The Use of Augmented Reality-Based Learning Media to Develop the Technology Literacy of Chemistry Teachers in the 21st Century

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Abstract. The 21st century chemistry learning process requires teachers to implement creative learning methods that are supported by technology. However, the teachers' ability to use technology in chemistry learning is still low. The purpose of this study was to develop the teachers' technology literacy using augmented reality-based learning media. This research used mix-method with sequential strategies of mixed methods. The first stage of this research was conducted by surveying the use of technology in chemistry learning. The instrument used was closed and open questionnaire. The second stage was carried out by collecting qualitative data through interview techniques. The data taken from this stage were to obtain the data of teachers' technology literacy after they received a training treatment using Augmented Reality based learning media. The research subjects consisted of 25 Chemistry teachers spread in Central Java. The results of the study show that teachers' literacy in chemistry learning is still low. The training of augmented reality-based learning increases the teachers' technology literacy. In addition, augmented reality-based learning media also assist teachers to introduce abstract concepts to students. In addition, this learning media also help teachers who have limited tools and materials in the laboratory to introduce the laboratory work virtually to the students.

INTRODUCTION

To make the world comfortable and liveable, the United Nations as an international non-profit organization issues Sustainable Development goals (SDGs). This program is an advanced program of the MDGs (Millennium Development goals) program. The SDGs consist of 17 goals with 169 measurable performance achievements and deadlines to be reached in 2030. One of the Sectors that are the focus of the SDGs is the quality of education. Education is the focus of the problem that must be resolved because there are still data that explain the low education of the world community, especially in developing countries. Indonesia as one of the UN member countries, which also implements the SDGs program, has the typical educational problems of developing countries. The problems include the lack of basic literacy skills of students. In addition, the low ability of school-age children and adults in mathematical and scientific abilities is also a problem of education in developing countries such as Indonesia. The problems still exist even though now all countries in the world have entered the century of the industrial revolution 4.0. The industrial revolution 4.0 can be interpreted as an era based on the Cyber-Physical System, a combination of the digital, physical, and biological domains [1]. In this era, 75% of the work involves the ability of science, technology, engineering and mathematics, internet of things, and lifelong learning [2]. For this reason, education in the 21st century or the era of the digital revolution demands a number of literacy abilities. Some of the literacy needed in the 21st century can be seen in Fig. 1.

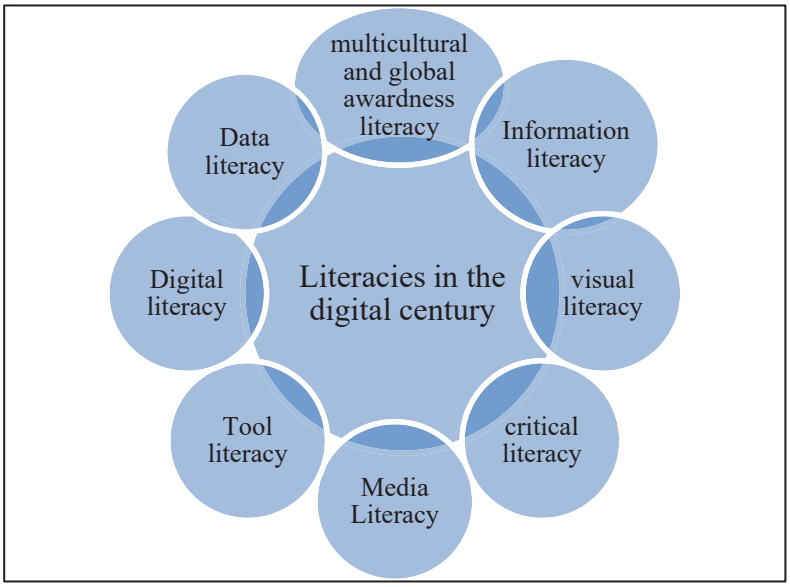

FIGURE 1. Literacies in the 21st century

Students in the 21st century are also different from the previous century. In this century, there is an increase in the ability of students to use technology to support the teaching and learning activities. Many research indicates that technology enhances students' comprehensive in science learning and impacts in the school classroom as being a powerful cognitive tool [3]. This increase requires a change in teachers as well [2]. In science learning, many researchers have been investigated the impact of using various technologies to support students' conceptual understanding, visualization and to promote instructional competency of the 21st-century teacher. Teachers in the 21st century are also required to have more capabilities in the field of digital technology to support their careers as educators in the 21st century. The ability of technological literacy is especially needed to overcome the low literacy abilities of mathematics and science in particular and other educational problems in general. However, so far, there has been no clear information about technology literacy that is possessed by teachers in Indonesia.

Chemistry is one of the subjects that has abstract material characteristics. This microscopic chemical material is rarely visualized by the teacher. During this time, students are only asked to memorize the material that has microscopic concepts. The students have also difficulty linking observable phenomena (macroscopic level) to molecular level (microscopic level) interaction [4] Consequently, the practicum activities are needed in chemistry subject to explain the phenomena of science. These phenomena can be seen through symptoms and signs that can be seen by students to show the existence of chemical reactions. However, the fact shows that practicum activities are rarely or even not carried out by the teachers during chemistry learning. The factors underlying the non-implementation of practicum in schools are the lack of laboratory infrastructure and the high burden of the curriculum in Indonesia. To solve the above problems, it is necessary to have the latest technology-based learning media that can help teachers to transfer the abstract information and simulate the virtual practicum activities. Augmented reality (AR) is a technology that can be used in science learning. AR is capable of displaying an abstract concept or microscopic phenomenon virtually without replacing the real environment [1,5]. For example, [6] were investigated about the impact of the AR on students' achievement, experience meaningful and interesting in chemistry which they found that The AR tool is beneficial in improving middle school students' learning outcome especially in a cognitive test.

Based on the above problems, there are two main objectives in this article. The first objective is to provide an overview of the information of chemistry teachers' technology literacy. Another one is to describe the use of AR learning media in developing teachers' technology literacy.

MATERIAL AND METHOD

This is a mix-method study with sequential mixed methods strategy. Mixed methods are methods that combine qualitative and quantitative approaches, especially on the data collection phase or methodology. In addition, this research also uses mixed model studies incorporating two approaches in all stages of the research process [7]. Descriptive research is a method which conducts the research about a group of people status, an object, a set of conditions, a system of thought or a class of events in the present [7]. The subjects of this study are 22 chemistry teachers in 12 schools on the island of Java.

The first phase of this research was performed by conducting a survey of the use of technology in learning chemistry. The instrument used was a closed and open questionnaire. The questionnaire instrument consisted of 24 statement items using a Likert scale and 10 items checklist of instruments that assess the Technology Knowledge (TK), Technology Content Knowledge (TCK), Technology Pedagogy Knowledge (TPK) and Technology Pedagogy Content Knowledge (TPCK).

The second stage is carried out by collecting qualitative data through interview and observation techniques. The data taken from this stage is to obtain the data of teachers' technology literacy after they received the treatment training using the Augmented Reality based learning media. The AR training was held for two days to introduce how to use AR-based learning media.

RESULT AND DISCUSSION

Technology Literacy

Technology literacy related to the use of technology for learning chemistry in this study was measured through 4 indicators. First indicator namely Technology Knowledge (TK). TK of chemistry teacher means knowledge about technology in teaching and learning. The second indicator was Technology Content Knowledge (TCK). TCK means knowledge of chemistry teacher about technology related to chemistry. The third indicator was Technology Pedagogy Knowledge (TPK). TPK is knowledge about the use of technology to teaching and understanding student's needs. The last indicator was Technology Pedagogy Content Knowledge (TPACK). The results of the 4 indicators of technology literacy can be seen in Fig. 2.

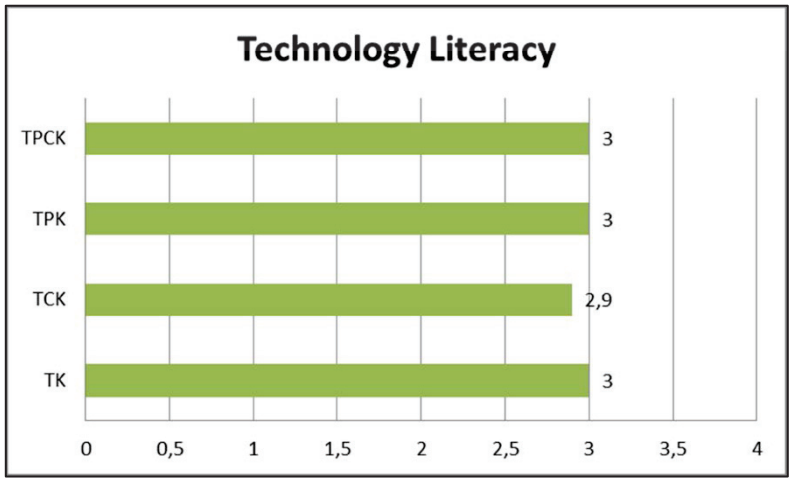

FIGURE 2. Chemistry teacher's Technology literacy

Based on Fig. 2, the logic can be drawn that the teachers' technology literacy in Indonesia is in the medium category or it is quite good. The figure shows that the teachers' TCK is the lowest indicator of teachers' technology literacy. There are 3 statement items on the TCK Indicator. The lowest score based on the results of the questionnaire given to the teachers is on the item: " *I have the technical skills that I need to utilize the technology*". The items of this statement indicate that chemistry teachers feel they do not yet have sufficient technical skills in the field of technology, especially those that support the teaching and learning activities. Another item that is in the low category is *"I utilize*

the technology in managing the students' chemistry assignments (such as using edmodo, moodle, google classroom, or others) ". The information obtained from this statement is that the teachers are not yet familiar with e-learning activities using the Learning Management System (LMS). Another statement that is also in the low category is: *" I often use animation to understand what happens on a small scale (microscopic) phenomenon that is found in daily life* ". Based on this statement, the information about the lack of use of animation to visualize the microscopic concept of chemistry can be known. It is important to emphasize that good visualization skills are needed in learning chemical concepts. The benefits of visual animation in learning chemistry can be seen in Fig. 3.

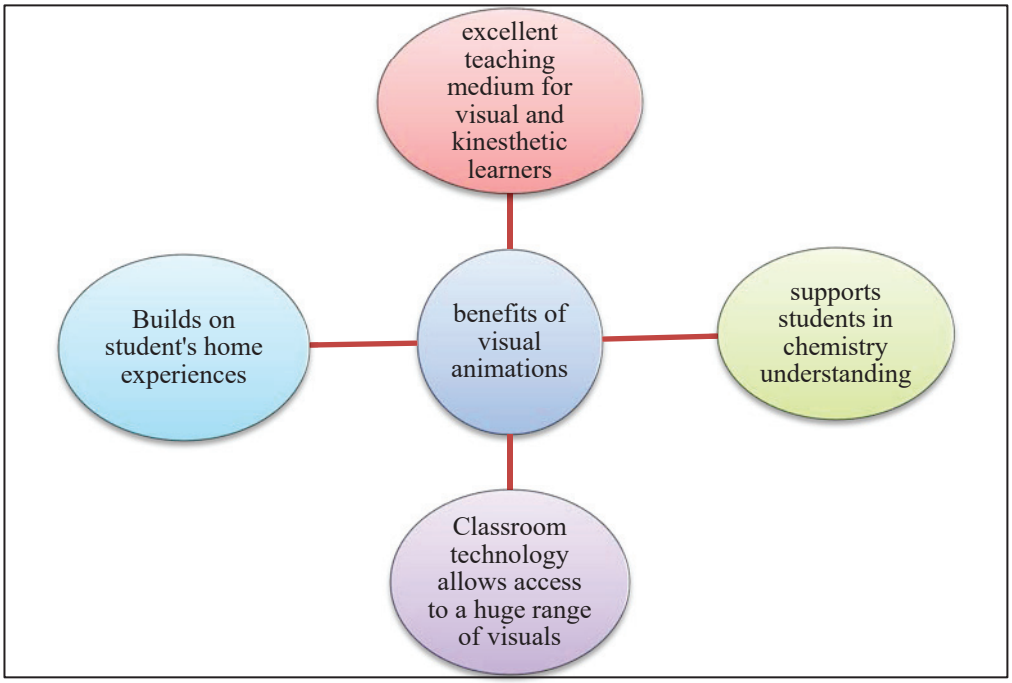

FIGURE 3. Benefits of Using Visual Animation in Chemistry Learning

The use of Augmented Reality in Chemistry Learning

To develop technology literacy in chemistry learning, in this study, the chemistry teachers were introduced to AR-based learning media. With the use of AR in learning chemistry, teachers are expected to increase their confidence in teaching and learning activities in the 21st century. In this study, the teachers were trained to use AR that is already available on the App Store. The applications used are RApp Chemistry and AR VR Molecule. This activity introduces the teacher what is needed to be able to use the AR application in learning chemistry. AR basically "only" requires a mobile phone and a marker to be able to run the application. In this training, teachers were given information about the marker and how to download it. Markers or patterns are tools that support AR software. Markers can be artificial and similar to QR codes or other things, chemical symbols or real objects. However, the most widely used markers in Indonesia are artificial markers and chemical symbols. In the RApp, the chemistry marker used is in the form of chemical symbols. The information available in the RApp chemistry marker is in the form of symbols of chemical elements, atomic numbers, mass numbers and outermost electron configurations using the theory of quantum mechanics. An example of the RApp Chemistry marker can be seen in Fig. 4.

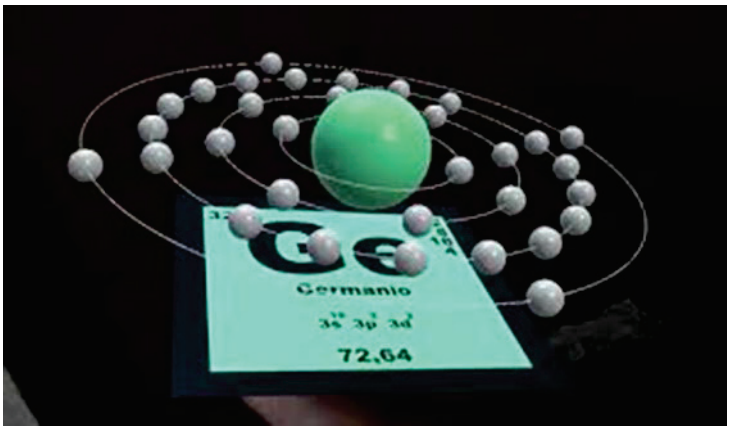

FIGURE 4. Example of AR marker RApp chemistry

The results of this training showed that 18 of 22 teachers stated that they felt they were helped to visualize sub-microscopic chemical material using AR. 4 other teachers felt that AR still had limitation. According to them, the limitation of AR is that it only can be used to explain certain topics. In addition, access to AR on Playstore is also still very limited. Meanwhile, in order to prepare AR which is not available in the play store, the teachers find it difficult with the coding language and the use of AR support software such as Adobe Flash, 3D unity blender and vuforia. The teachers also felt that AR could not be applied in schools because of school regulations that forbade students to bring mobile phones to class.

One of the challenges in teaching and learning activities in the technological age of the 21st century includes information, digital, and visual skills to prepare students to continue their education to a higher level and be able to adapt to the demands of this century. In the international level, the quality of education in Indonesia is still in the medium category. Meanwhile, the era of the industrial revolution demand in the field of information technology development has led to very rapid changes in all fields. For this reason, educators or teachers are required to have adequate technology literacy in teaching-learning activities, especially in learning science in which the mathematical and scientific skills of students in Indonesia are weak. Weak scientific skills are mainly based on the lack of available teaching aids or learning media that discuss a scientific phenomenon microscopically. In addition, one of the causes of the low science skills of students is the lack of frequency of experimental activities both at home and at school. The lack of experimental activities in learning science is caused by the lack of available time whereas the demand for the curriculum is very tight. There are also no suitable practical tools available.

Technology literacy is the ability to use the technology effectively and efficiently in a variety of academic, career and everyday life contexts. The results of this study indicate that even though the mastery of technology literacy falls into the sufficient category, it is known that most teachers in Indonesia access technology in learning activities only as of the users of information from search engines. To implement technology-based learning such as e-learning or blended learning, teachers in Indonesia are still not ready because they find it difficult and unfamiliar. The statement is contrary to the teachers' own thoughts which state that the technology must be used in learning. A number of studies show that the technology literacy of teachers can be mastered if it is influenced by the factors of teachers' attitudes toward the change. Teachers' readiness to always learn and their openness to new things is an attitude that is needed so that teachers have the same technology literacy as students. In addition, the teachers will have good technical literacy if they feel the technology is needed for their personal and career lives. Another reason supporting the mastery of technology literacy in teachers is it is easy for them to access the technology.

AR-based learning media, although giving positive feedback to the enthusiasm of students in teaching and learning, apparently, also has various limitations. One limitation is the scope of the availability of AR to be accessed by the users. The number of AR topics available in chemistry-related play stores in Indonesia is still less than 10 topics. In fact, the topic of chemistry studied at the high school level is 33 topics. In addition, the difficulty in applying AR in Indonesia is the policy of some schools to prohibit students from using mobile phones in class.

Although it has several limitations, the uniqueness of AR learning media in chemistry learning can still be used to attract the interests of students. AR has the ability to help students visualize the sub-level microscopic chemistry such as atoms, molecules, chemical bonds, and other materials that require microscopic explanation. The advantage of AR for learning chemistry is it is easier for the students to perform laboratory practice demonstration activities. AR can

help teachers who do not have a chemistry laboratory with complete equipment. The teachers can explain the work steps, types of equipment and chemicals, and show the science phenomena with AR. In addition, because it is easy to use, AR also increases the curiosity of the teachers in learning chemistry further at the microscopic level. This research showed the linear result with [8] studies that said AR implied chemistry learning activity. For this reason, it can be concluded that AR can develop the interest of teachers in mastering the technology literacy in education in general and chemistry education in particular. It's like AR technology can be employed in education to help learners approach information and its visual perception [9,10] but, implications to teacher education and teacher professional development are discussed.

CONCLUSION

The results showed that the mastery of technology literacy in Indonesian teachers is at a fairly good level, especially at the elementary level. However, other studies are needed on high-level technology literacy. This research also provides information related to the application of AR in learning chemistry. AR can be used to develop teachers' technology literacy.

ACKNOWLEDGMENTS

This publication was produced wholly, or in part, with funds from the Ministry of Research, Technology, & Higher Education (Kemristek-Dikti), under contract 012/UNIMUS.J/PJ/PG/2019. The content herein does not necessarily reflect the views of KEMRISTEKDIKTI, the Department, any other agency of the Indonesia Government, or any other source.

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April 2020

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