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Augmented Reality Media Development in STEAM Learning in Elementary Schools

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ABSTRACT

The need for technology-based media is vital in the era of 21st-century education. Here, augmented reality media is a medium predicted to provide a more realistic experience successfully and in line with the developmental phase of elementary school students. For this reason, this study aims to analyze the need for augmented reality media development and develop an initial design for augmented reality media development in STEAM learning in elementary schools. This research used the R&D method with two of the four stages of R&D research. These stages are preliminary studies and initial design development. The subjects of this study were seven teachers and 129 students of a public elementary school in East Java, Indonesia. The instruments of this research were questionnaires and interviews. Data analysis used descriptive statistics and interpretive analysis. The results of this study revealed that teachers and students needed media that can represent material in-depth, increase interest and motivation, and provide experiences, such as STEAM-based augmented reality learning media. Meanwhile, the initial design development results of STEAM-based augmented reality learning media were in the form of six types of designs, containing *Batik*, *Wayang* (puppet), *Gamelan*, *Borobudur* Temple, *Kereta Kencana* (golden chariot), and *Keris*.

1. INTRODUCTION

In 2015, the Partnership for 21st Century Learning developed a learning framework for the 21st century [1, 2]. This learning requires students to have skills in life and careers. The skills required include flexibility, adaptability, initiative and independence, social and cultural skills, productive accountability, leadership, and responsibility [3]. With these skills, students are required to have skills in learning and have new ideas, such as creative and innovation, critical thinking, problem-solving, communication and collaboration, seeking information, and using media and technology (such as information, media, and ICT literacy) [4-6].

Drake and Reid [7], Wagner [8], and the Change Leadership Group of Harvard University have identified the competencies and survival skills students need to face life, the world of work, and citizenship in the 21st century. They are emphasized on the following seven skills: (1) critical thinking, creative, and problem-solving skills, (2) collaboration and leadership, (3) dexterity and adaptability, (4) initiative and entrepreneurial spirit, (5) being able to communicate effectively both orally and in writing, (6) able to access and analyze information, and (7) have curiosity and imagination. These skills can cover the achievement/need for learning based on science, technology, machines, arts, and mathematics. For example, critical thinking and problem-solving skills are required skills in learning science and mathematics; the ability to access and analyze information is needed in technology learning; having a curiosity and imaginative become a necessity in learning art; dexterity and collaboration are needed in a variety of subject areas, such as machine learning, arts, science, and math.

In addition, the need for 21st-century educational skills goes hand in hand with technological developments [9]. This development is growing rapidly and swiftly. Undoubtedly, this development influences various sectors of human life, one of which is the education sector [10]. The most visible technological development is the use of gadgets, especially the utilization of smartphones in everyday life, including in the field of education [11]. It opens up great opportunities in utilizing application technology on smartphones to be developed into application-based learning media [12]. The technology that allows embedded in smartphones is augmented reality (AR) technology. AR technology utilization can also be applied in learning in elementary schools [13]. Moreover, at this time, elementary schools have implemented a thematic learning system for their students. Thematic learning is an approach that involves several fields of study to provide meaningful experiences for children [14]. It is meaningful because the child will understand the concepts learned through direct experience and connect with other concepts during learning. That way, the existence of AR technology has a role in mediating the delivery of material in thematic learning in elementary schools [15].

AR is a technology that can combine two- or three-dimensional virtual objects into a real environment, generating or projecting them in real-time [16]. Also, according to Fleck & Simon [17], AR is a technology that combines two-dimensional and three-dimensional virtual objects into a real three-dimensional environment. Learning media using AR is expected to be a source of learning for students. This media also functions as an independent learning medium for students [18]. AR media can also help students in learning outside of school hours. In their research, Syawaludin et al. [19] stated that AR technology could be an innovation in learning media

in schools without compromising the role of book media, and this media can be developed on various mobile devices with the Android Operating System (OS).

According to Goebert and Greenhalgh [20], the advantages of AR include an attractive visual display since it can display 3D objects and their animations as if they were in a real environment and juxtaposed with information about 3D objects so that they can make users interested in learning about them. AR technology is starting to be applied in education because it is innovative, real, and more real-time. This technology can be implemented in various media, such as desktop applications, smartphones, industrial fields, and even print media, such as books, magazines, or newspapers [21]. In addition, AR technology may be preferred in learning, especially in teaching abstract concepts, by looking at the cognitive stage development experienced by students [16].

On the other hand, the Ministry of Education in Indonesia has decided on provisions or regulations regarding the learning system [22]. One of the provisions developed in every educational institution today is thematic learning. This type of learning has spread at every level of education, including the elementary school. Thematic learning intentionally links several aspects of the lesson (intra- and inter-subject) [23]. This combination will produce complete knowledge and skills. It is said to be complete if learning is not only limited to one lesson content but also contains several other lesson contents [24]. This complete concept will be covered by the science, technology, engineering, art, and mathematical (STEAM) approach.

STEAM is integrated learning between science, technology, engineering, and mathematics to develop students' creativity through problem-solving processes in everyday life [25]. The definition of STEAM, according to Amo et al. [26], is an interdisciplinary approach to learning in which students implement science, technology, engineering, and mathematics in real contexts, connecting schools, the world of work, and the global community to develop STEAM in students. In addition, learning with the STEAM approach is also said to prepare students to face the real world full of problems to be ready in global competition. As revealed by Bybee [27], developed countries such as the United States have used STEAM to overcome problems and challenges that arise in the 21st century. It certainly does not rule out the possibility to apply in developing countries, such as Indonesia, to use STEAM so that later, students will be able to compete in various aspects in this modern era.

The STEAM learning process involves several key skills for 21st-century students, covering collaboration, creativity, critical thinking, computerization, cultural understanding, and independence in learning and career [28]. Thus, STEAM is designed to prepare students to face global competition by connecting the four aspects: science, technology, engineering, and mathematics. The four aspects of STEAM can make knowledge more meaningful if it is integrated into the learning process. Learning using the STEAM approach is also expected to produce meaningful learning for students by integrating knowledge, concepts, and logical skills [18, 29, 30]. In addition, STEAM is used to address the real world through a design-based problem-solving process such as that used by engineers or scientists [31]. According to Hsu et al. [32], some benefits of STEAM are that it makes students problem solvers, inventors, innovators, independent, logical thinkers, and technology literate.

In elementary schools, the STEAM approach aligns with the conditions of learning that must be applied in schools, especially thematic learning. STEAM is also suitable for application in thematic 2013 curriculum learning, which integrates several subjects. Applying the STEAM approach in the thematic learning process is expected to equip students with various skills to face competition in the 21st century.

Similar studies have been carried out by several previous researchers. Osadchyi and Varina [33] highlighted the analysis of the utilization of AR technology in the process of emotional development. Their findings resulted that AR technology has succeeded in increasing students' emotional stability and personality. In addition, other studies have examined the integration of STEM with AR utilization during online learning. The findings showed that AR and VR [34-37] were effectively implemented in online learning [38, 39]. Another study investigated AR technology in learning during a pandemic. The findings concluded that AR technology could be integrated into STEM learning [40, 41].

Moreover, several previous studies have highlighted and yielded findings regarding the use of AR technology in learning. However, striking differences were found. The current research develops AR technology in learning, but AR is not only used as technology but also as a learning medium. The AR media is also integrated with the STEAM approach. In addition, some previous findings only integrated STEM learning without adding the art aspect in STEM. Thus, the AR media studied in the current study are STEAM-based and focused on thematic learning. Furthermore, thematic learning is only applied in elementary schools. That way, it is interesting if elementary school students become the primary focus of developing media technology. At this level, they really enjoy learning that has the nuances of technology, so it feels right if the development of augmented reality media is carried out in elementary schools. Based on the description stated previously, this article aims to analyze the needs and develop an initial design of STEAM-based AR learning media in thematic learning in elementary schools.

2. METHODS

2.1 Research design

This research adopted research and development (R&D) [42, 43]. The stages of R&D research include preliminary studies, design preparation, product development, and product testing. This research has carried out two stages/parts of R&D. The stages conducted were the preliminary study stage and the design preparation. In the preliminary study stage, the researchers analyzed the initial problems of the research sample and explored in-depth information about the need for technology-based learning media on the perceptions of teachers and students. Meanwhile, the design preparation stage was carried out by compiling the initial design of the STEAM-based AR learning media prototype.

2.2 Sample and data collection

This study involved teachers and elementary school students in Tuban, East Java, Indonesia. The sampling technique/research participant was carried out by the purposive sampling technique. Students and teachers were from schools which had implemented STEAM. The choice of this subject was based on several reasons: (1) the teacher at the

elementary schools had attended STEAM learning training; (2) some teachers had tried to use STEAM; (3) teachers were accustomed to use audio, visual, and information technology-based media; (4) the school supported media development activities through collaboration between universities and schools. Based on those reasons, the research participants were seven teachers and 129 students and elementary school.

2.3 Collection of data

Data collection techniques employed questionnaires and unstructured interviews. The questionnaire in this study was a modified research result of Kobayashi et al. [44]. The questionnaire focused on extracting data about the application of STEAM and the use of learning media. There were two questionnaires: a questionnaire for teachers and students. The questionnaire was a closed questionnaire since the answers only contained two answer choices (yes or no). There were 15 questionnaire questions addressed to students about their response to media and STEAM learning. In addition, there was also a teacher's questionnaire about their response to media and STEAM learning with a total of 10 questionnaire questions. The type of questionnaire used was also the same, namely a closed questionnaire. Meanwhile, interviews were conducted to find out more about the needs of learning media. The type of interview used was an unstructured interview. This interview was addressed to teachers and students.

2.4 Analyzing of data

Research data were obtained and analyzed through four stages [43, 45]. Initially, the instruments were collected by distributing questionnaires. Then, the questionnaire data were classified based on the class, nature, type, and frequency of the data obtained. The classification of questionnaires included the implementation of thematic learning, STEAM, and the use of digital learning media. Next, the data were analyzed qualitatively. The data were sorted and linked to information relating to the focus of the research. Finally, the researchers interpreted the problem analysis results and the researchers' questions, and then concluded.

3. RESULTS AND DISCUSSION

The development of this learning media used a learning media design model with a development (R&D) model. R&D accommodates the real and urgent needs (real needs in the here-and-now) through developing solutions about a problem while generating knowledge used in the future [42]. This section describes two things that became the initial stages of research and development of augmented reality media in STEAM learning in elementary schools. The first is media needs analysis and initial media design.

3.1 Media needs analysis

Media needs data were obtained from distributing questionnaires and interviews to teachers and students. The main targets for collecting this data were teachers and students. Three results were obtained after collecting data through questionnaires and interviews. The first was distributing questionnaires to students to explore media needs and STEAM learning. Questionnaires focused on extracting data about media and STEAM learning in terms of student needs is presented in Table 1.

Table 1. Student questionnaire responses about media and STEAM learning

No	Question	Percentage	
		Yes (%)	No (%)
1.	Do you enjoy studying thematic material?	89.7	10.3
2.	Are thematic subjects a difficult subject?	66.2	33.8
3.	Have you ever had difficulty understanding the thematic material explained by the teacher?	70.2	29.8
4.	Has the teacher ever delivered material using the STEAM approach?	80.7	19.3
5.	Do you use learning media in studying thematic material?	91.4	8.6
6.	Do you study thematic material by utilizing technology?	86.2	13.8
7.	Are you interested in learning thematic by utilizing technology?	100	0
8.	Does using technology make it easier for you to understand thematic material?	87.9	12.1
9.	Is the use of technology important in thematic learning?	85	15
10.	Have you ever studied thematic material with android media?	0	100
11.	Do you use audiovisual media in your thematic learning?	84.5	15.5
12.	Do using audiovisual media in thematic learning help you solve problems in thematic learning?	91.4	8.6
13.	Have you ever learned to use augmented reality (AR) media in the form of three-dimensional animation?	0	100
14.	Are you interested in using augmented reality media in thematic learning?	91.4	8.6
15.	Do you need STEAM-based augmented reality media to use in thematic learning?	86.2	13.8

Based on the data from student questionnaires in Table 1 regarding student responses about augmented reality media and STEAM learning, the learning media used in thematic learning were generally only audiovisual media. Students had never studied with the STEAM approach and used augmented reality. It was certainly very stimulating for students to get to know something new by utilizing technology already used and was in great demand by students. Students could also easily understand the technology-integrated teaching materials.

The student questionnaire results concluded that students enjoyed learning thematic learning materials with different difficulty levels. In this regard, thematic learning is part of the ten thematic learning models [46]. Thematic learning has provided understanding, and some materials have resulted in new faces called themes. In Curriculum 2013, the main characteristics of thematic learning focus on active learning in children and creating learning principles that are fun and provide hands-on experience.

By applying thematic learning in the 2013 Curriculum, the orientation of student involvement through active, creative, interesting, and meaningful learning can be obtained. Thus, the learning process can provide experience and provision for students to compete with rapid changes and developments [47]. In fact, it is often found that thematic learning in elementary schools predominantly uses audio and visual media [48]. In

agreement with Sanabria and Aramburo-Lizarraga [49], audiovisual with the characteristics of a combination of visual and audio will be very helpful in mastering a concept.

Along with the development of technology and the demands of future times, the condition of Indonesian students is that they are the largest users of technology in the world. According to data results Cambridge Assessment International Education [50], it was revealed that 67% of Indonesian students used smartphones in learning, and 81% more often did homework with smartphones. Therefore, digital technology was developed to support learning by using augmented reality media smartphones. Augmented reality as a cognitive system can fully understand the user's perception [51]. It signifies that the need for augmented reality media is in proportion to the developmental phase of elementary school students, namely at the concrete operational stage [52-54].

Moreover, the use of augmented reality in learning media has shown very good results and is feasible to use; student response to the use of this media in learning is also very good, and students are enthusiastic in following the lesson [48]. For this reason, the application of AR media with the application of STEAM learning needs to be developed and implemented. The application of STEAM in learning is carried out to equip students to develop various skills, especially collaboration, communication, effectiveness, thoroughness, curiosity, creativity, systematic thinking, and problem-solving [49, 55, 56].

Second, the researchers collected questionnaire data regarding the teacher's needs. The questionnaire focused on extracting data about media and STEAM learning in terms of teacher needs is presented in Table 2.

Table 2. Teacher's questionnaire responses on media and STEAM learning

No	Question	Percentage	
		Yes (%)	No (%)
1.	Do you use media in thematic learning?	100	0
2.	Have you used technology in thematic learning?	83.3	16.7
3.	Have you implemented STEAM-based learning in thematic learning?	71.4	28.6
4.	Is the thematic learning media that you use integrated with STEAM?	0	100
5.	Has the media you used so far improved students' critical thinking skills?	16.7	83.3
6.	Do you need augmented reality learning media?	100	0
7.	Should thematic learning media be accessible anywhere through smartphone learning?	100	0
8.	Do you need STEAM-based augmented reality learning media?	100	0
9	Can STEAM-based augmented reality learning media make it easier for students to understand abstract concepts in thematic learning?	100	0

Based on Table 2, most of the teachers did not know very well about augmented reality and the STEAM approach. Teachers had used learning media in the thematic learning process in elementary schools, even though these media had not been fully integrated with the STEAM approach. In fact, choosing the right learning media will make learning more interesting and meaningful. In addition, teachers need augmented reality learning media that can be practically accessed anywhere through smartphone learning.

However, the media could not represent learning materials integrated with each other as a whole. In general, in thematic learning, determining the media to be applied is based on the amount of material content planned. Thus, one learning media does not only represent one material content.

In addition, many teachers did not understand how to create and have a fun learning atmosphere, even though they had implemented the 2013 Curriculum thematic learning from the planning, implementing, and evaluating stages effectively. Supposedly, the application of learning media helps teachers be more efficient in applied learning, especially in delivering material that requires a clearer explanation of the process in real terms. Hence, in following technological developments, teachers can produce augmented reality-based 3D media with the help of smartphones in their application.

Furthermore, based on the teacher's questionnaire, there was a conclusion that teachers did not fully use STEAM learning because they had only tried it a few times. Some teachers admitted that they did not fully understand STEAM learning. It is consistent with the research results from Mau'izhah et al. [57], explaining that the teacher understanding level of STEAM learning is different. However, all teachers agreed that they needed augmented reality media integrated with the STEAM approach so that the material can be more real and easier to convey in the current era of technological development.

Education in today's era accelerates teachers in integrating technology to achieve 21st-century skills, which continue to develop rapidly. Indonesia has responded to this condition by including STEAM education in the 2013 Curriculum revision [58]. The STEAM approach is applied in learning to utilize augmented reality by designing themes, including inter and Trans disciplinary. The scientists also point out that AR is crucial for implementing the STEAM approach in education [59]. In STEAM education, AR application brings lessons and textbooks to life using video, photos, and audio in an interactive platform [49, 60, 61]. Thus, it can support a practical, flexible, and directed learning process, following advances in science, technology, and art.

Based on the interview results, it was found that the teachers have applied a scientific and contextual approach in thematic learning so far. In the use of media, the teachers employed concrete and audiovisual media. However, concrete media used by teachers were not always there. Due to limited funds, the use of learning media could not assist all learning. In addition, in using audiovisual media, it was often constrained by tools, such as LCD and speaker, because on average, each school only had one LCD that could be used interchangeably. With this fact, STEAM learning-based augmented reality media is very much needed to support digital technology-based learning processes.

Third, the analysis was obtained from the conclusions of the two previous results, namely the results of needs according to teachers and students. Looking at the questionnaire results in Tables 1 and 2, the learning media generally implemented in thematic learning were only limited to audiovisual media and have not completely overcome problems in the learning process, especially in integrating materials based on science, technology engineering, art, and mathematics.

In addition, the increasingly rapid development of digital technology can shift and replace the role of humans so that all our needs can be obtained easily in a short time. Currently, teachers and students are certainly familiar with and operating smartphones. Based on the student and teacher response results in Tables 1 and 2, a learning media is needed by utilizing STEAM-based augmented reality technology using

mobile android. In its development, augmented reality has become the latest trend and innovation in the mobile-based digital world business.

Furthermore, teachers need STEAM-based augmented reality learning media because the media currently used are not fully representative and must adapt several media in one lesson. Some teachers have applied technology, but sometimes, the material could not be represented by the existing media since it is too abstract. Therefore, they hope that learning media that can represent material in depth can be made interactive, such as videos and animations, where each process is explained in detail and clear so that students can understand the material and apply it. It can be a way to make learning more effective, and students can participate actively in learning, especially in the application of 21st-century learning. Wittayakhom and Piriyasurawong [61] stated that technology facilitates the learning process and improves the education system's performance effectiveness and/or efficiency. With technology, students can access knowledge anytime and anywhere, reviewing difficult concepts or jumping ahead, if necessary, while teachers can transfer their knowledge to students quickly and efficiently. Thus, learning innovation through the STEAM approach and augmented reality media will produce interesting learning synergies.

The study results by Barma et al. [62] uncovered that augmented reality media could be done with data-based to create a real learning environment, even though objects, data, and actions are carried out virtually. Therefore, by combining augmented reality technology with the STEAM approach, it is hoped to create interesting teaching materials products and improve student learning outcomes. Augmented reality media can also increase student interest and motivate students to study harder, convey information between teachers and students, clarify the information provided, and provide learning experiences. It is in keeping with the opinion [63] that augmented reality media provides an enhanced learning experience based on situated learning theory and constructivist learning theory that work together.

Learning media using augmented reality media also stimulates students' mindsets in critical thinking about a problem in everyday life. It aligns with several prior studies [64-67] that the utilization of augmented reality media also encourages social and cognitive activity, motivation, and critical thinking, emphasizing physical movement; thus, students can actively learn, and teachers can explore new strategies to gain learning experiences. Therefore, the use of augmented reality media with STEAM learning is expected to overcome problems that often arise in elementary schools because, in its application, students must be creative, experienced, able to solve problems, analyze, synthesize, evaluate, implement real work practices, and better cognitive understanding.

3.2 Initial media design

This stage was an advanced stage after conducting a needs analysis. The research team designed the augmented reality media. The initial design is presented in the following figures.

Figure 1 is a media containing *Batik*. *Batik* is an Indonesian pictorial cloth made specifically by writing or applying wax on a cloth that has been given a certain pattern of motifs, which is then processed in a certain way with its characteristics. Types of batik based on the manufacturing process include: hand-written batik is a fabric designed with the texture and pattern using hands, stamped batik is a fabric decorated with the texture and pattern using a stamp tool, and painted batik is a process of making batik by directly painting on white fabric. The media contains integrated material: in science, there is material for changing the shape of objects; on technology and engineering, there are simple technology materials; in art, there is an introduction to fine arts; in mathematics, there is a material of two-dimensional figure.

Figure 2 is a media containing *Wayang* (puppet). *Wayang* is artificial puppets made of leather or wood carvings and others, which can portray characters in traditional drama performances (Balinese, Javanese, Sundanese, and others) and are usually played by someone called the *Dalang*. The media contains integrated material: in science, there is material for changing the shape of objects; on technology and engineering, there are simple technology materials; in art, there is an introduction to fine arts; in mathematics, there is a material of two-dimensional figure.

Figure 3 is a media containing *Gamelan*. *Gamelan* is a set of traditional Javanese, Sundanese, Balinese, and Lombok musical instruments with a pentatonic scale. The most commonly used instruments are the metallophone (is struck) and the hand-played membranophone. The media contains integrated material: in science, there is sound material; in technology and technique, there is simple and modern technology material; in art, there is an introduction to the art of music; in mathematics, there is material about geometry.

Figure 1. The initial design of batik augmented reality media

Figure 2. The initial design of *Wayang* augmented reality media

Figure 3. The initial design of gamelan augmented reality media

Figure 4. The initial design of the Borobudur temple augmented reality media

In Figure 4, it is a media containing *Borobudur* Temple. *Borobudur* Temple is a Buddhist temple located in Borobudur, Magelang, Central Java. This temple consists of six terraces, 2,672 relief panels, and 504 Buddha statues. The media contains integrated material: in science, there is material for changing the shape of objects; in technology and engineering, there are simple technology materials; in art, there is an introduction to fine arts; in mathematics, there is material about geometry.

Figure 5. The initial design of the Kereta Kencana augmented reality media

Figure 6. The initial design of the Keris augmented reality media

Figure 5 is the media containing *Kereta Kencana* [golden chariot]. The *Kereta Kencana* Kiai Garuda Yeksa is the great train of the Yogyakarta Palace, usually used for the new king's carnival around the palace fort. This chariot has four wheels and is pulled by eight horses. The media contains integrated materials: in science, there is axle wheel material; on technology and technique, there is material on transportation technology; in art, there is an introduction to fine arts; in mathematics, there is material for two-dimensional figures and geometry.

In Figure 6, it is the media containing *Keris*. The *Keris* is a dagger stabbing weapon, which is one of the distinctive cultures of the archipelago. In general, the *Keris* is made of iron, steel, and prestige stone or nickel, which is then forged and shaped by a master. The media contains integrated materials: in science, there is material on burning and mixing metals; in technology and engineering, there are simple technology materials; in art, there is an introduction to fine arts; in mathematics, there is a material of two-dimensional figure.

The initial design contained six media containing *Batik*, *Wayang*, *Gamelan*, *Borobudur* Temple, golden chariot, and *Keris*. The six initial designs of the media had met the integration of materials from science, technology and engineering, art, and mathematics. Under the STEAM principle, the material in STEAM learning is expected to be integrated [59]. The STEAM approach is also an activity to approach science, technology, engineering, and mathematical disciplines, using 21st-century skills [68, 69]. STEAM-based learning can be a powerful approach when integrated with interdisciplinary critique and collaboration [70]. Also, research findings have shown that students are satisfied with implementing STEAM and enjoy learning [71].

Apart from being integrated, the media has fulfilled the main learning principles following student development. Thus, the media is expected to support the active, iconic, and symbolic learning stages [72]. These stages are vital to support the achievement of student learning outcomes [73]. Supposedly, the learning design supports the inactive stage of development, namely a stage of learning by using concrete objects. Then, iconic is the stage of learning knowledge presented (embodied) in the form of visual images, pictures, or diagrams, which describe concrete activities in the inactive stage. Meanwhile, symbolic is the stage of learning by presenting knowledge through the form of abstract symbols, either verbal, mathematical, or other abstract symbols.

The design of augmented reality media development applications consists of the following components: (1) markers, symbols, or images designated to compare other images stored in the marker database; (2) video cameras, webcams, camera phones, or sensors used for image analysis and image recognition/tagging with 3D pose estimation and tracking systems; (3) display, computer monitor, or mobile phone screen or otherwise; (4) software or processing unit for creating 3D images or objects. It is in line with previous research [74-76] that the manufacturing stage refers to the software used, such as Sketch Up, *Vuforia*, unity 3D, and visual studio, to turn it into an application. Therefore, the application of augmented reality media is undoubtedly desirable to strengthen the above-mentioned 21st-century skills involved in STEAM studies. Thus, students can build their knowledge and understanding through digital technology-based projects.

4. CONCLUSIONS

Based on the research results and discussion, it can be concluded that teachers and students needed media that could represent material in-depth, increase interest and motivation, and provide experiences, such as augmented reality learning media in STEAM learning. This need was then realized by developing an initial media design following the expectations of teachers and students. The initial design paid attention to six components in the form of media containing Batik, *Wayang*, *Gamelan, Borobudur* Temple, golden chariot, and *Keris*. In addition, this research helps teachers create and develop media and learning approaches in the 21st-century era with digital technology, using STEAM with augmented reality media.

Based on the earlier conclusions, the development of augmented reality in STEAM learning is very much needed in elementary schools. The development does not only stop at the initial design but continues on augmented reality media. Teachers and students can use the initial design made as a visual medium to support learning.

This needs analysis study was still limited in scope to one regency, so the results could not be generalized. In addition, this research still relied on unstructured questionnaires and interviews so that other techniques are needed to strengthen the data to generate better data. The media developed was also still an initial design, so it is not optimal for STEAM learning.

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REFERENCES

[1] Anagün, Ş.S. (2018). Teachers' perceptions about the relationship between 21st century skills and managing constructivist learning environments. Int. J. Instr., 11(4): 825-840. http://dx.doi.org/10.12973/iji.2018.11452a

[2] Caena, F., Redecker, C. (2019). Aligning teacher competence frameworks to 21st century challenges: The case for the European Digital Competence Framework for Educators (D igcompedu). Eur. J. Educ., 54: 356-369. https://doi.org/10.1111/ejed.12345

[3] Chalkiadaki, A. (2018). A systematic literature review of 21st century skills and competencies in Primary education. Int. J. Instr., 11(3): 1-16. https://doi.org/10.12973/iji.2018.1131a

[4] Larson, L.C., Miller, T.N. (2011). 21st century skills: Prepare students for the future. Kappa Delta Pi Rec., 47(3): 121-123. https://doi.org/10.1080/00228958.2011.10516575

[5] OECD. (2015). The Definition and Selection of Key Competencies. Executive Summary.

[6] Partnership for 21st Century Learning, Framework for 21st Century Learning, 2007.

[7] Drake, S.M., Reid, J.L. (2018). Integrated curriculum as an effective way to teach 21st century integrated curriculum as an effective way to teach 21st century capabilities. Asia Pacific J. Educ. Res., 1(1): 31-50. https://doi.org/10.30777/APJER.2018.1.1.03

[8] Wagner, T. (2010). Overcoming The Global Achievement Gap (online). Cambridge, MA: Harvard University.

[9] Malik, R.S. (2018). Educational challenges in 21st century and sustainable development. J. Sustain. Dev. Educ. Res., 2(1): 9.

[10] Chang, T., Hong, G., Paganelli, C. (2021). Science direct innovation of dental education during COVID-19 pandemic. J. Dent. Sci., 16(1): 15-20. https://doi.org/10.1016/j.jds.2020.07.011

[11] Iivari, N., Sharma, S., Ventä-olkkonen, L. (2020). International journal of information management digital transformation of everyday life – How COVID-19 pandemic transformed the basic education of the young generation and why information management research should care? Int. J. Inf. Manage., 55: 102183. https://doi.org/10.1016/j.ijinfomgt.2020.102183

[12] Jabbar Alkubaisi, G.A.A., Al-Saifi, N.S., Al-Shidi, A.R., Al-Shukaili, Z.S. (2021). The quality of selected online learning platforms and their effect on education in the sultanate of Oman. Educ. Res. Int. https://doi.org/10.1155/2021/2570377

[13] Sahin, D., Meryem, R. (2018). Computers & education the effect of augmented reality technology on middle school students' achievements and attitudes towards science education. Comput. Educ., 144: 103710. https://doi.org/10.1016/j.compedu.2019.103710

[14] Wuryani, M.T., Yamtinah, S. (2018). Textbooks thematic based character education on thematic learning primary school: An influence. International Journal of Educational Methodology, 4(2): 75-81. https://doi.org/10.12973/ijem.4.2.75

[15] Ibáñez, M., Delgado-kloos, C. (2018). Computers & education augmented reality for STEM learning: A systematic review. Comput. Educ., 123: 109-123. https://doi.org/10.1016/j.compedu.2018.05.002

[16] Sirakaya, M., Cakmak, E.K. (2018). The effect of augmented reality use on achievement, misconception and course engagement. Contemp. Educ. Technol., 9(3): 297-314.

[17] Fleck, S., Simon, G. (2013). An augmented reality environment for astronomy learning in elementary grades: an exploratory study. In Proceedings of the 25th Conference on l'Interaction Homme-Machine, 2013, pp. 14-22.

[18] Lai, A.F., Chen, C.H., Lee, G.Y. (2019). An augmented reality-based learning approach to enhancing students'

science reading performances from the perspective of the cognitive load theory. Br. J. Educ. Technol., 50(1): 232-247. https://doi.org/10.1111/bjet.12716
[19] Syawaludin, A., Gunarhadi, Rintayati, P. (2019). Development of augmented reality-based interactive multimedia to improve critical thinking skills in science learning. Int. J. Instr., 12(4): 331-344. https://doi.org/10.29333/iji.2019.12421a
[20] Goebert, C., Greenhalgh, G.P. (2020). Computers in human behavior a new reality: Fan perceptions of augmented reality readiness in sport marketing. Comput. Human Behav., 106: 106231. https://doi.org/10.1016/j.chb.2019.106231
[21] Wang, M., Callaghan, V., Bernhardt, J., White, K.,Peña-Rios, A. (2018). Augmented reality in education and training: Pedagogical approaches and illustrative case studies. J. Ambient Intell. Humaniz. Comput., 9(5): 1391-1402. https://doi.org/10.1007/s12652-017-0547-8
[22] Efendi, M.Y., Hsi, N.L. (2020). The comparison of elementary curriculum education between Indonesia and Singapore. J. Teach. Learn. Elem. Educ., 3(1): 22. https://doi.org/10.33578/jtlee.v3i1.7323
[23] Chumdari, C., Sri Anitah, S.A., Budiyono, B., Nunuk Suryani, N. (2018). Implementation of thematic instructional model in elementary school. Int. J. Educ. Res. Rev., 3(4): 23-31. https://doi.org/10.24331/ijere.424241
[24] Pujiastuti, P., Herwin, Firdaus, F.M. (2021). Thematic learning during the pandemic: CIPP evaluation study. Cypriot J. Educ., 16(6): 2970-2980. https://doi.org/10.18844/cjes.v16i6.6481
[25] Perales, F.J., Aróstegui, J.L. (2021). The STEAM approach: Implementation and educational, social and economic consequences. Arts Educ. Policy Rev., 1-9. https://doi.org/10.1080/10632913.2021.1974997
[26] Amo, D., García-Holgado, A., Fonseca, D., et al. (2021). CreaSTEAM. Towards the improvement of diversity gaps through the compilation of projects, best practices and STEAM-Lab spaces. TEEM'21: Ninth International Conference on Technological Ecosystems for Enhancing Multiculturality, pp. 92-97. https://doi.org/10.1145/3486011.3486426
[27] Bybee, R.W. (2013). The case for STEAM Education: Challenges and Opportunities. NSTA Press.
[28] Ozkan, G., Umdu Topsakal, U. (2021). Exploring the effectiveness of STEAM design processes on middle school students' creativity. Int. J. Technol. Des. Educ., 31(3): 95-116. https://doi.org/10.1007/s10798-019-09547-z
[29] Kandil, B. (2021) The stem of meaningful learning. Middle East. J. Res. Educ. Soc. Sci., 2(3): 15-24. https://doi.org/10.47631/mejress.v2i3.268
[30] Susiani, T.S., Salimi, M., Hidayah, R. (2020). STEAM in art education course: Students perception. in Proceedings of the 4th International Conference on Learning Innovation and Quality Education, pp. 1-4. https://doi.org/10.1145/3452144.3452266
[31] Williams, J. (2011). STEAM education: Proceed with caution. Des. Technol. Educ. An Int. J., 16(1).
[32] Hsu, Y.C., Ching, Y.H., Baldwin, S. (20180. Physical computing for STEAM education: Maker-educators' experiences in an online graduate course. J. Comput. Math. Sci. Teach., 37(1): 53-67.
[33] Osadchyi, V.V., Varina, H.B. (2020). Use of AR / VR Technologies in the Development of Future Specialists' Stress Resistance: Experience of STEAM- Laboratory and Laboratory of Psychophysiological Research Cooperation.
[34] Fauville, G., Queiroz, A.C., Woolsey, E.S., Kelly, J.W., Bailenson, J.N. (2021). The effect of water immersion on vection in virtual reality. Sci. Rep., 11(1): 1-13. https://doi.org/10.1038/s41598-020-80100-y
[35] Georgieva-Tsaneva, G., Serbezova, I. (2020). Virtual reality and serious games using in distance learning in medicine in Bulgaria. Int. J. Emerg. Technol. Learn., 15(19): 223-230. https://doi.org/10.3991/ijet.v15i19.15753
[36] Harfouche, A.L., Nakhle, F. (2020). Creating bioethics distance learning through virtual reality. Trends Biotechnol., 38(11): 1187-1192. https://doi.org/10.1016/j.tibtech.2020.05.005
[37] McFaul, H., FitzGerald, E. (2020). A realist evaluation of student use of a virtual reality smartphone application in undergraduate legal education. Br. J. Educ. Technol., 51(2): 572-589. https://doi.org/10.1111/bjet.12850
[38] Altinpulluk, H., Kilinc, H., Firat, M., Yumurtaci, O. (2020). The influence of segmented and complete educational videos on the cognitive load, satisfaction, engagement, and academic achievement levels of learners. J. Comput. Educ., 7(2): 155-182. https://doi.org/10.1007/s40692-019-00151-7
[39] Faregh, S.A., Sisi, M.J. (2020). The impact of interactive augmented reality based education on the learning and remembering of empirical science lesson. Technology of Education Journal (TEJ), 14(3): 571-582. https://dx.doi.org/10.22061/jte.2019.4656.2099
[40] Petrov, P.D., Atanasova, T.V. (2020). The effect of augmented reality on students' learning performance in stem education. Information 2020, 11(4): 209 https://doi.org/10.3390/INFO11040209
[41] Yildirim, G., Elban, M., Yildirim, S. (2018). Analysis of use of virtual reality technologies in history education: A case study. Asian J. Educ. Train., 4(2): 62-69.
[42] Borg, M.G., Gall, W.R. (1989). Educational Research: An Introduction (5th ed.). New York: Longman, 1989.
[43] Creswell, J.W. (2014). Research design: Qualitative, quantitative and mixed methods. In Approaches: Fourth edition, Thousand Oaks, CA: Sage Publication, 2014.
[44] Kobayashi, K., Hatori, N., Sakai, H., et al. (2021). Comparison of questionnaire responses regarding awareness of Japanese Society of Hypertension guidelines for the management of hypertension between 2014 and 2019 in primary care. Hypertens. Res., 44(9): 1147-1157. https://doi.org/10.1038/s41440-021-00693-3
[45] Salimi, M., Dardiri, A., Sujarwo, S. (2021). The profile of students' eco-literacy at nature primary school. Cypriot J. Educ. Sci., 16(4): 1450-1470.
[46] Ain, N. (2017). Holistic thematic learning in the elementary school: Is it thematic and holistic? In Atlantis Press, 158: 919-928, https://doi.org/10.2991/ictte-17.2017.99
[47] Sijabat, O.P. (2019). Thematic character based learning in primary school. J. Kaji. Penelit. dan Pendidik. dan Pembelajaran, 3(2): 381-386.
[48] Setyawan, B., Rufii, N., Fatirul, A.N. (2019). Augmented reality dalam pembelajaran Ipa Bagi Siswa Sd. Kwangsan J. Teknol. Pendidik., 7(1): 78-90. https://doi.org/10.31800/jtp.kw.v7n1.p78--90

[49] Sanabria, J.C., Arámburo-Lizárraga, J. (2017). Enhancing 21st century skills with AR: Using the gradual immersion method to develop collaborative creativity. Eurasia J. Math. Sci. Technol. Educ., 13(2): 487-501. https://doi.org/10.12973/eurasia.2017.00627a
[50] Cambridge Assessment International Education. (2018). Global education census report 2018. Global Education Census Report 2018, p. 48.
[51] Istiningsih. (2020). Development of augmented reality (AR) learning media of natural science subject on subject matter of water cycle for MI grade V students. J. Imiah PGMI, 6(1): 73-87.
[52] Triwahyuni, E., Sudana, D., Setyosari, P., Kuswandi, D. (2020). The effects of picture word inductive model (PWIM) toward student's early reading skills of first-grade in the primary school. Elem. Educ. Online, 19(3): 1523-1536. https://doi.org/10.17051/ilkonline.2020.733100
[53] Suryanto, A., Kusumawati, D.A., Sanhoury, I.M.H. (2018). Development of augmented reality technology based learning media of lathe machines. J. Pendidik. Teknol. dan Kejuru., 24(1): 32-38. https://doi.org/10.21831/jptk.v24i1.18245
[54] Sumardani, D., Wulandari, A., Ramdina, A.N., Doriza, S. (2019). Penerapan teknologi augmented reality pada media pembelajaran poster tatasurya. Pros. Semin. Nas. Fis., VIII: 451-456. https://doi.org/10.21009/03.SNF2019.01.PE.57
[55] Dugger, W.E. (2010). Evolution of STEM in the United States. 6th Bienn. Int. Conf. Technol. Educ. Res., no. March, pp. 1-8.
[56] Seage, S.J., Türegün, M. (2020). The effects of blended learning on STEM achievement of elementary school students. Int. J. Res. Educ. Sci., 6(1): 133-140. https://doi.org/10.46328/ijres.v6i1.728
[57] Mau'izhah, F.R., Rahman, T., Mulyana, E.H. (2021). Dasar Pengembangan Media Sailboats a Track Model Pembelajaran Stem Untuk Kelompok B Sub Tema Benda-Benda Alam. J. Paud Agapedia, 5(2): 176-183. https://doi.org/10.17509/jpa.v5i1.39691
[58] Ishartono, N., Sutama, Prayitno, H.J., Irfan, M., Waluyo, M., Bin Sufahani, S.F. (2021). An Investigation of Indonesian in-service mathematics teachers' perception and attitude toward STEAM education. J. Phys. Conf. Ser., 1776(1). https://doi.org/10.1088/1742-6596/1776/1/012021
[59] Jesionkowska, J., Wild, F., Deval, Y. (2020). Active learning augmented reality for steam education—a case study. Educ. Sci., 10(8): 1-15. https://doi.org/10.3390/educsci10080198
[60] Chen, C.C., Huang, P.H. (2020). The effects of STEAM-based mobile learning on learning achievement and cognitive load. Interact. Learn. Environ., 1-17. https://doi.org/10.1080/10494820.2020.1761838
[61] Wittayakhom, N., Piriyasurawong, P. (2020). Learning management STEAM model on massive open online courses using augmented reality to enhance creativity and innovation. High. Educ. Stud., 10(4): 44. https://doi.org/10.5539/hes.v10n4p44
[62] Barma, S., Daniel, S., Bacon, N., Gingras, M.A., Fortin, M. (2015). Observation and analysis of a classroom teaching and learning practice based on augmented reality and serious games on mobile platforms. Int. J. Serious Games, 2(2). https://doi.org/10.17083/ijsg.v2i2.66
[63] Spector, J.M., Merrill, M.D., Elen, J., Bishop, M.J. (2014). Handbook of research on educational communications and technology: Fourth edition. Handbook of Research on Educational Communications and Technology: Fourth Edition, 2014, 1-1005. https://doi.org/10.1007/978-1-4614-3185-5
[64] Curcio, I.D.D., Dipace, A., Norlund, A. (2016). Virtual realities and education. Res. Educ. Media, 8(2): 60-68. https://doi.org/10.1515/rem-2016-0019
[65] Herpich, F., Nunes, F.B., Petri, G., Tarouco, L.M.R. (2019). How mobile augmented reality is applied in education? A systematic literature review. Creat. Educ., 10(7): 1589-1627. https://doi.org/10.4236/ce.2019.107115
[66] Peterson, K., Stone, B.A. (2019). From theory to practice: Building leadership opportunities through virtual reality science expeditions. Int. J. Whole Child, 4(1): 67-74.
[67] Fernandez, M. (2017). Augmented-virtual reality: How to improve education systems. High. Learn. Res. Commun., 7(1): 1. https://doi.org/10.18870/hlrc.v7i1.373
[68] Baran, E., Canbazoğlu Bilici, S., Mesutoğlu, C. (2015). Science, technology, engineering, and mathematics (STEM) public service announcement (PSA) development activity. J. Inq. based Act., 5(2): 60-69.
[69] Bequette, J.W., Bequette, M.B. (2012). A place for art and design education in the STEM conversation. Art Educ., 65(2): 40-47. https://doi.org/10.1080/00043125.2012.11519167
[70] Keefe, D.F., Laidlaw, D.H. (2013). Virtual reality data visualization for team-based STEAM education: Tools, methods, and lessons learned. Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics), 8022(2): 179-187. https://doi.org/10.1007/978-3-642-39420-1_20
[71] Kim, E.J., Kim, S.H., Nam, D.S., Lee, T.W. (2012). Development of STEAM program math centered for middle school students. Proc. 20th Int. Conf. Comput. Educ. ICCE 2012, pp. 747-751.
[72] Selzer, D.D. (2000). The effect of sequence of instruction on learning algebra concepts using enactive, iconic, and symbolic materials. University of San Francisco.
[73] Fyfe, E.R., McNeil, N.M., Son, J.Y., Goldstone, R.L. (2014). Concreteness fading in mathematics and science instruction: A systematic review. Educ. Psychol. Rev., 26(1): 9-25. https://doi.org/10.1007/s10648-014-9249-3
[74] Atthalariq, M., Setiyadi, D. (2021). The implementation of augmented reality and first person method of promotional media in Kemang Pratama Housing Bekasi. J. Mantik, 5(36): 1056-1064.
[75] Meily, S.O., Putra, I.K.G.D., Buana, P.W. (2021). Augmented reality using real-object tracking. J. Sist. Inf., 17(1): 20-29. https://doi.org/10.21609/jsi.v17i1.1036
[76] Putra, I.K.A.A., Putra, I.G.N.A.C. (2021). Development of augmented reality application for Canang education using marker-based tracking method. JELIKU (Jurnal Elektron. Ilmu Komput. Udayana), 9(3): 365. https://doi.org/10.24843/JLK.2021.v09.i03.p07