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Teachers' perspectives toward using augmented reality technology in science learning

Anggi Datiatur Rahmat[*], Universitas Negeri Yogyakarta, Postgraduate School, Yogyakarta, 55281, Indonesia, https://orcid.org/0000-0002-5174-892X.

Heru Kuswanto, Universitas Negeri Yogyakarta, Physics Education Department, Yogyakarta, 55281, Indonesia, https://orcid.org/0000-0002-2693-8078

Insih Wilujeng, Universitas Negeri Yogyakarta, Natural Sciences Education Department, Yogyakarta, 55281, Indonesia, https://orcid.org/0000-0003-1900-7985

Himawan Putranta, Universitas Islam Negeri Sunan Kalijaga, Physics Education Department, Yogyakarta, 55821, Indonesia, https://orcid.org/0000-0003-2646-8237

Arina Zaida Ilma, Universitas Negeri Yogyakarta, Natural Sciences Education Department, Yogyakarta, 55281, Indonesia, https://orcid.org/0000-0002-7577-206X

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Abstract

Augmented reality (AR) is a new technology in education, and teachers are still rarely familiar with the technology. The study aimed to introduce AR technology and determine the perspective of science teachers from various educational backgrounds on implementing AR in science learning. A mixed research design was employed in collecting quantitative and qualitative data using an online survey and one-on-one semi-structured interviews. The study participants are 32 teachers with different educational backgrounds in the Association of Science Education Teachers in West Bandung, Indonesia. The interviews were conducted with six participants selected randomly. The study found that many teachers had less knowledge of AR technology because they had experienced it for the first time. However, they were highly interested in implementing the technology in science learning after exploring its use independently. From the perspective of teachers, AR has the potential to be implemented in science learning. It could facilitate abstract concepts considered difficult for students to visualise and increase their interest and motivation in the learning process. Therefore, teachers need further training to implement AR optimally in science learning.

Keywords: Augmented reality, science education, teachers' perspectives, technology, TPACK framework

[*] ADDRESS FOR CORRESPONDENCE: Anggi Datiatur Rahmat, Postgraduate Universitas Negeri Yogyakarta, Jalan Colombo No. 1 Karangmalang, 55281, Yogyakarta, Indonesia

E-mail address: anggidatiatur.2022@student.uny.ac.id / Tel.: +6281395279479

1. Introduction

Science is one of the subjects students often consider difficult by assuming that it has many calculations, abstract concepts, and memorization (Scott et al., 2013). This subject is essential in the 21st century (McFarlane, 2013) because it trains students to think rationally and improve their communication and creative thinking skills (Eristya & Aznam, 2019). Furthermore, science learning enhances lives by using knowledge and facing an increasingly technological world (Baser et al., 2017). This becomes a challenge for teachers to ensure students are interested in learning science.

Rapid technological development also affects education, and teachers must use it to create an interactive and fun learning environment. Technology facilitates students to learn independently and explore their skills (Geng et al., 2019). In learning science, students must be equipped with real-life experiences (Karagozlu, 2018) and change abstract concepts into concrete ones (Fidan & Tuncel, 2019). The technology could provide exciting experiences and opportunities to design realistic, engaging, and fun learning environments (Cai et al., 2017). Therefore, integrating technology into learning science is necessary to develop students' thinking skills and improve their understanding and involvement in the learning process (Ningrum et al., 2021).

Integrating technology into the learning system requires creativity and qualified abilities from a teacher (Al-Rahmi et al., 2019). Most teachers have technological capabilities that have not been optimally implemented in the learning process. The limited availability of facilities and infrastructure causes them not to have the urge to be creative using technology (Talebian et al., 2014). Teachers rarely participate in technology-related training activities. One of the most common reasons for the lack of use of technology in the classroom is inadequate professional development and training (Ertmer et al., 2012). If teachers are not provided with effective professional development using technology, they cannot implement it optimally (Johnson et al., 2016).

Technology with the potential to provide real experiences to students is augmented reality (AR) (Chen & Wang, 2015). The Horizon report by the New Media Consortium's New Technology Initiative showed that AR is an emerging technology with the potential and impact learning and education (Becker et al., 2017). It supports students' motivation and is suitable for science learning (Karagozlu & Ozdamli, 2017). Additionally, AR makes representation appropriate, and science content is seen as a complex process to overcome abstract concepts into concrete (Salmi et al., 2017).

AR technology is still relatively new in education and has yet to be known to many teachers whose role is vital in integrating technology into learning (Admiraal et al., 2017). Implementation of AR in science learning is still limited, while in other countries, it is widely used in all education levels. In implementing AR in learning, some technical problems are often found, as is often experienced: scan markers are not detected. Therefore, the need for teacher training so that the use of AR technology is more effective.

Previous research involved 20 teachers with different backgrounds, namely philologist, information and communication technology (ICT), mathematics, art, engineering, environmental, physical education, chemistry, and physics, to identify teachers' points of view regarding AR technology in education (Tzima et al., 2019). One of the results of this study is the teacher's opinion regarding training where teachers need systematic training on AR technology so that it can produce optimal results when implementing it in class directly. In addition, other studies have also examined the opinion of pre-service teachers regarding AR in learning using an experimental study, namely the 65-minute laboratory session (Uluyol & Eryilmaz, 2014). The participants in this study were 51 pre-service teachers in the Department of Computer Education and Instructional Technology. The results indicate

that pre-service teachers express their opinions positively regarding the use of AR in educational settings.

Various perspectives regarding AR technology in learning are important because teachers from various educational backgrounds examine a problem differently. No literature has been found that reviews the perspective of science teachers who usually have different educational backgrounds, namely physics, chemistry, and biology. Also, experimental studies are rare in the literature and have the potential to be carried out regarding the use of AR in education. Therefore, this study aims to introduce AR technology to teachers using experimental studies. Besides, to determine teachers' perspectives regarding its implementation in science learning. It explored the teachers' interest in implementing AR in science learning and analysed their perspectives after training on using the technology. The research questions in this study are: (1) How do teachers know AR in science learning? (2) How are teachers interested in implementing AR in science learning? (3) What are teachers' perspectives on AR in science learning?

2. Research method

2.1. Research design

This study employed a mixed research design to collect quantitative and qualitative data. Given the complexity and ambiguity of integrating technology into the learning process according to the Technology, Pedagogy, and Knowledge (TPACK) framework, the assessment is recommended to combine quantitative and qualitative data (Archambault & Barnett, 2010). Quantitative data were collected using an online survey to investigate teachers' knowledge and interest in implementing AR technology in science learning. And qualitative data for exploring teachers' perspectives on AR technology.

2.2. Participants

The study was conducted at the Association of Science Education Teachers in West Bandung, West Java, Indonesia, on 24 female and 8 male science teachers. All participants were undergraduates with different but mostly biology educational backgrounds, as shown in Figure 1. The teachers' ages ranged between 25 and 40 years old, and had diverse teaching experiences, as shown in Figure 2.

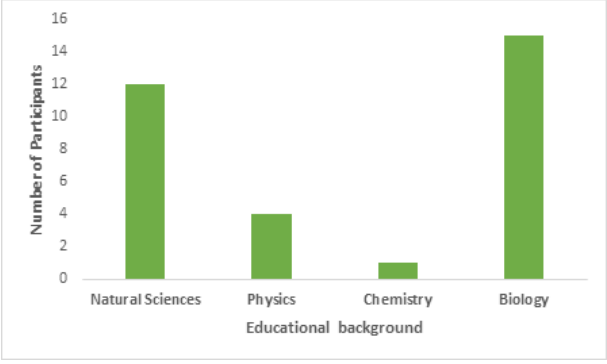


Figure 1. Educational Background of Science Teachers

Figure 1 shows that science teachers' backgrounds differ, mostly in biology. Their teaching experiences also vary, as shown in Figure 2.

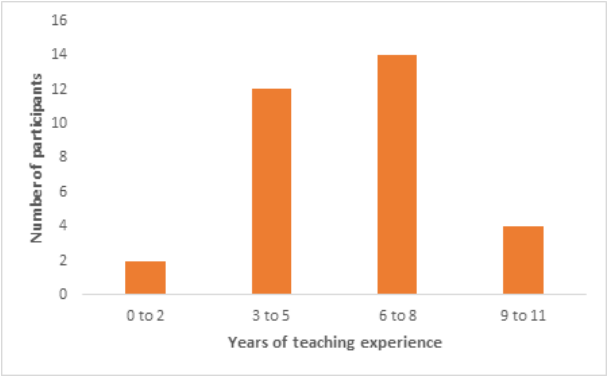


Figure 2. Teaching experience (years) of science teachers

This study selected six qualitative participants for interviews from various educational backgrounds, as shown in Table 1.

Table 1. The composition of participants selected for qualitative data

Educational background	Number of participants
Natural science	2
Biology	2
Physics	1
Chemistry	1

The selected participants have a teaching experience range of 5-8 years and represent each educational background to obtain a deeper understanding.

2.3. Data collection tools

Data were collected using an online survey and interviews. The online survey comprised two sections. The first section consists of the participant's educational background, years of teaching experience, and knowledge of AR technology. The second section was composed of eight questions to determine the teacher's interest in implementing AR technology in science learning. Participants were asked to fill out a Likert scale of 1-5. And the interview aims to analyse teachers' perspectives on implementing AR in science learning. All of the conversations in the interview were audio-recorded.

2.4. Data analysis

Quantitative data were analysed using Microsoft Excel to process basic statistics (Warner & Meehan, 2001). And the interview data audio-recorded were converted into sentences that matched the actual data, so there was no change. Each participant's interview was given a unique code, where B, NS, P, C, and 01 stood for Biology, natural science, physics, chemistry, and the teacher's code, respectively. All texts from interviews were coded according to the purpose of the study (Basit, 2003). After converting audio into a sentence, and the most relevant sentence was selected to answer the research question.

2.5. Program description

This program was conducted for 65 minutes to introduce AR technology to science teachers in three steps, as shown in Figure 3. In the first 20 minutes, the participants were informed about the study and the technology's applications in science learning. The following 35 minutes involved the participants testing the AR technology independently in topics such as physics, chemistry, and biology.

All teachers are given a link that can be accessed to download the AR application with an integrated camera. After downloading the application, they investigated and scanned the marker card to the camera to produce a 3D simulation. The last is distributed online surveys and interviews.

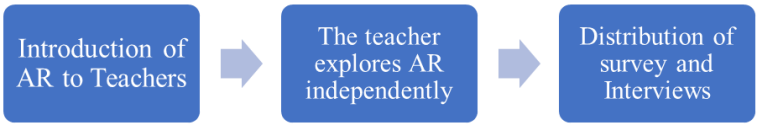
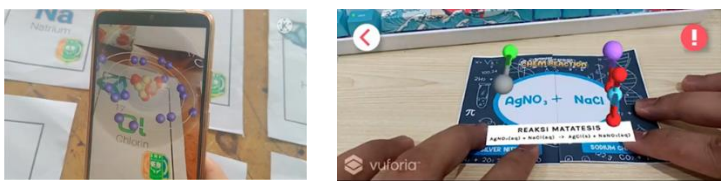


Figure 3. Procedure of Program

Teachers were introduced to AR technology's potential and use in the first stage. Figure 4 shows the documentation of AR introduction to teachers.

Figure 4. Introduction AR to teacher

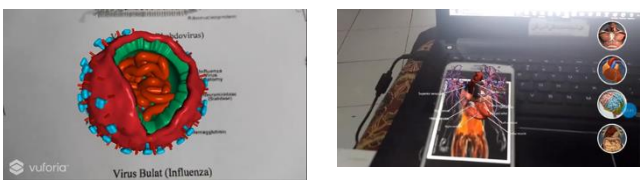
The teachers explored AR independently after understanding its use. Since the participants came from various educational backgrounds, they could choose their preferred content, such as physics, chemistry, or biology.



(a) (b)

Figure 5. Example of Implementing AR in Chemistry Concept

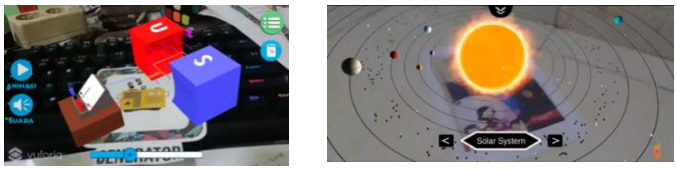
Figure 5 shows an example of AR in chemistry learning, where Figure 5(a) and (b) are the AR application to the atomic structure and an example of application in chemical reactions.



(a) (b)

Figure 6. Example of Implementing AR in Biology Concept

Figure 6 shows AR application in biology learning, whereas Figure 6(a) and (b) are an example of AR applications to explain viruses and human circulatory systems.



(a) (b)

Figure 7. Example of Implementing AR in Physics Concept

Figure 7 indicates the application of AR in physics learning, whereas Figure 7(a) and (b) are their implementations in magnetism and the solar system. After exploring AR independently, a questionnaire was distributed, and random interviews were conducted with teachers from various educational backgrounds.

3. Result

3.1. Teachers' knowledge of AR in science learning

AR is a new technology in education, and teachers are still rarely familiar with the technology. To integrate technology into the learning process, teachers must have adequate knowledge of the technology they will use. Teachers' knowledge of AR technology is shown in Table 2.

Table 2. Teachers' Knowledge of AR in Science Learning

Question	Yes (%)	No (%)
Have you heard of or seen AR before?	25.00	75.00
Have you ever used AR?	12.50	87.50
Have you ever used AR to teach science?	0.00	100.00

The science teacher's answers in Table 2 show that all the participants had not used AR to teach science, 25.00 % had heard of or seen AR before, while 12.50 % had used AR. The participants have used AR Animal Card and AR prayer app for kids' learning and Pokemon Go for location-based games. AR Animal Card 1 of 4, AR prayer app for kids 1 of 4, and Pokemon Go 2 of 4.

3.2. Teachers' interest in implementing AR in science learning

The online survey showed the teacher's interest in AR, as presented in Table 3. The survey consists of statements for 32 teachers. There are eight questions with five answer choices, namely SD (Strongly disagree), D (Disagree), N (Neutral), A (Agree), and SA (Strongly agree).

Table 3. Teachers' Interest in Implementing AR in Science Learning

No	Statements	SD (%)	D (%)	N (%)	A (%)	SA (%)	Total score	%	Description
1	I am interested in teaching using AR technology				4	28	156	97.50	Strongly agree
2	I believe that using AR in science learning improves students' understanding of concepts				24	8	136	85.00	Strongly agree
3	I believe using AR in science learning increases student learning motivation				27	5	133	85.13	Strongly agree
4	AR creates a comfortable and enjoyable learning environment for students				2	30	158	98.75	Strongly agree

No	Statements	SD (%)	D (%)	N (%)	A (%)	SA (%)	Total score	%	Description
5	AR helps students understand abstract concepts			2	24	6	132	82.50	Strongly agree
6	AR has many advantages when implemented in science learning				22	10	138	86.25	Strongly agree
7	The use of AR in science learning streamlines teaching time		12	3	10	7	108	67.50	Agree
8	The use of AR in science learning minimizes student boredom				21	11	139	86.88	Strongly agree

3.3. Teachers' perspectives on AR in science learning

Previously, all participants were asked about the difficulties in teaching science concepts to students. The six teachers interviewed stated they had found it challenging to teach science concepts to students. The difficult concepts to teach are solar systems, cells and systems in the human body, and atomic concepts because students find them hard to imagine. Also, difficulty explaining abstract physics concepts such as electricity, magnetism, and waves. Regarding the difficulties in teaching science concepts, ICT is suggested to provide concrete visual concepts to students.

All the interviewed respondents had experience teaching ICT in the learning process. Applications commonly used by teachers are Google form 5 of 6, Powerpoint 5 of 6, Video 5 of 6, Quiz 3 of 6, Kahoot 2 of 6, Live worksheet, and Physics Education Technology (PhET) 1 of 6. This study found that all participants had never seen AR technology before. The following are answers from teachers regarding their thoughts on AR technology

C1: *The first impression when seeing AR is amazement. When I scanned a marker paper and produced a 3D simulation image, I saw that this technology could be used in science teaching.*

B2: *When I saw AR, I felt I found an answer to my difficulties when explaining abstract science concepts, especially physics. I think this technology would make learning more fun.*

The chemistry and biology teachers stated that AR has the potential to be used in science learning. They were amazed by AR technology and thought they had found answers to difficulties in explaining abstract concepts to make learning more enjoyable for students.

NS1: *AR would facilitate learning abstract concepts and make them more contextual.*

P1: *AR has the potential to be used in science learning to increase students' learning motivation.*

Physics and natural science teachers also stated that AR is a potential technology to be applied in science learning. It facilitates abstract concepts, makes learning more contextual, and increases student motivation.

These statements show that AR is suitable for implementation in science learning. Since it is a new technology, teachers need the training to be proficient in its application:

B1: *AR has the potential to be used in science learning. However, teachers need the training to implement the technology into the learning process and overcome the obstacles during its implementation.*

The statement implies that AR is a potential technology in science learning. However, teachers need training to understand this technology before classroom implementation. Teachers were allowed to

try it independently by being asked: ''How urgently do teachers need advanced training in Augmented Reality?''. The answers were as follows:

NS1: *I need the training to overcome the obstacles in using the AR application, such as unreadable markers, immobile simulations, and the influence of internet connections*

B2: *I need advanced training in implementing AR in science learning according to student needs.*

The statements indicate that teachers needed advanced training before using AR in classroom learning. When trying the technology independently, they encounter obstacles they need training to overcome. Also, teachers need training on how to develop it based on students' needs.

The teachers were asked about the science concept that needs AR as learning media. The answers were as follows:

B2: *Materials that require AR in conveying science concepts are the solar and atomic systems, waves, and optics.*

P1: *Some materials suitable for implementing AR in science learning are the body's metabolic and circulatory systems, viruses, and materials that are difficult to visualise.*

C1: *AR could help explain abstract concepts that are difficult for students to understand, such as global warming, solar and atomic systems, structural layers, light waves, optics, electricity, and magnetism.*

Biology material that requires AR is the metabolic, circulatory, excretory, respiratory, and reproductive systems, viruses, and cells. Chemical materials are atomic systems, while physics materials include global warming, the solar system with structural layers, light waves, optics, electricity, and magnetism.

4. Discussions

4.1. Teachers' knowledge of AR in science learning

AR is a new technology in education and has the potential to be implemented to help understand science concepts. Science has abstract and new concepts that are difficult to concretize, requiring students' imagination (Karagozlu, 2018). Therefore, AR could help students understand these concepts when teachers know about using technology. The survey found that all participants had not used AR in science learning, 25% had heard of or seen the applications, and only 12.5% had used the technology. Applications used by the participants were children's learning media.

The teachers' insufficient knowledge of technological knowledge affects the classroom learning process (Taimalu & Luik, 2019). Teachers with better knowledge integrate technology better to produce better learning outcomes. Learning using AR technology will produce better learning outcomes than learning without technology (Sahronih et al., 2019). Teachers' knowledge of AR helps them cultivate 21st-century skills in students (Shafie et al., 2019). This technology helps students improve their critical thinking skills (Faridi et al., 2021), identify new phenomena that have never been seen before, and develop imagination skills (Sahin et al., 2020).

Currently, a new framework appears as a guideline and provides an overview to integrate technology effectively in the learning process is TPACK (Koehler & Mishra, 2009). This framework requires the teacher to combine three abilities: technology knowledge, pedagogy knowledge, and content knowledge in presenting concepts in the classroom (Tanak, 2020). AR is one of the technologies that can be integrated into learning. Presenting subject matter using technology and knowledge of technology-based learning strategies and methods will produce appropriate collaboration to make it easy for students to understand the material presented (Shafie et al., 2019).

Therefore, teachers need to have knowledge about AR before implementing this technology in classroom learning.

4.2. Teachers' interest in implementing AR in science learning

AR provides many benefits when learning, including science with many abstracts. It could help teachers solve problems regarding the difficulties of explaining abstract concepts (Salmi et al., 2017). Teachers must be interested in integrating technology into learning because it creates enjoyable learning environment. The survey showed that teachers are highly interested in implementing AR in science learning (Table 3).

Teachers are interested in teaching using AR, supporting a previous study that teachers desire to use AR in the learning process (Tzima et al., 2019). These results mean that AR is a solution technology in science learning. The survey also showed that teachers believe AR improves conceptual understanding, increases motivation, and creates an enjoyable learning environment. This is in line with a previous study that AR improves students' understanding of concepts (Karagozlu, 2018). Students learning using AR exhibit increased motivation (Erbas & Demirer, 2019) and interest because the application provides an enjoyable learning environment (Salmi et al., 2017). Similarly, 3D simulation in AR attracts students, increasing their learning motivation (Cai et al., 2012).

The many abstract science concepts that are difficult for students to understand could be understood using AR. Previous studies found that AR effectively explained abstract concepts (Karagozlu & Ozdamli, 2017) and material difficult for students to visualise, improving their imagination skills (Yilmaz, 2021). The application of AR in the learning process has many benefits. It is a suitable technology to explain abstract science concepts to increase students' understanding (Pranoto & Panggabean, 2019). AR reduces students' boredom during the learning process through 3D simulation.

4.3. Teachers' perspective on AR in science learning

The interview results showed that teachers encountered many difficulties in teaching science concepts. These difficulties can be overcome by integrating technology into the learning process (Fidan & Tuncel, 2018). All science teachers who participated in this study have experience using technology in learning. Technology-based learning increases enthusiasm and improves student academic achievements. These results support previous studies that technology affects students' enthusiasm and interest during learning and increases their curiosity (Onyema et al., 2019).

Although participants have experience using technology in the learning process, they stated they had not heard of or seen AR before. The teachers were amazed the first time they saw it and found answers to the difficulties experienced during the teaching process. This result supports a previous study that interviewed pre-service teachers with insufficient knowledge of the technology (Uygur et al., 2018). The study found that few teachers use technology, meaning its benefits in learning should be intensified.

AR could facilitate abstract science concepts and make learning contextual. The technology's 3D simulation helps visualise abstract concepts (Olim & Nisi, 2020). Furthermore, it has the potential to be used in learning to increase students' motivation and create a more contextual environment where real concepts are visualised. The technology could help overcome boredom among students, increasing their curiosity (Borrero & Márquez, 2012). Besides, AR improves students' multi-representation abilities in presenting 3D simulations (Jumini et al., 2021). They learn to define the interrelationships of AR variables using mathematical representation (Medina Herrera et al., 2019).

Furthermore, students learn to create designs of abstract concepts visualised using image representations (Carbonell Carrera & Bermejo Asensio, 2017).

The teacher's perspective also states that AR can be a fun new learning environment for students. This shows that AR technology creates an enjoyable learning environment, making students feel comfortable channeling their curiosity by asking questions (Bogusevschi et al., 2020). Furthermore, AR technology facilitates students to understand detailed science concepts by providing more explanations, increasing students' curiosity and learning outcomes (See et al., 2021).

However, much time is required to teach students how to use technology for the first time, necessitating integrating technology into learning to enhance their understanding. In line with this, previous studies found that technology-based learning improved students' academic achievement (Fidan & Tuncel, 2018). So, teachers still need advanced training to integrate AR technology into the learning process. The advanced training aims to overcome the obstacles encountered in its implementation. They should be taught to solve problems when implementing technology in the learning process. Additionally, teachers need training on developing AR according to students' needs.

5. Conclusions

AR is a technology that teachers are not yet familiar with. The result found that many teachers had less knowledge of AR technology because they had experienced it for the first time. Only 12.50% of teachers had used AR, but none had applied it in science learning. After the teachers explored the technology independently, they were interested in implementing AR technology in science learning. Previously, teachers had experience integrating technology into the learning process and found that technology makes it easier to explain abstract concepts that are difficult for students to visualise. According to the perspective teachers, AR has the potential to be implemented in science learning to facilitate abstract concepts and increase students' interest and motivation. Science teachers from various educational backgrounds have different difficulties in explaining science concepts. Therefore, they need advanced training to optimally implement AR in science learning according to student's needs.

The limitation of the study is a small sample size where only the Association of Science Education Teachers in one of the districts (West Bandung). Future research can combine several perspectives of science teachers based on their teaching areas. Besides, not all regions have sufficient capacity to integrate technology into learning. There is a need for training in integrating technology into the learning process, especially training on AR technology. Suggestions for further research can hold training in developing science content integrated with AR to enhance students' learning ability to be better.

Acknowledgments

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References

Admiraal, W., van Vugt, F., Kranenburg, F., Koster, B., Smit, B., Weijers, S., & Lockhorst, D. (2017). Preparing pre-service teachers to integrate technology into K–12 instruction: evaluation of a technology-infused approach. *Technology, Pedagogy and Education*, *26*(1), 105–120.

Al-Rahmi, W. M., Yahaya, N., Aldraiweesh, A. A., Alamri, M. M., Aljarboa, N. A., Alturki, U., & Aljeraiwi,

A. A. (2019). Integrating technology acceptance model with innovation diffusion theory: An empirical investigation on students' intention to use E-learning systems. *Ieee Access*, *7*, 26797–26809.

Archambault, L. M., & Barnett, J. H. (2010). Revisiting technological pedagogical content knowledge: Exploring the TPACK framework. *Computers & Education*, *55*(4), 1656–1662.

Baser, D., Ozden, M. Y., & Karaarslan, H. (2017). Collaborative project-based learning: An integrative science and technological education project. *Research in Science & Technological Education*, *35*(2), 131–148.

Basit, T. (2003). Manual or electronic? The role of coding in qualitative data analysis. *Educational Research*, *45*(2), 143–154.

Becker, S. A., Cummins, M., Davis, A., Freeman, A., Hall, C. G., & Ananthanarayanan, V. (2017). *NMC horizon report: 2017 higher education edition*. The New Media Consortium.

Bogusevschi, D., Muntean, C., & Muntean, G.-M. (2020). Teaching and learning physics using 3D virtual learning environment: A case study of combined virtual reality and virtual laboratory in secondary school. *Journal of Computers in Mathematics and Science Teaching*, *39*(1), 5–18.

Borrero, A. M., & Márquez, J. M. A. (2012). A pilot study of the effectiveness of augmented reality to enhance the use of remote labs in electrical engineering education. *Journal of Science Education and Technology*, *21*(5), 540–557.

Cai, S., Chiang, F.-K., Sun, Y., Lin, C., & Lee, J. J. (2017). Applications of augmented reality-based natural interactive learning in magnetic field instruction. *Interactive Learning Environments*, *25*(6), 778–791.

Cai, S., Wang, X., Gao, M., & Yu, S. (2012). Simulation teaching in 3D augmented reality environment. *2012 IIAI International Conference on Advanced Applied Informatics*, 83–88.

Carbonell Carrera, C., & Bermejo Asensio, L. A. (2017). Landscape interpretation with augmented reality and maps to improve spatial orientation skill. *Journal of Geography in Higher Education*, *41*(1), 119–133.

Chen, C., & Wang, C.-H. (2015). Employing augmented-reality-embedded instruction to disperse the imparities of individual differences in earth science learning. *Journal of Science Education and Technology*, *24*(6), 835–847.

Erbas, C., & Demirer, V. (2019). The effects of augmented reality on students' academic achievement and motivation in a biology course. *Journal of Computer Assisted Learning*, *35*(3), 450–458.

Eristya, A. M., & Aznam, N. (2019). Natural Science Learning With Modified Free Inquiry to Develop Students' Creative Thinking Skills. *Journal of Physics: Conference Series*, *1233*(1), 12107.

Ertmer, P. A., Ottenbreit-Leftwich, A. T., Sadik, O., Sendurur, E., & Sendurur, P. (2012). Teacher beliefs and technology integration practices: A critical relationship. *Computers & Education*, *59*(2), 423–435.

Faridi, H., Tuli, N., Mantri, A., Singh, G., & Gargrish, S. (2021). A framework utilizing augmented reality to improve critical thinking ability and learning gain of the students in Physics. *Computer Applications in Engineering Education*, *29*(1), 258–273.

Fidan, M., & Tuncel, M. (2018). Augmented reality in education researches (2012-2017): A content

analysis. *Cypriot Journal of Educational Sciences*, *13*(4), 577–589. https://doi.org/10.18844/cjes.v13i4.3487

Fidan, M., & Tuncel, M. (2019). Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education. *Computers & Education*, *142*, 103635.

Geng, S., Law, K. M. Y., & Niu, B. (2019). Investigating self-directed learning and technology readiness in blending learning environment. *International Journal of Educational Technology in Higher Education*, *16*(17), 1–22. https://doi.org/10.1186/s41239-019-0147-0

Johnson, L., Becker, S. A., Cummins, M., Estrada, V., Freeman, A., & Hall, C. (2016). *NMC horizon report: 2016 higher education edition*. The New Media Consortium.

Jumini, S., Cahyono, E., & Falah, M. M. (2021). Analysis of Students' Multi-Representation Ability in Augmented Reality-Assisted Learning. *Library Philosophy and Practice*, 1–8.

Karagozlu, D. (2018). Determination of the impact of augmented reality application on the success and problem-solving skills of students. *Quality and Quantity*, *52*(5), 2393–2402. https://doi.org/10.1007/s11135-017-0674-5

Karagozlu, D., & Ozdamli, F. (2017). Student opinions on mobile augmented reality application and developed content in science class. *TEM Journal*, *6*(4), 660.

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? *Contemporary Issues in Technology and Teacher Education*, *9*(1), 60–70.

McFarlane, D. A. (2013). Understanding the challenges of science education in the 21 st century: new opportunities for scientific literacy. *International Letters of Social and Humanistic Sciences*, *4*, 35–44.

Medina Herrera, L., Castro Pérez, J., & Juárez Ordóñez, S. (2019). Developing spatial mathematical skills through 3D tools: augmented reality, virtual environments and 3D printing. *International Journal on Interactive Design and Manufacturing (IJIDeM)*, *13*(4), 1385–1399.

Ningrum, V. F., Sumarni, W., & Cahyono, E. (2021). Development of Augmented Reality-Based Learning Media on Concept of Hydrocarbon to Improve Multi-representation Ability. *Jurnal Penelitian Pendidikan IPA*, *7*(SpecialIssue), 256–265.

Olim, S. C., & Nisi, V. (2020). Augmented reality towards facilitating abstract concepts learning. *International Conference on Entertainment Computing*, 188–204.

Onyema, E. M., Ogechukwu, U., & Anthonia, E. C. D. (2019). Potentials of mobile technologies in enhancing the effectiveness of inquiry-based learning approach. *International Journal of Education (IJE)*, *2*(01), 1–22.

Pranoto, H., & Panggabean, F. M. (2019). Increase the interest in learning by implementing augmented reality: Case studies studying rail transportation. *Procedia Computer Science*, *157*, 506–513.

Sahin, D., Yilmaz, R. M., Yilmaz, O., Karagozlu, D., Abdusselam, M. S., Karal, H., Fidan, M., & Tuncel, M. (2020). The effect of Augmented Reality Technology on middle school students' achievements and attitudes towards science education. *Computers and Education*, *52*(4), 407–424. https://doi.org/10.1016/j.compedu.2019.103710

Sahronih, S., Purwanto, A., & Sumantri, M. S. (2019). The effect of interactive learning media on

students' science learning outcomes. *Proceedings of the 2019 7th International Conference on Information and Education Technology*, 20–24.

Salmi, H., Thuneberg, H., & Vainikainen, M. P. (2017). Making the invisible observable by Augmented Reality in informal science education context. *International Journal of Science Education, Part B: Communication and Public Engagement*, *7*(3), 253–268. https://doi.org/10.1080/21548455.2016.1254358

Scott, P., Asoko, H., & Leach, J. (2013). Student conceptions and conceptual learning in science. In *Handbook of research on science education* (pp. 31–56). Routledge.

See, B. H., Gorard, S., Lu, B., Dong, L., & Siddiqui, N. (2021). Is technology always helpful?: A critical review of the impact on learning outcomes of education technology in supporting formative assessment in schools. *Research Papers in Education*, 1–33.

Shafie, H., Majid, F. A., & Ismail, I. S. (2019). Technological pedagogical content knowledge (TPACK) in teaching 21st century skills in the 21st century classroom. *Asian Journal of University Education*, *15*(3), 24–33.

Taimalu, M., & Luik, P. (2019). The impact of beliefs and knowledge on the integration of technology among teacher educators: A path analysis. *Teaching and Teacher Education*, *79*, 101–110.

Talebian, S., Mohammadi, H. M., & Rezvanfar, A. (2014). Information and communication technology (ICT) in higher education: advantages, disadvantages, conveniences and limitations of applying e-learning to agricultural students in Iran. *Procedia-Social and Behavioral Sciences*, *152*, 300–305.

Tanak, A. (2020). Designing TPACK-based course for preparing student teachers to teach science with technological pedagogical content knowledge. *Kasetsart Journal of Social Sciences*, *41*(1), 53–59.

Tzima, S., Styliaras, G., & Bassounas, A. (2019). Augmented reality applications in education: Teachers point of view. *Education Sciences*, *9*(2), 99.

Uluyol, Ç., & Eryilmaz, S. (2014). Examining Pre-Service Teachers' Opinions Regarding to Augmented Reality Learning-Arttırılmış Gerçeklik Öğrenmeye İlişkin Öğretmen Adaylarının Görüşlerinin İncelenmesi. *Gefad*, *34*(3), 403–413.

Uygur, M., Yelken, T. Y., & Cenk, A. (2018). Analyzing the views of pre-service teachers on the use of augmented reality applications in education. *European Journal of Educational Research*, *7*(4), 849–860.

Warner, C. B., & Meehan, A. M. (2001). Microsoft Excel™ as a tool for teaching basic statistics. *Teaching of Psychology*, *28*(4), 295–298.

Yilmaz, O. (2021). Augmented Reality in Science Education: An Application in Higher Education. *Shanlax International Journal of Education*, *9*(3), 136–148. https://doi.org/10.34293/education.v9i3.3907