Improving Biology Learning Through Augmented Reality Technology in Indonesia: A Review

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Abstract – Biology is always considered difficult either to teach or to learn. As a field of study that learning about living subjects, biology has very broad and abstract concepts. Many students find the abstract concepts of biology are hard to understand. Some students even feel that studying biology is a dull experience. This type of perception in students subsequently led to low academic achievement. Hence, an innovative and attractive learning approach is needed for teaching biology. Augmented Reality (AR) technology has a great possibility to improve biology learning experience due to its ability to concretize the abstract concepts in biology by providing natural interaction between virtual and real-time situations simultaneously. In the last decade, numerous research of implementing AR in education including biology learning have been studied globally and nationally. In order to evaluate the effectiveness of AR in improving biology learning especially for students in Indonesia, this literature review research is conducted. The reviewed articles are retrieved through Google Scholar database with the assigned criteria published between 2020 to 2024, AR implemented, biology learning, student perception, and/or achievement in biological studies. The analysis shows that implementing AR in biology learning increases students' interest, learning motivation, involvement, collaboration, independent learning, knowledge retention, and achievement. However, the conflicted finding is reported regarding the influence of AR on students' critical thinking ability. Technical problems related to downloading and distributing AR applications are the main challenge that has been reported when using AR in biology learning.

Keywords – biology learning, student perception, student achievement, augmented reality (AR)

I. INTRODUCTION

Biology is dubbed as one of the most difficult subjects, either to teach or to learn. Numerous studies have been conducted to investigate why students find biology hard to learn. The interesting thing is that after decades of research, the problem persists globally [1-4] and nationally [5-8].

While students' difficulties in learning biology is a known issue, it is important to understand the contributing factors that make learning biology is a hard task. The broadness field of study in biology, with many abstract and invisible contents [4] along with frequently used of scientific terms, are the most prominent issue regarding biology learning difficulties [8]. Many students also find that the subject is boring [1, 9] or less attractive either to be learned or as a related future career [10]. These factors can easily lead to students' low academic achievement. Hence, an innovative and attractive teaching and learning techniques are needed to overcome these learning problems in biology.

Augmented Reality (AR) is a technology that enables users to experience realistic interaction with both virtual and real-time situations simultaneously. The technology was termed as "Augmented Reality" in 1993 [11]. An overview study of AR by [12] shows that the technology has been implemented in many areas including tourism, archaeology, art, commerce, industrial manufacturing and restoration, education, emergency management, entertainment, and leisure. AR is especially valuable in situations where the objects or the even to be thought are not visible, demonstrating dangerous situations, concretizing abstract concepts, and presenting confusing levels of information [Yilmaz et.al., 2018 *in* 2]. Augmented Reality also has a great possibility to replace or enhance laboratory experience in students learning [13-15].

However, some still feel that cadavers and real experimental animals when related to studying anatomy cannot be replaced by virtual objects presented by AR [2].

Nevertheless, recent studies of implemented AR in teaching and learning show the possibility and ability of AR to improve the learning process and eventually improve students' perception and achievements. This paper will evaluate the effectiveness of implementing AR in biology learning especially in Indonesia.

II. RESEARCH METHODOLOGY

A literature review [16] type of research is presented in this paper. The research is conducted by reviewing published research articles regarding Augmented Reality (AR) in teaching and learning biology in Indonesia. The order of tasks in conducting the research consists of collecting the library material, studying the presented data, managing the data, and analyzing it so it can be concluded and reported. The articles are analyzed qualitatively with Miles and Huberman Model [17], where the collected data will be reduced, analyzed, and then concluded.

The articles are selected through Google Scholar and should meet the designed criteria which are published within 2020 to 2024, AR implemented, biology learning, students' perception, and/or achievement in biological studies. Initially, 30 articles were selected. However, further inspection showed that although the AR-integrated media were successfully created, their effectiveness in biology learning process (indicated either by students' academic achievement or observed scholastic learning behavior before and after using AR media) had not been studied. Another reason for eliminating the initially selected articles was the science concepts, which were reported to be taught by using AR, were not part of the

biology concepts. This case mostly applied to articles that implement AR at preschool and elementary levels of education. Ultimately, only 12 research articles were qualified to be reviewed.

III. RESULTS AND DISCUSSION

The articles analysis (Table. 1) showed that Augmented Reality (AR) technology had been implemented into different types of learning media, biology concepts, types of students, and levels of education. The AR technology has been incorporated into marker books/sheets [9, 18, 19, 21, 23-28], text book [18], learning module [20], and e-comic [22]. It was used to teach the names of fruits in pre-school [19], digestive [21, 25] and human circulatory system [22, 26] in elementary school, human reproductive system in middle school [20], arthropod [18], plant life cycle [9], sense of hearing [24], structure and function of plant and animal tissues [28] in high school and the concept of cell [23] in university for undergraduate students. The AR technology was able to help both regular students [9, 18, 19, 21-28] and students with special needs [20] in learning biology. The AR learning media was mostly developed to teach students in high school [9, 18, 21, 24, 27, 28] and elementary school [21,22,25,26] which are 50% and 25% of the total figure respectively.

Generally, AR has shown a lot of benefit in supporting biology learning in Indonesia education. The students' achievements and perception toward biology has been improved when AR is introduced to the learning process. However, some articles report that difficulties and problems are also found and encountered while teaching biology with AR.

Table 1. Implemented Augmented Reality in Biology Learning

Research Article	Result of Study
[18]	Augmented Reality is very feasible in supplementing practical work for learning Arthropod in Islamic-based science for High School students. **The implemented technology increases student motivation and enthusiasm in learning.** However, technical problems such as weak signals, unsupported devices, and unavailability of the application in Play Store/App Store make the downloading process difficult.
[9]	**Augmented Reality able to improve high school student's understanding of plant life cycle concepts** but does not improve student's creative thinking skills. Augmented Reality is suitable to be used in teaching high level cognitive concepts.
[19]	**Augmented Reality Book statistically helps improve children's motivation and understanding in learning fruit names in pre-school.**
[20]	**Augmented Reality learning media is quite effective in increasing middle school student's enthusiasm and understanding, including students with special needs, in learning reproduction concepts.** However, adjustment is still needed because the incorporated videos are less effective for students with hearing impairment.
[21]	**Implementation of Augmented Reality technology through a scientific approach statistically increases high school student's critical thinking in learning the digestive system concept.**

Research Article	Result of Study
[22]	**Integrated Augmented Reality in Electronic Comic Books significantly increases elementary student's interest in learning the human circulatory system.**
[23]	**Implementing smartphone-based Augmented Reality technology able to increase undergraduate student learning motivation, understanding, scientific vocabulary, discussion participation, and critical thinking skills in learning the concept of Cell.** Augmented Reality Technology makes the visualization of cell materials that are invisible to the five senses possible
[24]	The android-based Augmented Reality (AR) application successfully displays the 3D object of the ear organ. **The AR technology increases student interest in learning the sense of hearing concept and helps high school students understand the structure and function of the ear.**
[25]	Augmented Reality media in learning digestive system initiate positive feelings in elementary students. **The using of AR increases student interest and learning motivation.** However, support from educators, the government, parents, and schools are needed to successfully implement AR as Interactive learning media.
[26]	**Augmented Reality in learning media effectively increases elementary student's post-test scores in the circulatory system concept.**
[27]	**Implementing Augmented Reality in Biology learning improves high school student motivation and knowledge retention. Student involvement, collaboration, and independent also reportedly strengthen.**
[28]	**Augmented Reality (AR) incorporated into biological learning effectively improve high school student motivation in learning structure and function of plant and animal tissue.** However, the motivation to learn using AR technology does not linear with student motivation in learning science.

3.1 Benefit of Augmented Reality (AR) in Biology Learning

Based on the review result, there are some main advantages to incorporating AR into biology learning environment. [18] in her study observed that AR technology increased student interest, enthusiasm, and motivation in learning. It also provided and encouraged independent learning in students. The same findings also reported by [20], [21] and [27], seeing real images of objects virtually in 3D piqued student interest in learning and subsequently encouraged the student to be actively involved in the learning process.

The ability of AR to visualize abstract concepts in the real world engages student attention and interest. Motivating students to learn and enhancing student understanding and knowledge retention. When subjected to the same concept of study student who learned with AR tend to score higher than their counterpart who learned through the conventional method. This finding was observed by [19] in preschool students, [26] in elementary school students, and [9] in high school students. In their research, [27] stated that student knowledge retention was increased by AR. The 3D technology in AR can maximize the information processing and deliver it to the long-term memory.

Another benefit that was also reported by researchers who implemented AR in biology learning was the increase in student collaboration and critical thinking skills. [23]

observed that using smartphone-based AR in the learning process increased student interest and led to an increase in participation in class discussions and critical thinking skills. The ability of AR to increase student critical thinking was also reported by [21]. They saw that in the learning environment where augmented reality was used as learning media, students were encouraged to investigate and collaborate which then led to the development of their creative thinking skills. Student actively and independently tried to find information in AR by implementing learning media to solve the predetermined problem without relying on their teacher. However contradictory result was reported by [9], while AR able to improve student knowledge and understanding, it was failed to improve student's creative thinking skills due to time limitation in learning.

3.2 Limitation of Augmented Reality in Biology Learning

Even though implementing AR technology has been reported to improve biology learning, some problems and difficulties are also detected in the learning process. Two main issues of AR implementation in biology learning were reported in the selected research articles of this review paper. (1) learning with AR is time-consuming [9] and (2) technical problems with AR applications. The technical problems were mainly related to downloading and distributing the AR application which consisted of the size of the APK file being quite big [20], unsupported device, problems with the internet signal [18], and app unavailability in the app store/play store [18, 24].

IV. CONCLUSION

In conclusion, Augmented Reality (AR) technology has been positively implemented in biology learning from pre-school to university level of education. It shows a positive impact either on typical students or students with special needs. Incorporating AR into biology learning media can improve student motivation and interest in biology learning, subsequently improving their knowledge and understanding of biology concepts. However, some issue, mainly related to technical problems, still needs to be addressed for successfully implementing AR into the biology teaching and learning process.

Another issue that also came to light when conducting this research is the fact that the successfully designed AR as teaching and learning media has not been tested in the actual learning environment. Thus, future research should be conducted to evaluate the ability of these AR media to improve students' learning achievement and experience. It is also necessary to conduct an intensive study on which concepts in biology that teachers find difficult to teach and/or students find difficult to learn. The information will be beneficial to decide the concepts that the AR technology is necessary to be implemented.

To summarize, AR technology, with its vast development, has a great potential to be one of the best tools to be incorporated in biology future learning. However, it also has issues and limitation. In order to be successfully implemented into Indonesia's learning system it will need support from the government, schools, teachers, students, and parents.

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