system by using marker based augmented reality," in *Proceedings of the 4th International Conference of the Virtual and Augmented Reality in Education, VARE 2018*, Genoa, Italy, November 2018.

[32] E. V. Haryanto, E. L. Lubis, and A. Saleh, "Implementation of augmented reality of android based animal recognition using marker based tracking methods," *Journal of Physics: Conference Series*, vol. 1361, no. 1, Article ID 012019, 2019.

[33] M. Abdul Aziz and N. A. A. Aziz, "The current trends of augmented reality in early childhood education," *The International Journal of Multimedia & Its Applications*, vol. 10, no. 6, pp. 47–58, 2018.

[34] A. R. Pratama, "Fun first, useful later: mobile learning acceptance among secondary school students in Indonesia," *Education and Information Technologies*, vol. 26, no. 2, pp. 1737–1753, 2021.

[35] F. Bakri, O. Oktaviani Marsal, and D. Muliyati, "Textbooks equipped with augmented reality technology for physics topic in high-school," *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, vol. 5, no. 2, pp. 113–122, 2019.

[36] D. Paredes-Velasteguí, A. Lluma-Noboa, D. Olmedo-Vizueta, D. Avila-Pesantez, and J. Hernandez-Ambato, "Augmented reality implementation as reinforcement tool for public

textbooks education in Ecuador," in *Proceedings of the 2018 IEEE Global Engineering Education Conference (EDUCON)*, pp. 1243–1250, Santa Cruz de Tenerife, Spain, April 2018.

[37] A. M. Lund, "Measuring usability with the use questionnaire," *Usability interface*, vol. 8, pp. 3–6, 2001.

[38] D. Lestari and Z. K. Prasetyo, "A review on ICT literacy in science learning," *Journal of Physics: Conference Series*, vol. 1233, no. 1, Article ID 012097, 2019.

[39] M. E. Webb, "Affordances of ICT in science learning: implications for an integrated pedagogy," *International Journal of Science Education*, vol. 27, pp. 705–735, 2002.

[40] Y. Zheng, I. H. Chen, and I.-H. Chen, "The relation between ICT usage and 15-year-old students' science self-efficacy," *International Journal of Information and Education Technology*, vol. 11, no. 2, pp. 88–95, 2021.

[41] S. Ridho, S. Wardani, and S. Saptono, "Development of local wisdom digital books to improve critical thinking skills through problem based learning," *Journal of Innovative Science Education*, vol. 9, no. 3, pp. 1–7, 2021.

[42] B. Pratiwi, J. Copriady, and L. Anwar, "Implementation of phenomenon-based learning E-module to improve critical thinking skills in thermochemistry material," *Jurnal Pendidikan Sains Indonesia*, vol. 9, pp. 575–585, 2021.

[43] M. I. S. Guntur, W. Setyaningrum, and H. Retnawati, "Can augmented reality improve problem-solving and spatial skill?" *Journal of Physics: Conference Series*, vol. 1581, Article ID 012063, 2020.

[44] S. Rahimi and V. J. Shute, "First inspire, then instruct to improve students' creativity," *Computers & Education*, vol. 174, Article ID 104312, 2021.

[45] O. Titova, P. Luzan, N. Sosnytska, S. Kulieshov, and O. Suprun, "Information and communication technology tools for enhancing engineering students' creativity," in *Design, Simulation, Manufacturing: The Innovation Exchange, Lecture Notes in Mechanical Engineering*, pp. 332–340, Springer, Berlin, Germany, 2021.

[46] A. Henukh and I. M. Astra, "The use of Google classroom as ICT literacy to improve physics students collaboration skill in industrial revolution 4.0," *AIP Conference Proceedings*, vol. 2331, Article ID 030002, 2021.

[47] A. García-Valcárcel and J. Mena, "In-service teachers' use of ICT for the promotion of collaborative professional learning," in *Research Anthology on Facilitating New Educational Practices through Communities of Learning*, pp. 287–301, IGI Global, Hershey, PA, USA, 2021.

[48] A. Nofitasari, L. Lisdiana, and A. Marianti, "Development of my biology app learning media based on android materials of food digestion systems as student learning source at ma," *Journal of Innovative Science Education*, vol. 9, no. 3, pp. 70–78, 2021.

[49] B. Zhu and H. Feng, "Building structure simulation system based on BIM and computer model," *Journal of Sensors*, vol. 2021, Article ID 8244582, 2021.

[50] K. Li and S. Wang, "Development and application of VR course resources based on embedded system in open education," *Microprocessors and Microsystems*, vol. 83, Article ID 103989, 2021.

[51] A. Kumar, A. Mantri, and R. Dutta, "Development of an augmented reality-based scaffold to improve the learning experience of engineering students in embedded system course," *Computer Applications in Engineering Education*, vol. 29, no. 1, pp. 244–257, 2021.

[52] D. Karagozlu, "Determination of the impact of augmented reality application on the success and problem-solving skills of students," *Quality and Quantity*, vol. 52, no. 5, pp. 2393–2402, 2018.

[53] L. Tomczyk, V. C. Jáuregui, C. A. D. L. H. Amato, and M. Porta, "Are teachers techno-optimists or techno-pessimists? A pilot comparative among teachers in Bolivia, Brazil, the Dominican Republic, Ecuador, Finland, Poland, Turkey, and Uruguay," *Education and Information Technologies*, vol. 26, pp. 2715–2741, 2021.

[54] I. Stojšić, A. Ivkov-Džigurski, and O. Maričić, "The readiness of geography teachers to use mobile devices in the context of immersive technologies integration into the teaching process," *Geographica Pannonica*, vol. 23, pp. 121–133, 2019.

[55] E. Elisa, A. Farhan, and F. Herliana, "High school Physics teachers' perceptions of the learning revolution era 4.0 at training activities in Bener Meriah Regency," *Journal of Physics: Conference Series*, vol. 1882, Article ID 012030, 2021.

[56] S.-C. Chang and G.-J. Hwang, "Impacts of an augmented reality-based flipped learning guiding approach on students' scientific project performance and perceptions," *Computers & Education*, vol. 125, pp. 226–239, 2018.

[57] M. Fidan and M. Tuncel, "Integrating augmented reality into problem based learning: the effects on learning achievement and attitude in physics education," *Computers & Education*, vol. 142, Article ID 103635, 2019.

[58] C. Chin and L.-G. Chia, "Problem-based learning: using students' questions to drive knowledge construction," *Science Education*, vol. 88, no. 5, pp. 707–727, 2004.