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THE EFFECTIVENESS OF AUGMEMTED REALITY AND FLIPPED CLASSROOM IN BIOLOGY LEARNING: A META-ANALYSIS

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Keywords

Augmented Reality, Flipped Classroom, Biology learning

Abstract

This study aims to analyze the effectiveness of the use of Augmented Reality (AR) and the Flipped Classroom learning model in Biology learning through meta-analysis methods. Technology-based learning, such as AR, and flipped learning approaches (Flipped Classroom) are increasingly popular in science education, especially Biology, as they are both believed to improve concept understanding, student engagement, and learning outcomes. This meta-analysis was conducted by collecting and analyzing data from a variety of relevant empirical studies to assess the impact of the two models on students' academic achievement, conceptual comprehension, and critical thinking skills. The results of the meta-analysis showed that the use of AR and Flipped Classroom significantly improved students' understanding of Biology material and learning motivation compared to conventional learning methods with a value of d = 1,804 p< 0.001 high effect size category. Flipped Classroom is more effective in improving critical thinking skills, while AR makes a great contribution to the visualization and understanding of complex concepts. This study concludes that the integration of AR and Flipped Classroom in Biology learning has great potential to improve the quality of learning and student learning outcomes.

1. INTRODUCTION

Biology plays an important role in education because it studies all aspects of life, from the molecular level to the ecosystem. Biology helps students understand how living organisms interact with their environment and how biological processes affect life on earth (Ramadhan & Suyanto, 2020; Kagnici & Sadi, 2021). In an era characterised by environmental changes, developments in medical technology, and global challenges such as global warming and the health crisis, an understanding of Biology is becoming increasingly essential (Ebrahim & Naji, 2021). Through learning Biology, students are not only taught fundamental concepts about the human body, plants, animals, and microorganisms, but also given insights into global issues related to health, conservation, and ecosystem sustainability (Bozdağ et al., 2021; Oktarina et al., 2021).

In addition, Biology builds critical and analytical thinking skills, which are essential in solving real-life problems. Students are trained to observe, hypothesise, conduct experiments, and analyse data, which are essential skills in scientific research and evidence-based decision-making (Isaak et al., 2022). In a world increasingly influenced by technological innovation and biotechnology, a strong understanding of Biology also opens up opportunities for students to engage in a wide range of careers in health, environment, scientific research and food technology. Thus, the importance of learning Biology lies in its role in preparing a generation that is more aware of global issues, has strong scientific skills, and is able to contribute to innovative solutions to the world's challenges (Ilma et al., 2022; Shaaban, 2023).

Challenges in learning Biology are often related to the complexity of the material that students must understand. Many concepts in Biology are abstract, such as genetics, evolution, and molecular mechanisms in cells, which are difficult to understand through verbal explanations or text alone (Romero-García et al., 2023). In addition, Biology also involves many new and complicated technical terms, so students often struggle to remember and understand these concepts in depth. Traditional teaching methods that focus on lectures and memorisation are often ineffective in helping students understand the relationships between interrelated concepts in Biology. The inability to visualise these concepts concretely is a major obstacle in improving student understanding (Ruiz-Palmero et al., 2023; Ningsih et al., 2023).

In addition, the limited learning facilities and infrastructure in schools is also a challenge. Biology learning, which ideally involves direct experiments in the laboratory, is often hampered by the limitations of adequate facilities, equipment and practicum materials. In some cases, teachers face obstacles in integrating innovative technologies, such as virtual simulations or interactive tools, which can actually help students understand difficult Biology concepts (Jasman et al., 2024). As a result, students often only get theory without enough practical experience. These challenges call for innovations in Biology teaching methods, including the use of technologies such as Augmented Reality and more active and interactive learning approaches such as Flipped Classroom. Therefore, technology is needed that can help the biology learning process (Salas-Rueda, 2023; Jasman et al., 2024).

he development of technology in education has brought significant changes to the way learning is delivered and accessed. One technology that is gaining popularity is Augmented Reality (AR), which combines the real world with interactive virtual elements to create a more dynamic and immersive learning experience. In science learning, especially Biology, AR allows students to visualise objects that are difficult to access in the real world, such as human anatomy, cells, or ecosystems in detail (Tuzzahra et al., 2022). This technology provides a more immersive learning experience as students can interact directly with three-dimensional visualisations, thus improving their understanding of abstract concepts that are difficult to explain only through text or two-dimensional images (Aidoo et al., 2022). The application of AR also helps overcome the limitations of physical laboratories in schools, allowing students to 'experience' experiments or biological processes without the need for specialised equipment.

In addition to AR, the Flipped Classroom learning model is also increasingly used as a solution to overcome challenges in science learning. In this model, students learn basic materials independently outside of class through videos or digital reading materials, while in-class time is used for more in-depth discussions, problem-solving and collaborative activities (De Guzman & Magpantay, 2022; Wangda et al., 2024). This approach allows students to learn at their own pace before class, so they are better prepared to engage in active classroom activities. For Biology learning, the Flipped Classroom model is very effective as it provides more time in class to do practical activities, such as case analyses, experiments, or group discussions. These two technologies, AR and Flipped Classroom, have been proven to increase students' engagement and deepen their understanding in science learning, making it an innovative solution to overcome various challenges in Biology learning (Ramadhan & Suyanto, 2020; Byeon & Kwon, 2023).

As the use of Augmented Reality (AR) and Flipped Classroom in learning becomes increasingly popular, many studies have been conducted to evaluate the effectiveness of these two methods, especially in Biology learning (Ilma et al., 2020; Putra et al., 2022). Each study offers mixed findings regarding the positive impact of these technologies on student learning outcomes, such as improved concept understanding, student engagement, and development of critical thinking skills (Geng & Yamada, 2020; Buchner & Zumbach, 2018); Schmidthaler et al., 2023). However, variations in methodology, research populations and learning contexts often lead to different conclusions. Some studies show that AR is effective in visualising abstract concepts, while others highlight the success of Flipped Classroom in promoting independence and active interaction in the classroom. With so many scattered research results, there is a need to bring these findings together in order to gain a more thorough understanding of the overall impact of AR and Flipped Classroom in the context of Biology learning (Ariyati et al., 2024).

Therefore, meta-analyses are needed to provide a more systematic and comprehensive evaluation. Meta-analysis allows researchers to collect data from multiple studies, quantitatively analyse the results, and identify common patterns or trends that emerge from the various studies. Through this approach, we can address the variation in results from individual studies and provide a more accurate effect estimate of the effectiveness of AR and Flipped Classroom. In addition, meta-analysis also helps identify factors that influence the success of these methods, such as learning conditions, age group, or the type of material taught. Thus, the results of the meta-analysis will provide more in-depth and informative insights for educators and researchers on how to optimally utilise AR and Flipped Classroom in Biology learning.

2. RESEARCH METHODS

This study used a meta-analysis approach to evaluate the effectiveness of using Augmented Reality (AR) and Flipped Classroom in learning Biology. This meta-analysis was conducted by collecting, analysing, and integrating quantitative data from various relevant studies, both published and unpublished. Data sources were taken from reputable scientific databases such as Google Scholar, Scopus, and Web of Science, with inclusion criteria that included empirical studies comparing Biology learning outcomes between students using AR and/or Flipped Classroom with traditional learning methods. Studies included in this analysis had to measure specific learning outcomes, such as concept understanding, critical thinking skills, or student engagement. Articles that did not provide quantitative data or that were not relevant to the research topic were excluded from the analysis.

The data analysis process involved several stages. Firstly, data coding was conducted to classify study results based on research characteristics such as research design, sample size, education level, and type of learning outcomes measured. Secondly, effect sizes were calculated to measure the impact of AR and Flipped Classroom on student learning outcomes in each study. The statistical technique used was a random-effects model to handle the variation between studies. The results of this meta-analysis were then visualised in the form of a forest plot to show the variation in effects from each study and calculate an overall estimate of the effectiveness of these two learning methods. A heterogeneity analysis was also conducted to assess the extent to which between-study variation affected the results. Furthermore, the criteria for the effect size value in the study can be seen in Table 1.

Table 1. Criteria Nilai Effect Size

Effect Size	Category
Between -0.15 and 0.15	No Effect
Between 0.15 and 0.40	Low Effect
Between 0.40 and 0.75	Moderate Effect
Between 0.75 and 1.10	High Effect
Between 1.10 and 1.45	Very High Effect
1.45 or higher	Amazing Effect

Source:(Nurtamam et al., 2023; Setiawan et al., 2022); Zulyusri et al., 2023); Abdullah et al., 2024)

3. RESULT AND DISCUSSION

Based on the results of data search through the database, 24 studies/articles met the inclusion criteria. The effect size and error standard can be seen in Table 2.

Table 2. Effect Size and Standard Error Every Research

Code Jurnal	Years	Effect Size	Standard Error
R1	2022	1.18	0.33
R2	2022	0.94	0.40
R3	2023	1.14	0.44
R4	2022	0.78	0.30
R5	2024	0.69	0.26
R6	2024	1.30	0.35
R7	2024	1.52	0.49
R8	2024	1.45	0.40
R9	2024	0.83	0.38
R10	2022	0.52	0.19
R11	2022	0.61	0.29
R12	2024	0.43	0.21
R13	2023	0.49	0.23

R14	2024	0.94	0.41
R15	2022	1.09	0.42
R16	2023	0.66	0.22
R17	2024	1.35	0.42

Based on Table 2, the effect size value of the 24 studies ranged from 0.43 to 1.35. According to Borenstein et al., (2007) Of the 24 effect sizes, 7 studies (41.17 %) had medium criteria effect sizes and 10 studies (58.82 %) had high criteria effect size values. Furthermore, 17 studies were analyzed to determine an estimation model to calculate the mean effect size. The analysis of the fixed and random effect model estimation models can be seen in Table 3.

Table 3. Fixed and Random effect

	Q	**df**	**p**
Omnibus test of Coefficients Model	52.193	1	< 0.001
Test of Residual Heterogeneity	103.082	16	< 0.001

Based on Table 3, a Q value of 103.082 was obtained higher than the value of 52.1943 with a coefficient interval of 95% and a p value of 0.001 <. The findings can be concluded that the value of 17 effect sizes analyzed is heterogeneously distributed. Therefore, the model used to calculate the mean effect size is a random effect model. Furthermore, checking publication bias through funnel plot analysis and Rosenthal fail safe N (FSN) test (Tamur et al., 2020; Badawi et al., 2022; Ichsan et al., 2023b; Borenstein et al., 2007; Zulkifli et al., 2022). The results of checking publication bias with funnel plot can be seen in Figure 2.

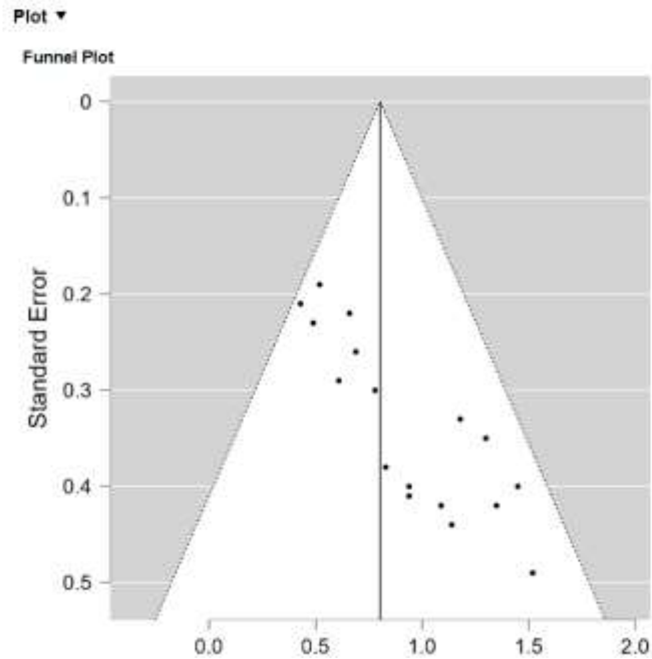

Figure 2. Funnel Plot

Based on Figure 2, the analysis of the funnel plot is not yet known whether it is symmetrical or asymmetrical, so it is necessary to conduct a Rosenthal Fail Safe N (FSN) test. The results of the Rosenthal Fail Safe N calculation can be seen in Table 4.

Tabel 4. Fail Safe N

File Drawer Analysis			
	Fail Safe N	Target Significance	Observed Significance
Rosenthal	783	0.050	< 0.001

Based on Table 4, the Fail Safe N value of 783 is greater than the value of 5k + 10 = 5(17) + 10 = 95, so it can be concluded that the analysis of 17 effect sizes in this data is not biased by publication and can be scientifically accounted for. Next, calculate the p-value to test the hypothesis through the random effect model. The results of the summary effect model analysis with the random effect model can be seen in Table 5.

Tabel 5. Mean Effect Size

Coeficient						
	Effect Size	Standard Error	z	p	Coeficient Interval	
					Lower	Upper
Intercept	0.804	0.289	9.625	< 0.01	0.721	1.052

Table 5, explains the significant influence of the application of augmented reality and flipped classroom in students' biology learning with a score ($d = 0.804$; $p < 0.001$). This influence belongs to the high effect size category. These findings conclude that the implementation of Augemented Reality (AR) and flipped clasroom is effective for teachers in biology learning. Augmented reality provides an interactive learning experience by visualizing complex biological concepts through technology, so students can understand the material in a more immersive way (Kangdon Lee, 2012). Flipped classrooms, on the other hand, reverse traditional patterns of learning by moving theoretical learning outside the classroom and discussion or practical activities within the classroom, allowing students to be more active in the learning process (Garzón, 2021; Altinpulluk, 2019).

Based on the results of the meta-analysis, the use of AR is proven to increase student engagement because it is able to present material that is difficult to understand abstractly into more concrete and visually accessible. Students can interact directly with 3D models of cells, organs, or other biological processes, which reinforces their understanding of basic biological concepts (Cabero & Barroso, 2016). Research also shows an increase in learning motivation because students feel more interested and involved in the learning process when using AR compared to traditional learning methods (Oktarina et al., 2018; Elmqaddem, 2019). Meanwhile, flipped classrooms provide time flexibility for students to understand the basic material independently before entering the classroom. It provides space for more in-depth discussions, problem-solving, and practical activities relevant to biology material. In this meta-analysis, flipped classrooms showed effectiveness in improving students' critical thinking skills, as they already have basic knowledge before class discussions and can focus more on application and analysis (Oktarina et al., 2021; Ichsan et al., 2023b).

The combination of AR and flipped classroom in biology learning resulted in a significant improvement in student learning outcomes compared to conventional methods. AR allows for interactive and engaging presentation of material, while flipped classrooms optimize face-to-face time for more collaborative, problem-solving-based activities. The two complement each other by combining technological advantages and a more active pedagogical approach. The importance of innovation in teaching methods in the field of biology (Bower et al., 2014), especially when utilizing technology to improve the quality of learning. Both of these methods not only support a deeper understanding of the material but also help develop important skills such as critical thinking and collaboration, which are essential in the modern world of education.

CONCLUSION

From the results of this meta-analysis, it can be concluded that the use of AR and Flipped Classroom significantly improves the understanding of Biology material and students' learning motivation compared to conventional learning methods with a value of $d = 0.804$; $p < 0.001$ high effect size category. Flipped Classroom is more effective in improving critical thinking skills, while AR makes a great contribution to the visualization and understanding of complex concepts. This study concludes that the integration of AR and Flipped Classroom in Biology learning has great potential to improve the quality of learning and student learning outcomes. The combination of AR and Flipped Classroom is expected to create a more interactive and engaging learning environment, thus encouraging students to be more active in their learning process. This study recommends that educators consider using these two methods simultaneously to maximize the learning potential of biology, as well as encourage further research to address the challenges that may arise in their implementation.

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