Android-based augmented reality in science learning for junior high schools: Preliminary study

Triana Rejekiningsih, Iwan Maulana, Mochamad Kamil Budiarto, Taufiq Subhanul Qodr
Department of Educational Technology, Faculty of Teacher Training and Education, Universitas Sebelas Maret,
Surakarta, Indonesia

Article Info	ABSTRACT
	Technology in education encourages more effective learning facilitation processes. The lack of variation and innovation in the use of technology used in the form of learning media as a means of supporting learning activities raises many new problems for educational institutions. This research aims to identify the need to create innovations in the implementation of science learning, whose research focus is to analyze the needs for developing smartphone-based innovative augmented reality (AR) learning media. This research is descriptive qualitative. Data collection techniques are observation, interviews, and questionnaires. Teachers and students of junior high schools in Surakarta became the subject of this research. The results showed that students were less focused and unmotivated when participating in the learning process. In addition, the use of learning media is still conventional and not interactive, even though currently all students have smartphones. Based on field facts, the media used by teachers still tends to be conventional, and the majority of students have technological devices such as smartphones, there is great potential for developing innovative technology-based learning media. Smartphone ownership and the lack of interactive learning media are important foundations in innovating the development of smartphone-based augmented reality.

Corresponding Author:

Triana Rejekiningsih
Department of Educational Technology, Faculty of Teacher Training and Education,
Universitas Sebelas Maret
Ir. Sutami Street no. 36 Kentingan, Jebres, Surakarta, Central Java, Indonesia
Email: triana_rizq@staff.uns.ac.id

1. INTRODUCTION

Science is a compulsory subject that plays an important role in school education. This cannot be underestimated because, during the science learning process, the values of scientific attitudes are instilled, which are intrinsically linked to the national education objectives defined in Law No. 20 of 2003. "National education aims to develop students' potential to become human beings who believe and fear God Almighty, have noble character, knowledge, health, competence, independence, creativity, and become responsible and democratic citizens."

Science is a knowledge that is widely known as a scientific product [1] with findings through a long series of systematic studies/scientific processes [2], the scientific attitude that one has determines the success of which is conducting this study. Science subjects are expected to provide students with opportunities to learn about their surroundings and themselves, as well as to develop in their opportunity to implement what they have learned in their daily lives. Science subjects aim to help students understand the relationship between scientific concepts and everyday life [3], [4].

A variety of factors contribute to poor student learning outcomes in science subjects. The low science score on national exams is due to the low cognitive level of learning taught in schools, which consists of only understanding and memorizing. In contrast, the national science exam questions are combined in with high-level ability test questions, potentially cause students to struggle. Problems arise as a result of both internal and external factors, leading to poor student learning outcomes [5], [6]. Internal factors include intelligence, attitudes, talents, interests, and student motivation, while external factors are teacher role and school facility infrastructure [7]. Internal factors, the teacher is faced with a variety of student characteristics that vary in school-based learning activities. Some students could carry out their learning activities smoothly and successfully, but many students faced various challenges in their learning [8], [9]. Meanwhile, in terms of external factors, the teacher's role as the manager of learning is the most influential factor in the learning process. As the manager of learning, the teacher must be able to organize, explore potential, and develop strategies that contribute to increasing student motivation and learning outcomes. However, according to several studies, the teacher's role in the learning process is still not fully appreciated; the teacher still follows a traditional teacher center pattern, wherein the teacher first illustrates the skills and knowledge that are taught to students as a whole, limiting students to developing their knowledge and making the learning process less motivating and active [4], [10], [11].

Motivation as a driving force for learning activities to achieve maximum learning outcomes is referred to as student learning motivation. This confirms that motivation plays a significant role in determining student learning success or failure, because someone who is not motivated will not engage in learning activities [12]. The use of interactive media in the learning process is another aspect that influences student achievement of learning success competencies [13]–[15].

The results of preliminary observations at several Surakarta schools, including Muhammadiyah Surakarta Junior High School 1 and Muhammadiyah Surakarta Junior High School 7, were collected through observations of the learning process. In general, traditional learning methods are still used in science subjects. In this case, the discussion and lecture methods are still centered on the teacher, making the learning class emerge monotonous and less interactive because the interactions that occur are only one-way. Teachers rarely use media because it requires considerable preparation, particularly for media based on electronics and digital, as well as a lack of teacher training to create interactive media and knowledge of the most recent technological developments used as interactive media.

The use of interactive media is considered very important; media as an instrument also affects the atmosphere and conditions of the learning environment [16]. This is enhanced by the presence of "media" technology, which has the potential of making learning less teacher-centered [17], [18]. Even though the focus is now more on learning students (student-centered), the teacher is no longer a source in the process. Students' prior learning, but as a facilitator who assists them in expanding their knowledge. Therefore, technology-enabled learning will lead in more innovative teaching and learning activities [18], [19]. This is due to the fact that technology encompasses a wide range of topics, including problems in everyday life, current sources of information, concept simulations, and communication with professionals in their fields [11], [20]. Furthermore, technology-assisted learning is considered to complement conventional teaching and learning activities [21], [22].

Smartphones are one of the latest technological devices that can be integrated into the educational process as a type of learning media [23], [24]. The increasing number of smartphone users in Indonesia provides significant prospects for developing educational technologies. Augmented reality (AR) is one of the most recent breakthrough technologies in education that can be used as a new medium and a complement to current learning [24], [25]. In the world of education, augmented reality in the learning process is an attempt to adapt to the era of the fourth industrial revolution. Therefore, both teachers and students are expected to be familiar with and use current technology, especially Android-based media.

Some studies have been conducted on the development and use of augmented reality as a learning media. Marta [19] mentioned that in relation to the integration of digital devices, teachers used mobile learning during the learning process in class, indicating that the use of mobile learning technology is feasible to be used in and its benefits disseminated for the learning process In general, secondary education is the level of education with the most integration of technology or electronic devices in the classroom, followed by primary education and pre-school education in third place [19], [23], [26]. Then, in other studies, augmented reality technology was used as a medium to teach students about the butterfly life cycle [27]. Students can observe the life cycle by using their smartphones to observe the growth of virtual caterpillars on host plants to become butterflies. The participants were randomly selected and assigned to the experimental and control groups after using the augmented reality system. The statistical test revealed that the experimental group's learning effectiveness is better than the control group's [27]. Therefore, it shows that using augmented reality media in butterfly life cycle learning can improve students' understanding. Moreover, studies on augmented reality journal articles were examined [28]. The majority of studies reported that the learning process was better in educational settings 53.3%, learning motivation was 28.1%, student involvement in learning was

15.6%, learning comfort increased by 12.5%, and a positive attitude increased by 12.5%. These results suggest that the use of augmented reality media has the potential to increase student learning performance, foster learning motivation, positive attitudes, and a sense of comfort in learning.

At the vocational high school level, augmented reality has also been used as an instructional media. The study revealed that the development of AR technology for productive subjects at the vocational high school level could meet students' needs to improve skills, cognitive, and affective, and make it easier for students to understand abstract things [29]. The use of mobile-based augmented reality in learning implementation can increase student motivation to learn. This is based on some of the support provided by interactive learning media for increased awareness, satisfaction, and self-confidence factors that arise within students [30]. A review of the use of augmented reality in science, technology, engineering, and mathematics (STEM) learning revealed that augmented reality-based learning applications provide a learning activity that can provide a stimulus to students, because a number of features and designs are similar, allowing students to have an influence on increasing their conceptual understanding [24], [31].

The learning process is based on some of the descriptions of field facts. This is still a barrier to media innovation in instructional media. It is necessary to identify students' needs for innovative learning media integrated with information and communications technology (ICT) and to motivate students throughout the learning process. This study examines the implications of using smartphones as a learning resource. As previously stated, there are numerous descriptions of the benefits of augmented reality, which is commonly used as a learning medium. Then, the purpose of this research is to identify the need to produce augmented reality-based learning media that can be used during the learning process. Identification of needs is the first step in a series of smartphone-based augmented reality product development processes for science learning, teachers and students become the focus of the subject for this needs analysis activity considering that they are two core components of learning activities, so that the fulfillment of needs will be achieved both in terms of student needs. as well as the need for teachers to optimize the learning process through innovative learning media. Thus, the learning media innovation products developed will be in accordance with the facts on the ground and the needs of potential users. Therefore, this study aims to identify the needs of teachers and students in innovating in the development of digital learning media, especially smartphone-based augmented reality for science learning. Then, the objective of this study is to identify a need in ways to produce augmented reality-based learning media which can be used during the learning process. As a result, the objective of this study is to identify teacher and student needs in order to innovate in the development of digital learning media, specifically smartphone-based augmented reality for science learning.

2. RESEARCH METHOD

This research is a preliminary study or evaluation of student needs, in some terms it is included in needs analysis research. The qualitative research method is used to select a data collection method [32]. Data collection techniques were carried out through observation, interviews, and giving questionnaires [33]. For research sample, namely students and teachers of Muhammadiyah 1 and 7 Junior High Schools in Surakarta which as a whole the number of students who were the sample of the study were 120 students and four teachers of science subjects. The data analysis technique used is descriptive analysis, using data triangulation [32]. Data from each source is collected through research instruments such as observations, interviews and needs analysis questionnaires described through percentages to see how students think about augmented reality-based learning media [34].

3. RESULTS AND DISCUSSION
3.1. Overview of learning activities in junior high school

Based on the results of observations, when the learning process takes place, the teacher delivers material from textbooks. The teacher used an LCD projector with a simple power point presentation media that was not interactive to explain the material. This is due to the fact that the explanation in Theory only includes text and a few images as examples. Meanwhile, when the teacher asked questions, nearly all of the students were deafeningly silent and unable to respond. Therefore, the learning that takes place is tends to be teacher-centered. Even though interactive media development will provide innovation and a more dynamic learning environment, teachers lack sufficient time management skills and the ability to operate learning media based-apps.

Overall, it was discovered that several problems, among others, were discovered during the learning process: i) Teachers continue to teach using traditional methods; ii) Students are less motivated, so they are not actively involved in the learning process; iii) The use of interactive media in learning has not been maximized; and iv) Facilities for developing interactive media products in schools are still confined.

3.2. Identification of teacher's views on the use of ICT and smartphones in learning activities

To fulfill a comprehensive analysis of needs for the development of an interactive media product for learning, the following are the results of questions and answers with the teacher about the learning process that has occurred thus far. The teacher's results and answers provide evidence that the teachers were found always preparing learning tools (such as lesson plans and media) prior to carrying out learning activities. The teacher then begins the learning process by discussing learning competencies, responding to the material, and mastering the material. Meanwhile, the use of learning media by teachers revealed that, thus far, the media used were insufficient and had not yet fulfilled their skills due to teachers' lack of knowledge of developing a learning media product integrated with ICT and smartphones. Based on the results of the interviews, there are numerous opportunities for using technology such as smartphones in the learning process, indicating that schools have permitted the use of smartphones to support the learning process, though with notes, it must be under the supervision and direction of the teacher. In this example, teacher assistance was required so that the teacher could create smartphone-based interactive media. The statement stated that the teachers supported media development, but only if it is beneficial to the learning process and has the potential to become an innovation if used in classroom learning activities.

3.3. Needs analysis questionnaire to students

This section presents the results of the questionnaire distribution to students. The research sample consisted of 181 students from Muhammadiyah 1 and 7 Junior High Schools in Surakarta. Table 1 shows an accumulation table that begins with the results of a needs analysis based on a distributed questionnaire. The table shows the student's responses to questions 1, 2, and 3. Many students do not understand the material presented during the learning process. The teacher does not use media in interactive or up-to-date learning, such as gadgets, when delivering material. Furthermore, in question number 4, information was obtained that as many as 93% of students expressed their desire to use augmented reality as learning media. Furthermore, students already have smartphones to run Android-based augmented reality media when the science learning process is strengthened through a questionnaire. The next question was obtained 97% of the students' answers, stating "Yes" that they have a smartphone as illustrated in the Table 2.

Table 1. The results of the student need analysis questionnaire

No.	Questions	Answer (%) N=181	
		Agree	Disagree
1	Do you understand the material presented by the teacher?	30%	70%
2	Do teachers use media in the learning process?	26%	74%
3	Do teachers use gadgets as media in learning?	4%	96%
4	Do you agree with using augmented reality media in science learning?	93%	7%

Table 2. Student ownership of smartphones

No.	Questions	Answer (%) N=181	
		Yes	No
1	Do you have a smartphone?	97%	3%

3.4. Discussion

Based on the results of the study, the science subjects at senior high school (SMA) Muhammadiyah Surakarta remain to lack sufficient instructional media. This is based on observations and interviews with the teacher, which revealed that the teacher prefers to use the lecture method during the science learning process, which is accompanied by light discussions with students. The situation of the learning media used in junior high school (SMP) Muhammadiyah Surakarta, on the other hand, revealed that teachers' use of learning media in the teaching and learning process is still relatively low. This result is certainly not in line with the principle of learning which must accommodate the needs of students and the learning system, where in the composition of the learning system apart from the material, the teacher and the environment also need the presence of the media as an intermediary in delivering messages and facilities that provide convenience for students to learn. about a certain material. Even more, learning science in the field requires special consideration in terms of implementation because an efficient learning process produces the best learning outcomes [35], [36].

Teachers need to consider learning resources as one of the best options for creating an effective learning environment. Textbooks, course materials, and other learning content that can be used to support teaching, learning, and research. Textbooks, course materials, and other learning content are examples of learning resources that can be used to promote teaching, learning, and research [37], [38]. Furthermore, one

of the efforts that teachers can make is to use instructional media to more concretely present a series of procedures for science learning materials [39], [40]. Misconceptions in students will be reduced by using learning media [41], [42]. Therefore, learning media will help students better understand the subject taught by the teacher during learning activities, considering that so far 70% of students still tend to have difficulty understanding the subject. Essentially, learning media can be one of the teachers' efforts to help them in delivering the subject so that it is easily accepted and understood by students; however, the learning process used has not optimized this potential, as evidenced by student responses indicating that the teacher does not use learning media during the learning process. Nevertheless, the use of instructional media can help students understand abstract material [43], [44]. Besides, instructional media can explain subject delivery in a visually appealing, innovative, and integrative way [11]. Therefore, using interactive media can improve learning processes and outcomes. Teachers can benefit from the use of augmented reality-based learning media in all aspects of the teaching and learning process [45]. Teachers should have the desire and need to learn how to use instructional media effectively in the teaching and learning process [46].

There have been many emerging uses and research results from the use of AR in various educational institutions. Augmented reality (AR)-based learning media are appropriate for vocational school students to use in order to reduce the level of abstraction of the subject being taught [47], [48]. In addition, augmented reality media can improve learning outcomes and student learning completion. The results of implementing AR media in biology learning are deemed useful, with the potential to increase achievement completion by 76% [49]. In the context of the broad use of augmented reality to classroom learning, as well as independent learning, it is well known that AR can promote collaborative learning around virtual content, which in turn can facilitate personally meaningful experiences for each student [50]. In line with this, mobile-based learning media could help non-technical students learn with greater motivation [51]. However, their success in achieving learning goals or competencies will depend on proper planning and implementation, considering their backgrounds and characteristics. The results of the questionnaire revealed that nearly all students, 97%, already own a smartphone, indicating a potential for the use and development of learning media based on augmented reality through smartphone devices [52]–[54].

Based on previous studies which demonstrated that augmented reality had many benefits in promoting the learning process, this was in line with students' opinions, with nearly 97 % agreeing to develop digital media for learning based on augmented reality. The success of developing a learning media, in this case augmented reality for learning activities cannot be separated from needs analysis activities as a basis for identifying various problems and formulating answers to problems [55]–[57].

Based on the prior description and discussion, teachers must be able to develop learning content that is integrated with technology, such as smartphones, that students are now familiar with, while also taking into account the characteristics and phases of student development. Students' learning activities are organized to make achieving competency easier for them. Therefore, teachers should integrate learning activities with a range of methods and media options, as well as use a development approach to help students better understand a subject and think in harmony with their classmates. Smartphone-based learning media, particularly AR, proves to be a promising solution for addressing the various issues that teachers and students experience during the learning process. Teachers should develop learning media integrated with technology, such as today's smartphones, based on the description and discussion. The AR has been familiar to students while taking into account the characteristics and stages of student development. Learning activities are intended to help students in achieving competence. Thus, teachers should combine learning activities with a wide range of methods and media options, as well as use a developmental approach to make it easier for students to understand a subject and consider in harmony with students. Smartphone-based learning media, in this case AR, has seemed to be appropriate for mending the various issues faced by teachers and students during the learning process.

4. CONCLUSION

Based on the results and discussion of needs analysis with a sample of teachers and junior high school students, a conclusion can be derived that the use of instructional media in science learning has not been implemented optimally. The lack of smartphone-based interactive media to support learning is considered to be an impediment to achieving learning objectives, despite the fact that teachers already have access and competencies to use smartphones as supporting media for the learning process, but this is rarely implemented due to educators' limited abilities in developing smartphone-based learning media. Students were found to be enthusiastic about developing learning media innovation products based on Android, particularly augmented reality. Teachers need smartphone-based learning media to help them explain abstract subject, especially in chemistry courses. In the case of learning resources, the learning media that should be developed in science learning in smartphone-based media consider the characteristics and needs of students.

The results of the study can be used to help teachers develop a dynamic learning environment by integrating technology. For other researchers working in education, this study could be used as a fundamental basis and input for developing other smartphone-based teaching media and augmented reality, which is exciting and appropriate for students during the learning process.

REFERENCES

[1]   E. Rofiah, N. S. Aminah, and W. Sunarno, "Development of science learning modules based on high order thinking skills (HOTS) to improve critical thinking skills of class VIII SMP/MTs students," (in Indonesian), *INKUIRI: Jurnal Pendidikan IPA*, vol. 7, no. 2, p. 285, Aug. 2018, doi: 10.20961/inkuiri.v7i2.22992.

[2]   X. Tang and D. Zhang, "How informal science learning experience influences students' science performance: a cross-cultural study based on PISA 2015," *International Journal of Science Education*, vol. 42, no. 4, 2020, doi: 10.1080/09500693.2020.1719290.

[3]   J. Jufrida, F. R. Basuki, W. Kurniawan, M. D. Pangestu, and O. Fitaloka, "Scientific literacy and science learning achievement at junior high school," *International Journal of Evaluation and Research in Education (IJERE)*, vol. 8, no. 4, pp. 630-636, 2019, doi: 10.11591/ijere.v8i4.20312.

[4]   M. Suendarti and V. Virgana, "Elevating natural science learning achievement: Cooperative learning and learning interest," *Journal of Education and Learning (EduLearn)*, vol. 16, no. 1, pp. 114–120, 2022, doi: 10.11591/edulearn.v16i1.20419.

[5]   R. Idris, "Overcoming learning difficulties with a cognitive psychology approach," (in Indonesian), *Lentera Pendidikan: Jurnal Ilmu Tarbiyah dan Keguruan*, vol. 12, no. 2, pp. 152–172, Dec. 2009, doi: 10.24252/lp.2009v12n2a3.

[6]   D. I. Hadi and J. Junaidi, "Efforts to improve critical thinking skills through the application of problem-based learning models in sociology learning class XI IPS 2 SMA Negeri 1 Pariaman," (in Indonesian), *Jurnal Socius: Journal of Sociology Research and Education*, vol. 4, no. 1, p. 22, Mar. 2018, doi: 10.24036/scs.v4i1.14.

[7]   F. Fakhrurrazi, "The Nature of Effective Learning," (in Indonesian), *At-Tafkir*, vol. 11, no. 1, pp. 85–99, Oct. 2018, doi: 10.32505/at.v11i1.529.

[8]   J. W. Lin, M. H. Yen, J. C. Liang, M. H. Chiu, and C. J. Guo, "Examining the factors that influence students' science learning processes and their learning outcomes: 30 years of conceptual change research," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 12, no. 9, 2016, doi: 10.12973/eurasia.2016.000600a.

[9]   A. K. Haqiqi, "Analysis of the Factors Causing Difficulties in Learning Science for Middle School Students in Semarang City," (in Indonesian), *Edu Sains: Jurnal Pendidikan Sains & Matematika*, vol. 6, no. 1, p. 37, Oct. 2018, doi: 10.23971/eds.v6i1.838.

[10]   N. Halimah, K. Suma, and P. Sarini, "The effect of group investigation type cooperative learning model assisted by virtual laboratory media on students' science learning outcomes," (in Indonesian), *Jurnal Pendidikan dan Pembelajaran Sains Indonesia (JPPSI)*, vol. 2, no. 1, p. 35, Mar. 2019, doi: 10.23887/jppsi.v2i1.17220.

[11]   N. F. Saidin, N. D. Abd Halim, and N. Yahaya, "A Review of Research on Augmented Reality in Education: Advantages and Applications," *International Education Studies*, vol. 8, no. 13, pp. 1–8, Jun. 2015, doi: 10.5539/ies.v8n13p1.

[12]   R. Roemintoyo, C. V. Zeyn, A. Nurhidayanti, and M. Budiarto, "Implementation of the ARCS Learning Model and Building Component Teaching Aids to Improve Learning Outcomes of State Vocational High School Students," *International Journal of Instructional Technology and Educational Studies*, vol. 3, no. 1, pp. 33–37, Jan. 2022, doi: 10.21608/ihites.2021.103005.1065.

[13]   V. Motamedi, "The promises of presentational technology for teaching and learning," *Journal of Education and Learning (EduLearn)*, vol. 13, no. 3, pp. 416–419, 2019, doi: 10.11591/edulearn.v13i3.13175.

[14]   C.-C. Kao and Y.-J. Luo, "Effects of Multimedia-Assisted Learning on Learning Behaviors and Student Knowledge in Physical Education Lessons: Using Basketball Game Recording as an Example," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 15, no. 01, pp. 119–139, Jan. 2020, doi: 10.3991/ijet.v15i01.11393.

[15]   R. M. Sinaga, T. Trisnaningsih, P. Pujiati, and D. Sudarmansyah, "Development of Learning Media Based on Mobil Learning Application," *Jurnal Pendidikan Progresif*, vol. 9, no. 1, pp. 50–58, 2019, doi: 10.23960/jpp.v9.i1.201907.

[16]   A. I. Sari, N. Suryani, D. Rochsantiningsih, and S. Suharno, "Digital Learning, Smartphone Usage, and Digital Culture in Indonesia Education," *Integration of Education*, vol. 24, no. 1, pp. 20–31, Mar. 2020, doi: 10.15507/1991-9468.098.024.202001.020-031.

[17]   B. Raji, "Significance and challenges of computer assisted education programs in the UAE: A case study of higher learning and vocational education," *Education and Information Technologies*, vol. 24, no. 1, pp. 153–164, Jan. 2019, doi: 10.1007/s10639-018-9767-6.

[18]   Z. G. Shatri, "Advantages and disadvantages of using information technology in learning process of students," *Journal of Turkish Science Education*, vol. 17, no. 3, pp. 420–428, 2020, doi: 10.36681/tused.2020.36.

[19]   L. C. Marta, "The Integration of digital devices into learning spaces according to the needs of primary and secondary teachers," *TEM Journal*, vol. 8, no. 4, pp. 1351–1358, 2019, doi: 10.18421/TEM84-36.

[20]   H. Fitria and S. Suminah, "Role of Teachers in Digital Instructional Era," *Journal of Social Work and Science Education*, vol. 1, no. 1, pp. 70–77, 2020, doi: 10.52690/jswse.v1i1.11.

[21]   M. T. Machmud, A. P. Widiyan, and N. R. Ramadhani, "The development and policies of ICT supporting educational technology in Singapore, Thailand, Indonesia, and Myanmar," *International Journal of Evaluation and Research in Education (IJERE)*, vol. 10, no. 1, pp. 78–85, Mar. 2021, doi: 10.11591/ijere.v10i1.20786.

[22]   M. A. Moreira, V. M. H. Rivero, and J. J. Sosa Alonso, "Leadership and school integration of ICT. Teachers perceptions in Spain," *Education and Information Technologies*, vol. 24, no. 1, pp. 549–565, Jan. 2019, doi: 10.1007/s10639-018-9789-0.

[23]   R. Roemintoyo and M. K. Budiarto, "Flipbook as Innovation of Digital Learning Media: Preparing Education for Facing and Facilitating 21st Century Learning," *Journal of Education Technology*, vol. 5, no. 1, p. 8, Apr. 2021, doi: 10.23887/jet.v5i1.32362.

[24]   N. Elmqaddem, "Augmented Reality and Virtual Reality in Education. Myth or Reality?" *International Journal of Emerging Technologies in Learning (iJET)*, vol. 14, no. 03, p. 234, Feb. 2019, doi: 10.3991/ijet.v14i03.9289.

[25]   M. S. Sidhu and J. G. Ying, "Experiencing new learning, interaction and visualization process using augmented reality technology," *TEM Journal*, vol. 6, no. 2, pp. 222–231, 2017, doi: 10.18421/TEM62-05.

[26]   A. H. Ziadat, "The impact of E-learning in developing academic skills and social interaction among students with learning disabilities in Jordan from the perspective of their teachers," *TEM Journal*, vol. 8, no. 4, pp. 1440–1448, 2019, doi: 10.18421/TEM84-48.

[27]   W. Tarng, K.-L. Ou, C.-S. Yu, F.-L. Liou, and H.-H. Liou, "Development of a virtual butterfly ecological system based on augmented reality and mobile learning technologies," *Virtual Reality*, vol. 19, no. 3–4, pp. 253–266, Nov. 2015, doi: 10.1007/s10055-015-0265-5.

[28]   S. N. A. Majid and A. R. Salam, "A Systematic Review of Augmented Reality Applications in Language Learning," *International Journal of Emerging Technologies in Learning*, vol. 16, no. 10, 2021, doi: 10.3991/ijet.v16i10.17273.

[29]   M. Mantasia and H. Jaya, "Development of augmented reality technology as strengthening and supporting learning methods in vocational schools for the implementation of the 2013 curriculum," (in Indonesian), *Jurnal Pendidikan Vokasi*, vol. 6, no. 3, pp. 281–291, Nov. 2016, doi: 10.21831/jpv.v5i3.10522.

[30]   T. Khan, K. Johnston, and J. Ophoff, "The Impact of an Augmented Reality Application on Learning Motivation of Students," *Advances in Human-Computer Interaction*, vol. 2019, pp. 1–14, Feb. 2019, doi: 10.1155/2019/7208494.

[31]   M.-B. Ibáñez and C. Delgado-Kloos, "Augmented reality for STEM learning: A systematic review," *Computers & Education*, vol. 123, pp. 109–123, Aug. 2018, doi: 10.1016/j.compedu.2018.05.002.

[32]   C. A. McKim, "The Value of Mixed Methods Research: A Mixed Methods Study," *Journal of Mixed Methods Research*, vol. 11, no. 2, 2017, doi: 10.1177/1558689815607096.

[33]   E. A. Kyza, Y. Georgiou, M. Souropetsis, and A. Agesilaou, "Collecting ecologically valid data in location-aware augmented reality settings: A comparison of three data collection techniques," *International Journal of Mobile and Blended Learning*, vol. 11, no. 2, pp. 78–95, 2019, doi: 10.4018/IJMBL.2019040106.

[34]   N. Elangovan and E. Sundaravel, "Method of preparing a document for survey instrument validation by experts," *MethodsX*, vol. 8, 2021, doi: 10.1016/j.mex.2021.101326.

[35]   R. Amelia, U. Salamah, M. Abrar, D. Desnita, and U. Usmeldi, "Improving Student Learning Outcomes Through Physics Learning Media Using Macromedia Flash," *Journal of Education Technology*, vol. 5, no. 3, pp. 491–500, 2021, doi: 10.23887/jet.v5i3.36203.

[36]   Y. Bai, "On Modern Computer Assisted Language Learning Facilities and its Integrated Teaching," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 13, no. 11, p. 225, Nov. 2018, doi: 10.3991/ijet.v13i11.8542.

[37]   Y. Park, "A pedagogical framework for mobile learning: Categorizing educational applications of mobile technologies into four types," *The International Review of Research in Open and Distributed Learning*, vol. 12, no. 2, p. 78, Feb. 2011, doi: 10.19173/irrodl.v12i2.791.

[38]   M. A. Camilleri and A. C. Camilleri, "Digital Learning Resources and Ubiquitous Technologies in Education," *Technology, Knowledge and Learning*, vol. 22, no. 1, pp. 65–82, Apr. 2017, doi: 10.1007/s10758-016-9287-7.

[39]   R.-J. Chen, "Investigating models for preservice teachers' use of technology to support student-centered learning," *Computers & Education*, vol. 55, no. 1, pp. 32–42, Aug. 2010, doi: 10.1016/j.compedu.2009.11.015.

[40]   A. Garcia, J. Abrego, and J. Jauregui, "Technologies Frequently Used by Elementary Principals," *Universal Journal of Educational Research*, vol. 7, no. 1, pp. 95–105, Jan. 2019, doi: 10.13189/ujer.2019.070113.

[41]   R. Capuno, H. Revalde, J. O. Etcuban, M. Aventuna, G. Medio, and R. A. Demeterio, "Facilitating Learning Mathematics Through the Use of Instructional Media," *International Electronic Journal of Mathematics Education*, vol. 15, no. 1, May 2019, doi: 10.29333/iejme/5785.

[42]   I. R. Karo and R. Rohani, "Benefits of Media in Learning," (in Indonesian), *AXIOM: Jurnal Pendidikan dan Matematika*, vol. 7, no. 1, Jun. 2018, doi: 10.30821/axiom.v7i1.1778.

[43]   S. Suyitno, "Development of Interactive Multimedia Measurement Techniques to Improve Learning Outcomes of Vocational High School Students," (in Indonesian), *Jurnal Pendidikan Teknologi dan Kejuruan*, vol. 23, no. 1, pp. 101–109, 2016, doi: 10.21831/jptk.v23i1.9359.

[44]   N. Ignatova, V. Dagienė, and S. Kubilinskienė, "ICT-based Learning Personalization Affordance in the Context of Implementation of Constructionist Learning Activities," *Informatics in Education*, vol. 14, no. 1, pp. 51–65, Apr. 2015, doi: 10.15388/infedu.2015.04.

[45]   J. Yip, S.-H. Wong, K.-L. Yick, K. Chan, and K.-H. Wong, "Improving quality of teaching and learning in classes by using augmented reality video," *Computers & Education*, vol. 128, pp. 88–101, Jan. 2019, doi: 10.1016/j.compedu.2018.09.014.

[46]   S. Deb, Suraksha, and P. Bhattacharya, "Augmented Sign Language Modeling (ASLM) with interaction design on smartphone - an assistive learning and communication tool for inclusive classroom," *Procedia Computer Science*, vol. 125, pp. 492–500, 2018, doi: 10.1016/j.procs.2017.12.064.

[47]   T. Prasetiyo, P. Setyosari, and S. Sihkabuden, "Development of augmented reality media for building image engineering expertise program in vocational middle school," (in Indonesian), *JINOTEP (Jurnal Inovasi dan Teknologi Pembelajaran) Kajian dan Riset dalam Teknologi Pembelajaran*, vol. 4, no. 1, pp. 37–46, Jan. 2018, doi: 10.17977/um031v4i12017p037.

[48]   T. D. Pamungkas, "Android-based augmented reality media and the curiosity about mathematics," in *Journal of Physics: Conference Series*, 2020, vol. 1663, no. 1, doi: 10.1088/1742-6596/1663/1/012016.

[49]   I. Aripin and Y. Suryaningsih, "Development of Biology Learning Media Using Android-Based Augmented Reality (AR) Technology on the Concept of the Nervous System," (in Indonesian), *Sainsmat: Jurnal Ilmiah Ilmu Pengetahuan Alam*, vol. 8, no. 2, p. 47, Oct. 2019, doi: 10.35580/sainsmat82107192019.

[50]   K. R. Bujak, I. Radu, R. Catrambone, B. MacIntyre, R. Zheng, and G. Golubski, "A psychological perspective on augmented reality in the mathematics classroom," *Computers & Education*, vol. 68, pp. 536–544, Oct. 2013, doi: 10.1016/j.compedu.2013.02.017.

[51]   H. F. Hanafi, C. S. Said, M. H. Wahab, and K. Samsuddin, "Improving Students' Motivation in Learning ICT Course with the Use of A Mobile Augmented Reality Learning Environment," *IOP Conference Series: Materials Science and Engineering*, vol. 226, p. 012114, Aug. 2017, doi: 10.1088/1757-899X/226/1/012114.

[52]   M. C. Lam et al., "Interactive augmented reality with natural action for chemistry experiment learning," *TEM Journal*, vol. 9, no. 1, pp. 351–360, 2020, doi: 10.18421/TEM91-48.

[53]   J. Chipps, J. Kerr, P. Brysiewicz, and F. Walters, "A Survey of University Students' Perceptions of Learning Management Systems in a Low-Resource Setting Using a Technology Acceptance Model," *CIN: Computers, Informatics, Nursing*, vol. 33, no. 2, pp. 71–77, Feb. 2015, doi: 10.1097/CIN.0000000000000123.

[54]   H. Elmunsyah, W. N. Hidayat, and K. Asfani, "Interactive learning media innovation: utilization of augmented reality and pop-up book to improve user's learning autonomy," *Journal of Physics: Conference Series*, vol. 1193, p. 012031, Apr. 2019, doi: 10.1088/1742-6596/1193/1/012031.

[55]   M. K. Budiarto, H. Joebagio, and S. Sudiyanto, "Student's View of Using Digital Learning Media in Classroom Activities: A Case of Public Senior High School in Cirebon, Indonesia," *Jurnal Pendidikan Progresif*, vol. 10, no. 1, pp. 47–54, 2020, doi: 10.23960/jpp.v10.i1.202006.

[56] D. Saputri, Fitriani Eka and Annisa, Muhsinah and Kusnandi, "Development of Science Learning Media Using Android-Based Augmented Reality (AR) for Class III Students of SDN 015 Tarakan," (in Indonesian), *Widyagogik: Jurnal Pendidikan dan Pembelajaran Sekolah Dasar*, vol. 6, no. 1, pp. 57–72, 2018, doi: 10.21107/widyagogik.v6i1.4562.

[57] I. Nasrulloh and A. Ismail, "ICT-based learning needs analysis," (in Indonesian), *Jurnal Pendiidkan Teknologi Informasi dan Komunikasi (PETIK)*, vol. 3, no. 1, pp. 28–32, 2018, doi: 10.31980/jpetik.v3i1.355.

BIOGRAPHIES OF AUTHORS

Triana Rejekiningsih [iD] [g] [sc] [○] is a Lecturer and Head of the Master of Educational Technology Study Program, Faculty of Teacher Training and Education, Sebelas Maret University. Dr Triana Rejekiningsih research interest is in the field of 21st century Education and Learning Technology. She can be contacted at email: triana_rizq@staff.uns.ac.id.

Iwan Maulana [iD] [g] [sc] [○] is an Assistant Lecturer in the Master of Educational Technology Study Program, and a student of the Doctoral Program of Education, Faculty of Teacher Training and Education, Sebelas Maret University. His research focuses on Educational Technology, Augmented Reality, Multimedia, Learning Management Systems, Instructional Media, Design Instructional. He can be contacted at email: Imaw1993@student.uns.ac.id.

Mochamad Kamil Budiarto [iD] [g] [sc] [○] is an Assistant Lecturer in the Master of Educational Technology Study Program, Faculty of Teacher Training and Education, Sebelas Maret University, and a Tutor Tuton in Univeritas Terbuka. His research focuses on the fields of educational technology, interactive learning media, e-learning, and entrepreneurial learning. He can be contacted at email: mkbudiarto@student.uns.ac.id.

Taufiq Subhanul Qodr [iD] [g] [sc] [○] is an Assistant Lecturer in the Master of Educational Technology Study Program, Faculty of Teacher Training and Education, Sebelas Maret University. His research focuses on Educational Technology, Virtual Reality, Multimedia, Learning Management Systems. He can be contacted at: taufiqsubhanul@student.uns.ac.id.