Implementing augmented reality to improve students' biology learning outcomes: Gender-based effect

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ABSTRACT

The current study examined the difference in students' biology learning outcomes based on gender following the implementation of Augmented reality (AR). A gender equality study is useful as a foundation for establishing gender-sensitive learning. Gender equality promotes higher productivity and development outcomes, therefore it has favorable effects on economic and technological growth, as well as social fairness. We administered a quasi-experimental non-equivalent pretest-posttest control group design. The research population is all of class X public high school in Pamekasan Regency, Indonesia. The research samples were 56 senior high school students in class X. The classes that will be used as research samples are first tested for equality. The equivalence test analysis will use analysis of variance (ANOVA) by utilizing the SPSS 23.00 for windows program. Participants' learning outcomes were measured using an essay test. The revised Blooms taxonomy indicators were used as the reference to construct the tests. The test covered the indicators of applying (C3), analyzing (C4), and synthesizing (C5). The participants' answered were evaluated using a 4-point scale rubric adopted from Hart. One-way ANCOVA (analysis of covariance) was performed, involving the pretest scores as the covariate. The results showed that there was no difference in biology learning outcomes between male and female students involved in this study ($p>0.05$). These findings demonstrate that the implementation of augmented reality can close the gender gap in biology education. Augmented reality can be a solution to improve the learning environment in biology classrooms and facilitate gender-based learning demands.

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1. INTRODUCTION

Biology is the discipline of science that investigates the material features of living organisms. Biology refers not only to scientific facts concerning perceptible natural events, but also to abstract notions or concepts, such as chemical metabolic processes in the body, hormone system, coordination system, or photosynthesis. The objects studied in Biology are extremely different in terms of their microscopic and macroscopic sizes, affordability, safety (pathogenic bacteria/viruses), and use of Latin scientific names [1]. Abstract concepts that cannot be presented throughout the learning process foster unfavorable attitudes among students, causing them to struggle with concept comprehension [2], which impairs their learning outcomes.

In Indonesia, cognitive learning outcomes have become the primary learning objective [3]. Learning outcomes, also known as competencies, are a combination of knowledge, skills, attitudes, and values [4]. The desired outcomes of a learning process are known as learning outcomes [5]. In addition, learning outcomes can be defined as statements describing what students should know, be able to accomplish, and comprehend at completion of a learning process [6]. Learning outcomes measure and report student achievement [5]. Reports on learning outcomes clarify program objectives and learning requirements, making it easier for students, parents, and teachers to achieve learning goals [6]. Cognitive learning outcomes can be observed on students' report cards and scores of national exams.

According to research, pupils in Madura, East Java, Indonesia have poor cognitive biology learning outcomes [3]. Among the cities in East Java, Madura is ranked lowest based on high school students' national test results from the 2018 academic year. This unsatisfactory outcome indicates that students' conceptual grasp remains inadequate. Findings of previous study indicated that students have trouble comprehending biological phenomena that are not visible to the human eye; they found that several Biology ideas were too abstract and featured a large number of foreign terms, particularly Latin words [7].

Conventional learning approaches that are still implemented in secondary school classrooms might contribute to pupils' low learning outcomes, particularly in biology. Until date, the utilization of learning methods or media in the classroom has not been able to produce an effective learning process. Besides, learning practices do not align with the present setting [8]. In fact, learning biology necessitates that students simultaneously acquire knowledge of biology and apply skills in real-world settings [9]. Moreover, learning must enable students to comprehend concepts and foundations in professional growth, technology, and innovation [10]. Therefore, there needs to be an update in the learning process [11] by incorporating technology as a pedagogical resource [12]; thus, the learning process can accommodate the challenges of the twenty-first century.

In today's digital culture, technology has emerged as a crucial educational resource [13]. Augmented reality (AR) is one of the most recent developing technologies. Since AR can be accessed through smartphones, the learning potential of augmented reality is beginning to be widely recognized [14]. AR technology can present virtual 3D objects, combine the actual and virtual worlds, be interactive in real time, and harmonize virtual and real items [15]. AR is a technology that projects computer-generated things, such as texts, photos, and videos, and 3D models, onto the user's view of the actual world [16], [17] thereby enhancing the user's comprehension of the real world [14].

Augmented reality can be integrated into textbooks, allowing them to display 2D/3D objects, video, animation, text, and sound. AR-integrated textbooks resemble printed books but feature virtual items [18]. Textbooks that integrate AR help enrich students' reading experience because they are more interactive and can improve thinking skills [19]. A study has found that AR-integrated textbooks have a substantial impact on the learning environment and student behavior in the classroom [20]. It has also been shown that AR textbooks affect not just students' academic performance, but also their active engagement in the learning process [21].

Through AR, abstract concepts will be visualized through virtual objects. Furthermore, AR offers proximity and deeper absorption because AR has the ability to visualize objects that are not apparent [22]. Through the immersive, fun, and realistic learning experience provided by AR, the learning environment becomes supportive and thus can develop collaborative, independent, and problem-based learning [23]. The incorporation of AR into the classroom increases student engagement with anatomy [24]. AR technology expands human perception, enabling learners to see, hear, and touch things they cannot otherwise [25].

Several studies have demonstrated that AR can increase student learning outcomes [2], [10], [26]–[28]; especially higher order thinking skills [29]. In a study [30], an AR learning system was designed to improve students' reading skills in scientific classes. The study indicated that multimedia learning enhanced student achievement and motivation significantly. Moreover, the study showed that the amount of extraneous cognitive burden fell dramatically during AR-facilitated learning activities.

Utilizing augmented reality in education can improve conceptual knowledge [22], [31]. The results of the study [24] indicate that the deployment of augmented reality in the classroom enhances spatial abilities, the capacity to assimilate more complex content, and the capacity to comprehend fundamental concepts. AR also assists pupils in concentrating on the important concepts and preventing errors at every level [32]. The application of AR videos enhances the learning experience, learning efficiency, and student satisfaction [28]. The implementation of AR in the classroom also boosts student motivation and learning achievement during the science learning process [33].

Previous studies demonstrate that AR plays a vital role in enhancing student learning outcomes. However, researchers have not yet revealed the role of gender in the deployment of AR for learning. Gender has the capacity to affect learning outcomes differently. Differences in the structure and characteristics of male and female brain development can lead to disparities in academic achievement between the gender.

These differences have the potential to impede the success of biology education. According to previous researches [34], [35], there are distinctions between the male and female brain structures. Males possess 4% more neurons than females, although female Neuropil is more developed than male Neuropil [34], [36]. Consequently, cognitive and neurobiological pathways differ [37]. These differences impact the learning process and the development of language [34]. According to research [38], male have superior spatial competence compared to female, although women are superior in language processing.

On the basis of the Empathizing and Systemizing (E–S) paradigm, it is expected that the cognitive styles of persons in different academic subjects will vary [39]. The E–S theory demonstrates that men are more capable of systematizing, whilst women are more empathetic [40]. Not only does systematizing demand attention to detail in order to comprehend the system, but also the capacity to integrate it into a functional whole. Empathizing is the ability to perceive verbal and nonverbal signs and to synthesize mental states in order to elicit appropriate emotional responses [41].

Studies demonstrate that male and female students have distinct cognitive learning outcomes. Research by Sansgiry, Bhosle, and Sail [42], revealed that female pharmacy students had greater cognitive learning results than males. In addition, female had a better cumulative grade point average (CGPA) than male [43]. Furthermore, Salem *et al.* [44] showed that female students had a higher GPA than male students. In biology disciplines, women have superior cognitive learning results than men [45].

Different findings were reported by several researchers [46], [47] who stated that the average learning outcomes of males were higher than those of females in biology. Another study [48] also found that male students outperformed female students in the field of computer hardware and microprocessors. In addition, there was no difference in male and female students' science achievement [49], [50]. However, according to Spinath, Freudenthaler, and Neubauer [51], the impact of gender on academic performance cannot be explained in detail. A research report [52] indicated that female students performed better in Indonesian and English than male students. Meanwhile, male pupils performed better in science classes. In addition, researchers found that there was no difference between male and female students in terms of mathematics achievement.

In general, investigations of gender-related learning outcomes reveal a gender disparity in learning. It is vital to recognize the gender gap since education should provide equal benefits to male and female pupils. A study identified gender equality as a fundamental development objective [53]. In this vein, one of the Millennium Development Goals (MDGs) is gender equality, which includes education. Moreover, gender equality can raise the productivity of the current generation and improve future development results [53]. Gender equality also has substantial consequences for economic and technical growth, as well as social fairness [54].

Based on the preceding context, this study examined the difference in students' biology learning outcomes based on gender following the implementation of AR-integrated textbooks technology in the classroom. A study on the impact of AR-integrated textbooks in bridging the gender gap in the classroom is crucial for the development of successful learning. Gender equality in terms of learning opportunities and learning outcomes would be the primary challenge for the Indonesian government during the next decade [52]. This study was conducted with tenth graders in a high school in Madura, East Java, Indonesia and focused on biology instruction performed at the school.

2. RESEARCH METHOD

2.1. Research design

The present study was a quantitative research. A quasi-experimental study with a non-equivalent pretest-posttest control group design was employed. This study aims to reveal learning outcomes differences based on gender in augmented reality learning. Table 1 displays the research design. Gender (male and female) constituted the independent variable of the study, while cognitive learning outcomes were the dependent variable.

Table 1. Research design

Pre-test	Gender	Post-test
O1	Male	O2
O3	Female	O4

O1, O3=Pretest scores; O2, O4=Posttest scores

2.2. Population and sample

The population of this study consisted of all senior high school students from public schools in Pamekasan, Indonesia. The sample was selected randomly based on the results of the equivalence test. A total of 56 (30 female and 26 male) students from two classes participated in this study.

2.3. Research procedure

Both classes implemented the Think-Pair-Share (TPS) strategy, which in detail consisted of: i) Think, where students completed the worksheet individually; ii) Pair, at which students formed a pair and discussed their work to formulate the best answer; iii) Share, where students presented their discussion results. The TPS learning activities were supported by AR technology. An essay test was administered to the participants prior to and at the conclusion of the learning activities to measure their learning outcomes. The students' answers were evaluated using a rubric [55].

2.4. Research instruments

This study employed learning tools as the instruments, including the biology subject's syllabus, lesson plans, student worksheet, and observation sheets to assess the implementation of the learning process. The AR technology used in this study was marker-based, where superimposed digital objects were drawn on the textbook's images. This technology allowed students to interact with the digital objects by pushing the play button.

Another instrument used in this study was an essay test. It was administered to measure students' learning outcomes. The essay test was constructed based on the revised Blooms taxonomy levels of C3 (applying), C4 (analyzing), and C5 (synthesizing). The test went through expert validation prior to use. Expert validation was conducted to examine the test's construct validity. During expert validation, the validators were allowed to provide suggestions for the test's improvement. The results of the expert validation showed that twenty-three questions were valid and reliable. Participants' test answers were evaluated using a 4-scale rubric adapted from [55].

2.5. Data analysis

Data analysis was performed using a one-way ANCOVA, involving the pretest scores as the covariate. Before conducting the ANCOVA, assumptions tests were done. The data normality was examined using the Kolmogorov-Smirnov test, while the homogeneity of variance was examined using the Levene's test. Data analysis was done using the IBM SPSS Statistics 23 software for Microsoft Windows.

3. RESULTS AND DISCUSSION

A one-way ANCOVA with the pretest scores as the covariate was used to investigate the difference in biology learning outcomes between male and female students in the AR-integrated classroom. The analysis results showed that F count=0.973, p value=0.328 while the value of $p>\alpha$ ($\alpha=0.05$). The analysis results indicated that H0 was accepted. It can be further deduced that there was no significant difference in the posttest learning outcomes between the male and female students controlling for pretest scores as presented in Table 2.

Table 2. The results of a one-way ANCOVA on students' learning outcomes based on gender

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected model	310.705a	2	155.352	19.249	.000
Intercept	4274.024	1	4274.024	529.583	.000
Pretest	296.978	1	296.978	36.798	.000
Gender	7.855	1	7.855	.973	.328
Error	427.739	53	8.071		
Total	384329.389	56			
Corrected total	738.443	55			

3.1. The difference between male and female students in learning outcomes (Gender-based analysis)

The statistical analysis showed that there was no significant difference in learning outcomes between male and female students involved in the AR-integrated classroom (Table 2). The results suggested that the implementation of AR technology in the classroom was successful and could minimize gender disparity in biology classrooms. These results also demonstrated that the usage of AR was effective in aiding both male and female students' cognitive development.

Because male and female students had the same learning experience using AR, there was no difference in their learning outcomes. Both male and female students participated actively in the learning process. The adoption of AR in biology classrooms affords students the opportunity to collaborate. AR learning allows for a more concrete learning experience for students [56]; because students can interact with virtual items, their perceptions and interactions with the actual world are enhanced [57]. Additionally, AR allows for experiments that are impossible in the real world [56].

This finding is consistent with the theory of constructivism, which holds that knowledge is the consequence of an individual's active participation (learning by doing) [58]. According to constructivist theory, AR technology enables pupils to generate new information by reviewing their past knowledge [59]. The primary advantage of AR is that it facilitates effective learning based on the "learning by doing" paradigm [9], [60]. The integration of AR technology into instructional materials can pique students' interest and motivate them to actively engage in learning [57], [60], [61]. Further, it was said that the use of technology in the classroom allows students to investigate a phenomenon and duplicate it [57]. Augmented reality can motivate students to learn because it delivers a visually appealing, interactive, and learning-supportive display.

Based on the principle of multimodal learning espoused in [62], [63], AR visualization can assist students in selecting and organizing pertinent spatial information, leading to a higher level of learning. Based on the findings of this study, the AR-integrated learning activities were greatly beneficial for the visual and spatial development of female students. Objects and animations in three dimensions assisted female students in learning complex topics and required them to think visually-spatially [59]. Because the male students in this study had to communicate the results of group work during the learning process, the application of augmented reality in the classroom aided their language development. These results imply that the application of augmented reality in biology classrooms helps to meet the learning requirements of all genders.

This study showed that there was no difference in learning results between male and female students since they shared the same interest in AR-integrated learning. This is consistent with the findings of several studies [64]–[66] which indicate that male and female students have an interest in AR learning. AR learning boosts students' interest in learning activities. According to the research report [67], AR's informative, interactive, and visual aspects can influence students' focus structures (perceived benefits, perceived pleasure and satisfaction). This suggests that AR promotes an interest in learning biology in both genders, so that both male and female students become more focused on learning and have the same perceptions of pleasure and satisfaction in learning. Despite so, this requires additional research.

AR technology has the potential to positively and creatively bridge gender, physical, mental, class, and racial gaps in the classroom [25]. AR technology expands human perception, allowing people to see, hear, and touch things they cannot do in real life [25]. AR technology enables students to connect with virtual and real-time applications and provides a natural experience for users [9], [16].

The results of this study corroborate the findings of several researchers [26], [65] who concluded that there was no difference between male and female students' posttest scores in scientific lessons using AR learning. Another study [68] also discovered that the English-learning accomplishments of male and female students in AR-integrated learning were comparable. Augmented Reality proved equally successful in enhancing male and female performance on assembly tasks [69]. Furthermore, Valencia, Burgos, and Branch analysis of 66 publications released between 2017 and 2021 revealed no significant difference between men and women in terms of AR learning knowledge acquisition [70]. The conclusion of previous study [31] confirms that the deployment of AR is possible to close the gender performance and retention gap in geography classes. Another research report showed that there was no significant difference in spatial thinking skills between male and female students [71].

Other findings [30], [68], [72] demonstrated that implementing augmented reality can lessen the cognitive load of students. There was no difference between male and female students regarding augmented reality use and cognitive strain [72]. The use of AR in education lessens the mental strain of both male and female students [72]. The findings of this study, however, counter claims that men profit more from AR implementation, even though it has been demonstrated that male students have greater posttest scores than female students [73]. Thus, the application of gender-related AR presents potential for more research.

4. CONCLUSION

The current study showed that there was no significant difference in biology learning outcomes between male and female students. Therefore, it suggests that the implementation of augmented reality (AR) in biology courses offers benefits for both male and female students so that they can develop a strong grasp and conception of biology concepts. This study's findings imply that the application of augmented reality is capable of closing the gender gap in biology education. AR-integrated learning is a comprehensive learning strategy that may suit the educational requirements of students. In biology education, educators should be able to integrate AR into instructional resources, because AR learning can improve the learning environment and enable gender-based learning demands.

We are aware of the study's shortcomings. One is that this study was limited to examining gender differences in student learning outcomes with a small number of samples. In addition, AR technology was exclusively applied to biology disciplines in this study. Therefore, similar research can be undertaken with a larger population coverage, in many locations, age groups, and subject populations. Processing of research data was limited to one semester. Further research might be conducted to assess students' comprehension of various subject areas and classes. Studies related to AR can also be done by involving different variables.

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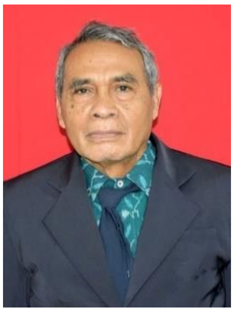

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