Augmented reality based on stem for supporting science literacy in vocational education

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Abstract. AR development is becoming very popular in various fields of science. Some researchers have demonstrated that AR has the potential in science, technology, engineering, and mathematics (STEM). Puse of total AR integrated STEM needs to be studied more deeply, how STEM-AR characteristics, and how the potential of AR-based STEM to support the scientific literacy of students. Searches through relevant sources, the online database of which seven ACM Digital Library, ERIC, ieeexplore, ISI Web of Science, ScienceDirect, Scopus, and Springer. The results showed that the use of STEM-AR potentially an effort to improve science literacy.

1. Introduction

Augmented Reality (AR) is a technology that projects a digital object in a real-world object [1]. The elements of the real world captured by the camera in the form of multimedia such as text, images, video, 3D or animated [2]. Similar to the AR technology that is currently developed is VR (Virtual Reality). VR is a digital space where users can actually do the movement based on the virtual objects are combined with real world [3]. While AR allows users only to observe the virtual objects are combined with real world [4].

AR has been there more than 50 years ago [5]. Form of application of AR is in marketing, videogames, and tourism [6]. But this time AR has been widely applied in the world of education [7]. The main advantage of the AR application in education is to provide skills training [8]. AR can help students engage in authentic exploration in the real world and virtual objects such as text, video, and pictures [9]. AR development is becoming very popular in various fields of science. Some researchers have demonstrated that AR has the potential in science, technology, engineering, and mathematics (STEM), including spatial skills, practical skills, conceptual understanding, and scientific inquiry learning [10,11].

STEM is an education or interdisciplinary approach that combines science, technology, engineering and mathematics. Improving teaching and learning in STEM education has become an important factor for the economy in developing countries, developed countries and countries with stable economies such as Europe and the United States [12], country Australia, and other industrialized countries, require STEM-literate workforce for economic prosperity, productivity and global competitiveness [13]. Through STEM learning, learners can have showed the best ability to transfer entire problem-solving tasks [14].
In the context of vocational education, STEM education aims to develop learners who STEM literate [15]. The literacy skills of learners can be measured by PISA (Program for International Student Assessment) conducted by the Organization for Economic Cooperation and Development (OECD) or the organization for economic cooperation and development [16]. The results of PISA 2015 tests and evaluation of the performance of learners Indonesia is still low. The average score for the attainment of science learners Indonesia is ranked 62 out of 70 countries evaluated. These results will have an impact on science literacy learners. Therefore, puse of total AR integrated STEM need further study how the characteristics of STEM-AR, and how potential STEM-AR in supporting scientific literacy of students.

2. Theoretical framework

2.1. Augmented Reality (AR)

In augmented reality technology, there are three characteristics that form the basis of which is a combination of the real and virtual worlds, interactions that runs in real-time, and the last characteristic is the shape of an object in the form of three-dimensional or 3D models [17]. Contextual data form the AR system may include location data, audio, video or in the form of 3D model data. Development that will be proposed in this study is that the AR-based android with 3D models. A marker made based learning materials that become a topic of discussion, the sensors will lead to the marker through a smartphone camera. Then will appear the learning materials in accordance with the desired marker.

In making AR Some things needed are [18]:

- 3D model of the object to be combined with the real world
- Correspondence between the real world with 3D models through calibration
- Tracking is used to determine the real-world perspective.
- Real-Time display combined with the original image as well as computer graphics created based on the model.
- Time and accuracy in response to movement between images and graphics greatly influence the effectiveness of the system

The steps in the manufacture of AR can be seen in the picture below:

![Figure 1. The steps in the manufacture of AR.](image)

2.1.1. Template learning materials. Objects that are template learning materials, is the target image and then be recognized by a smartphone camera when tracking [19].

2.1.2. Marker. AR Markerless used to track objects without special marker reality. To track objects, depending on the system Markerless AR tracking natural features. AR Markerless track with an existing image that is then used as a target or image to be detected to display virtual objects [20].
2.1.3. **Vuforia.** Vuforia is a library or SDK (Software Development Kit) which is used as a support for AR in mobile devices such as Android and iOS as shown in Figure 2. Vuforia analyze the images using a detector marker and generate information, for example: text, video, 3D objects or animations virtual camera of the marker is detected by API Vuforia [21]. Very helpful Vuforia Augmented Reality application developers to develop applications for the basic code Augmented Reality Vuforia provided by the library that supports iOS, Android, and Unity3D. It supports developers to create applications that allow in virtually every type of smartphone and tablet. Vuforia features a Markerless capable of using colorful markers without using a black frame marker. Therefore, users do not need to use a conventional marker-shaped black and white squares.

![Figure 2. Architecture Vuforia.](image)

2.1.4. **Android.** Android is an open source operating system for mobile devices [22]. It was developed by the Open Handset Alliance, which consists of software developers, hardware developers, and providers such as Google, HTC, Intel, Motorola, Qualcomm, T-Mobile and NVIDIA. In application development, Android offers a SDK (Software Development Kit) Android provides the tools and APIs for application developers to the Android platform. Android uses Java as a programming language [23,24].

2.2. **STEM science, technology, engineering and mathematics**

2.2.1. **Science.** Systematic study of the nature and behavior of matter and the physical universe based on observation, experiment, measurement, and the formulation of laws to illustrate the fact in general.

2.2.2. **Technology.** Branch knowledge related with the creation and use of technical means, and association with people's lives and the environment, describe the field of industrial arts, engineering, applied science, and pure science.

2.2.3. **Engineering.** The art or science of making practical application of pure science knowledge. Such as physics and chemistry, such as in construction machinery, bridges, buildings, mines, ships, and chemical plants.

2.2.4. **Mathematics.** Group-related science, including algebra, geometry, calculus, focused study of numbers, value, shape and space, and the interrelationships by using a special notation.
STEM learning needs to emphasize certain aspects of the learning process [25] include: (1) institute questions (science) and defining the problem (engineering); (2) develop and use models; (3) plan and carry out investigations; (4) analyze and interpret data (mathematics); (5) use math; information and computer technology; and computational thinking; (6) establish explanation (science) and designing solutions (Engineering); (7) involved in the argument based on evidence; (8) acquire, evaluate, and communicate information

2.3. Science literacy
Fives et al summarizes the aspects of the literacy skills of science: the role of science (role of science), think and work scientifically (scientific thinking and doing), science and society (science and society), mathematics in science (mathematics and science) and affective aspects contained in the component of motivation and confidence in science (science motivation and beliefs) [26].

3. Method
This article draws on September until December 2018. There are three stages used to gather relevant resources that can support the discussion. These stages can be seen in the figure 3.

![Figure 3. Stage collection of literature sources.](image)

Literature searches were done to find the relevant sources, there are seven online databases of which ACM Digital Library, ERIC, ieeexplore, ISI Web of Science, ScienceDirect, Scopus, and Springer. The search using keywords STEM for vocational education, Augmented Reality for learning, scientific literacy, ICT literacy, Vocational Education, Search result content articles that meet the needs of the discussion will be stored in folders based on search keywords content. In this study, there are 5 folders containing a collection of references on this subject, namely STEM folder, folder Augmented Reality, Science Literacy folder, folder Technology Literacy and Vocational Education Learning folder.

Source library that has been sought and collected and then discussed through qualitative analysis. The author conducted a review process of articles to then prepare this article with the support of various sources of information have been sought.

4. Results
4.1. Characteristics of AR-based STEM
There are three characteristics that define Augmented Reality (AR). The third characteristic is 1) combining real and virtual world, 2) interactively in real-time, 3) allows the AR is currently a popular topic in education research Ibanez and Radu have reviewed 26 articles, then identify the positive impact of AR technology in education [27,28]. Radu conclude that AR can assist in increasing student motivation, improve collaboration among students, develop spatial skills, and improve the performance in physical tasks. In a recent study, Akçayır through 68 research articles on the use of AR in education, they reported that AR technology has the potential to support learning and teaching [29]. In addition, research Bacca present a systematic review analyzed 32 studies published between 2003 and 2013, they analyzed the use, benefits, limitations, effectiveness, challenges and features of the AR in education [30]. They stated that the main advantage of AR is that it can improve some aspects such as motivation, interaction, and collaboration, while the main limitations of AR is used. There are still students who are difficult to operate the AR technology.
Some articles review about the potential of AR in the field of STEM knowledge. AR has been developed in the learning of mathematics, mechanics, physics, urban planning, and many others [31]. Another study states that the application of AR in learning physics in the laboratory can have positive effects on the skills and attitudes of learners [32]. Another experiment involving the AR in mathematics exhibition, that respondents expressed a positive thing on the use of AR in mathematics [33].

AR integrated development in line with the characteristics of STEM. There are three characteristics into STEM learning criterion [34]. First, focus on the STEM learning issues and real problems. STEM learning encourages students to recognize the environment, the economy, and the problems surrounding them, and to develop solutions. Second, STEM education has the characteristics to guide the engineering design process. Activities to design trains students to identify problems, create and develop solutions. The process of designing using the student's ability to put the idea on the basis of scientific concepts into a design. In engineering learners out ideas, determine the pace of work, to try and fix it, learn from mistakes made, to try and fix it, learn from mistakes made, try again with a new and better way.

The third characteristic in STEM learning is hands on their activities. In this case the AR become one of the technologies that support the hands on activities in STEM characteristics. Hands on activities supported by the AR is an attempt to take advantage of interactive technology. Liou et al presents a more active approach is through the use of AR as interactive technologies [35]. The AR application allows students to explore the knowledge base through integrated 3D animation in AR. Just as research [36], a book that modifications in the form of a 3D virtual enables students to see its proper perspective in every page of the book.

In a STEM-based operator of the necessary AR applications that have been downloaded through Play Store on android smartphone. Objects that are template learning materials, is the target image and then be recognized by a smartphone camera when tracking [37]. Learning materials contained on template, integrated in STEM learning. Once the object captured by the camera will display the 3D, after which the user can play the application. Operation of STEM-based AR can be seen in Figure 4.

![Figure 4. The operator of AR-based STEM.](image_url)

4.2. STEM-AR in support of science literacy

One way to improve science literacy in learning by linking a science concept with emerging topics and interesting in real life. This can be supported by developing Augmented Reality STEM-based vocational education in the learning process. With the presence of STEM-AR is expected to improve the literacy skills of science and technology students. The specific objective of developing the skills of scientific literacy are: 1) students can determine and investigate the science of Nature, 2) students can improve vocabulary oral and written are required to understand and communicate science and, 3) the student can improve the relationship between science, technology and community [38].

STEM education is an attempt to build a society that is aware of the importance of STEM literacy. STEM literacy refers to the ability of individuals to apply an understanding of how tight the competition works in the real world that requires four interrelated domains. Table 1 literacy STEM [39].
Table 1. Literacy STEM.

| Scientific Literacy | National Science education Standards (1996) | Knowledge and understanding of scientific concepts and processes required to make decisions, participation in the affairs of society and culture, and economic productivity |
|---------------------|-----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                     | Organization for Economic Cooperation and Development (2003) | The ability to use scientific knowledge (in physics, chemistry, biology and earth and space science. Participate in decisions affecting the life and health sciences, earth and the environment, and technology |

| Technology Literacy | National Assessment Governing Board (2012) | Capacity to use, understand and evaluate the technology, as well as to understand the principles of technology and strategies required to develop solutions and achieve goals |
|---------------------|-----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                     | International Technology Education Association (2007) | Ability to demonstrate creativity and innovation, communicate and collaborate, conduct research and use information, think critically, solve problems, make decisions and use technology effectively and productively |
|                     |                                                                 | The ability to understand the increasing sophistication over time, how technology is created and how it is shaping society, and subsequently shaped by society |

| Engineering Literacy | Organization for Economic Cooperation and Development (2003) | The ability to systematically and creatively apply scientific principles and mathematics to practical ends such as the design, manufacture, and operation of efficient and economical structures, machining processes, and systems |
|----------------------|---------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                      | Accreditation Board for Engineering and Technology (2010) | Knowledge of mathematics and natural sciences gained by study, experience, and practices that are applied to develop ways to harness the economic and natural forces for the benefit of mankind |

| Mathematical Literacy | Program for international Student Assessment (2006) | The capacity to identify, understand and engage in mathematics, and to make judgments about the role that mathematics plays in the private lives of the present and future of each individual, work life, social life with peers and family. |
|-----------------------|--------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                       | National Council of teacher of mathematics (2000) | The ability to read, listen, think creatively, and to communicate about the problem situation, mathematical representations, and solutions to develop and deepen the understanding of mathematics. |

Utilization of computer-based media in learning becomes an important part that needs to be developed to improve students' scientific literacy. Opinion Herga et al. states that the multimedia learning can provide a visualization on a microscopic level, sub-microscopic and symbolic, giving the world a dynamic presentation of sub micro particles, contribute to the inactivation of understanding of the concept and motivation to learn [40].

Additionally, Mayer states that the use of multimedia can make learning more meaningful [41]. The meaningful learning is defined as learning to equip students with the concepts that can be stored in long term memory and is able to apply the concept in real conditions, new, and different. Meaningful learning is interrelated with science literacy process consisting of the domain of science, scientific knowledge, the students' attitudes towards science are framed in the context of the domain [42]. Domain context with regard to application of the concept in real conditions / daily life.
5. Conclusion
Through literature search relevant online database contained seven of which ACM Digital Library, ERIC, ieeexplore, ISI Web of Science, ScienceDirect, Scopus, and Springer. The search using keywords STEM for vocational education, Augmented Reality for learning, scientific literacy, ICT literacy, Vocational Education, from these sources, it shows that STEM-AR has the potential to be developed as an effort to improve students' scientific literacy. The specific objective of developing the skills of scientific literacy are: 1) students can determine and investigate the science of Nature, 2) students can improve vocabulary oral and written are required to understand and communicate science and, 3) the student can improve the relationship between science, technology and community [43].

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