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ORIGINAL

Enhancing Learning Outcomes through Cooperative Project-Based Learning with Augmented Reality Integration

Mejora de los resultados del aprendizaje mediante el aprendizaje cooperativo basado en proyectos con integración de realidad aumentada

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ABSTRACT

This study investigates the integration of Cooperative Project-Based Learning (CPjBL) with Augmented Reality (AR) to enhance student learning outcomes in the context of artificial intelligence education. The study employed a Nonequivalent Control Group Design to compare the effects of this integrated approach with traditional learning methods. The experimental group, which utilized CPjBL enhanced by AR, demonstrated significant improvements in their academic performance, engagement, and problem-solving skills, as shown by pre-test and post-test assessments. In contrast, the control group, following traditional teaching methods, showed smaller improvements. The integration of AR provided students with an interactive and immersive learning experience, facilitating the visualization of complex AI concepts and promoting collaborative problem-solving. This approach not only enhanced students' knowledge retention but also developed their critical thinking, teamwork, and communication skills. The findings suggest that the use of AR in CPjBL creates a more engaging and effective learning environment, aligning educational practices with the technological advancements required in today's workforce. The study concludes that the integration of CPjBL with AR is an effective strategy for improving student learning outcomes and preparing students for real-world challenges in their careers. This research contributes to the growing body of literature on the potential of combining innovative teaching strategies with emerging technologies in education.

Keywords: Cooperative Project-Based Learning; Augmented Reality; Learning Outcomes.

RESUMEN

Este estudio investiga la integración del Aprendizaje Cooperativo Basado en Proyectos (CPjBL) con la Realidad Aumentada (RA) para mejorar los resultados de aprendizaje de los estudiantes en el contexto de la enseñanza de la inteligencia artificial. El estudio empleó un diseño de grupo de control no equivalente para comparar los efectos de este enfoque integrado con los métodos de aprendizaje tradicionales. El grupo experimental, que utilizó CPjBL mejorado con RA, demostró mejoras significativas en su rendimiento académico, compromiso y habilidades de resolución de problemas, como se muestra en las evaluaciones previas y posteriores a la prueba. En cambio, el grupo de control, que siguió métodos de enseñanza tradicionales, mostró mejoras

menores. La integración de la RA proporcionó a los estudiantes una experiencia de aprendizaje interactiva y envolvente, facilitando la visualización de conceptos complejos de IA y promoviendo la resolución colaborativa de problemas. Este enfoque no sólo mejoró la retención de conocimientos de los estudiantes, sino que también desarrolló su pensamiento crítico, su trabajo en equipo y sus habilidades comunicativas. Los resultados sugieren que el uso de la RA en el CPjBL crea un entorno de aprendizaje más atractivo y eficaz, alineando las prácticas educativas con los avances tecnológicos requeridos en la mano de obra actual. El estudio concluye que la integración de CPjBL con RA es una estrategia eficaz para mejorar los resultados de aprendizaje de los estudiantes y prepararlos para los retos del mundo real en sus carreras. Esta investigación contribuye al creciente cuerpo de literatura sobre el potencial de combinar estrategias de enseñanza innovadoras con tecnologías emergentes en la educación.

Palabras clave: Aprendizaje Cooperativo Basado en Proyectos; Realidad Aumentada; Resultados del Aprendizaje.

INTRODUCTION

Background of The Study

The integration of innovative educational methodologies is crucial in addressing the evolving demands of the contemporary job market. Traditional educational systems often fall short in equipping students with the necessary skills to navigate complex challenges. One promising approach to enhance learning outcomes is Cooperative Project-Based Learning (CPjBL), which emphasizes collaboration among students on projects that tackle real-world problems. This method fosters active engagement, teamwork, communication, and problem-solving skills, all of which are essential in today's professional landscape.[1]

Moreover, the incorporation of Augmented Reality (AR) into educational practices has gained significant traction. AR enhances the learning experience by providing interactive and immersive environments where students can engage with content in three-dimensional formats. This technology allows learners to visualize complex concepts, making abstract ideas more tangible and comprehensible.[2] For instance, AR can facilitate the understanding of intricate subjects like molecular structures in chemistry or physical phenomena, thereby enriching the educational experience.[3]

The combination of CPjBL and AR presents a unique opportunity to create a more dynamic and effective learning environment. By integrating AR into CPjBL, educators can enhance students' ability to think creatively and collaboratively while solving problems.[4] This synergy not only makes learning more engaging but also aligns educational practices with the technological advancements that characterize modern society.[5] Research indicates that AR can significantly improve students' educational motivation, critical thinking, and self-efficacy, particularly when used in project-based contexts.[1]

Furthermore, the literature highlights the potential of AR to create hybrid learning environments that support the development of critical skills necessary for the workforce. For example, studies have shown that AR can facilitate independent collaborative exercises that enhance critical thinking and problem-solving abilities.[1,6] As such, the integration of AR in CPjBL is not merely a trend but a strategic approach to preparing students for future challenges in their careers.[7]

The Need for Innovative Learning Strategies

The rapid advancement of technology necessitates a transformation in educational methodologies to better prepare students for the complexities of the modern workforce.[8] Traditional educational systems, which often emphasize theoretical knowledge and rote memorization, are increasingly inadequate for developing the critical thinking, problem-solving, and collaborative skills that are essential in today's job market.[9,10] As such, innovative learning methods are imperative to meet the evolving demands of society.

Project-Based Learning (PjBL) has emerged as an effective pedagogical approach that addresses these challenges by engaging students in real-world projects that require problem-solving and collaboration.[11,12] PjBL allows students to learn through direct experience, fostering practical skills that are highly valued in professional settings.[10,13] However, while PjBL is beneficial, its effectiveness can be further enhanced through the integration of modern technologies that facilitate deeper engagement and understanding.

Cooperative Project-Based Learning (CPjBL) builds upon the principles of PjBL by emphasizing teamwork and collaboration among students. In CPjBL, learners work together on projects, exchanging ideas and solving problems collectively, which mirrors the collaborative nature of many workplaces today.[14,15] This approach not only cultivates essential soft skills but also prepares students for the realities of working in teams, which is increasingly prioritized by employers.[10,15]

One promising technology that can significantly enhance the CPjBL experience is Augmented Reality (AR). AR provides an interactive and immersive learning environment, allowing students to visualize and engage with educational content in a more tangible manner. This technology can simulate real-world scenarios, making complex concepts more accessible and engaging.[7,16] For instance, AR can be utilized in science education to help students understand molecular structures or physical phenomena, thereby enriching their learning experience.[17,18]

The integration of AR within CPjBL has the potential to create a dynamic learning environment that encourages creativity and critical thinking.[19] Research indicates that AR can facilitate independent collaborative exercises that enhance critical thinking and problem-solving skills.[6,7] By providing students with immersive experiences, AR not only makes learning more engaging but also helps them develop the competencies necessary for navigating real-world challenges.[6,10]

The Role of Cooperative Project-Based Learning

Cooperative Project-Based Learning (CPjBL) is an approach that combines teamwork with project-based learning. In this model, students work together in groups to complete a project that has specific goals or problems to solve. Through collaboration, they not only learn technical skills related to the project but also develop social and communication skills that are crucial in the professional world.[14]

One of the primary benefits of CPjBL is increased student motivation. When students are involved in real-world projects that are relevant to their lives, they are more motivated to learn because they can see the direct impact of their efforts.[20] Additionally, project-based teamwork teaches important values such as responsibility, trust, and collaborative skills, all of which are essential in a professional setting.[21]

CPjBL also encourages the development of problem-solving skills. While working together on a project, students are often faced with challenges that require critical thinking and creativity. This enables them to develop skills that will be highly useful in their personal and professional lives. Moreover, by reflecting on the projects they complete, students can gain a deeper understanding of their learning process and how they can improve their strategies moving forward.[22]

Furthermore, CPjBL strengthens interpersonal and teamwork skills. In this process, students learn how to communicate effectively with their teammates, listen to others' opinions, and resolve conflicts that may arise. These skills are crucial in both educational and professional contexts.[21,23] CPjBL also instills a sense of ownership over the projects they work on, which boosts their responsibility and achievement.[14]

Augmented Reality in Education

Augmented Reality (AR) is a technology that combines digital elements with the real world in an interactive manner. In the context of education, AR allows students to engage with learning content in three-dimensional formats, providing them with a more immersive experience. AR can help visualize abstract or complex concepts, such as molecular structures in chemistry or phenomena in physics, in a more tangible and understandable way.[2,5]

One of the main advantages of AR in education is its ability to provide a more engaging learning experience.[24,25] Using devices such as smartphones or tablets, students can see objects or information superimposed onto the real world, making learning more dynamic and interactive.[14,17] Additionally, AR can overcome the limitations of space and time, allowing students to access learning materials anytime and anywhere.[1,6]

Previous research has shown that AR can increase student engagement in the learning process.[10,26] Studies have indicated that using AR can help students understand difficult concepts more easily and in a more enjoyable way.[27] Furthermore, AR can enhance the learning process by providing practical, real-world experiences that are difficult to achieve through traditional learning methods.[17,18]

Integrating AR into Cooperative Project-Based Learning (CPjBL) offers a significant opportunity to create a richer and more effective learning experience.[26,28] With AR, students can collaborate on creating and completing projects that leverage this technology, such as building real-world simulations or interactive presentations.[3,14] AR can enrich the projects they work on with visual elements that enhance understanding and engagement.

Purpose of this Study

The primary objective of this study is to explore the potential for enhancing learning outcomes through the integration of Cooperative Project-Based Learning (CPjBL) and Augmented Reality (AR). Specifically, the research aims to assess how AR can enrich the learning experience within CPjBL, thereby improving student engagement, conceptual understanding, and the development of collaborative skills. Given that CPjBL has already proven effective in enhancing both social and cognitive skills, this study seeks to determine whether the addition of AR offers additional benefits in achieving more effective and impactful learning outcomes.

Moreover, this study intends to evaluate how AR can address challenges commonly encountered in project-

based learning, particularly in collaborative settings. By providing an immersive and interactive environment, AR is expected to deepen students' understanding of the subject matter while fostering better communication and teamwork among group members. This research aims to provide empirical evidence on the effectiveness of AR in facilitating collaborative problem-solving and enhancing the learning process within project-based frameworks.

In addition, the study aims to offer practical insights for educators and policymakers on the importance of integrating technology, particularly AR, into modern educational strategies. As the digital age demands innovative teaching methods, this research seeks to provide guidelines for developing effective, technology-enhanced learning environments that can address the evolving needs of students. Ultimately, the study aspires to contribute to the literature on innovative learning methodologies by exploring how AR and CPjBL can complement each other, creating a more engaging and effective learning experience for students.

METHOD

Research Design

This study utilizes a Nonequivalent Control Group Design, which is categorized under Quasi-Experimental Design. This design was chosen as it aligns with the research objectives, which aim to examine the differences in learning outcomes between the group receiving treatment (experimental group) and the control group that does not. The Quasi-Experimental Design is an extension of the True Experimental Design and is considered more appropriate than Pre-Experimental Design.[29]

In this study, there are two groups of subjects: the experimental group, which receives the treatment in the form of technology-based learning, and the control group, which uses traditional learning methods. The research subjects consist of students from the Department of Informatics Engineering at Universitas Ibnu Sina, with each group comprising 20 students. The study will take place over eight meetings, with different procedures for the experimental and control groups, in line with the aim of testing the effectiveness of technology-enhanced learning in improving student learning outcomes.

Table 1. Research Design

Group	Pre-Test	Treatment (X)	Post-Test
Experiment	O_1	X	O_2
Control	O_3	-	O_4

Explanation:

O_1 & O_3: Pretest observation for the experimental and control group.

X: The treatment or intervention given to the experimental group

O_2 & O_4: Posttest observation for the experimental and control group.

Hypothesis

The primary hypothesis of this study is as follows:

a. H1: The implementation of Cooperative Project-Based Learning (CPjBL) integrated with Augmented Reality (AR) results in a significant difference in the learning outcomes of students compared to the traditional learning method used in the control group.

b. H0: The implementation of Cooperative Project-Based Learning (CPjBL) integrated with Augmented Reality (AR) does not result in a significant difference in the learning outcomes of students compared to the traditional learning method used in the control group.

Data Collection Instrument

This study will collect data primarily through tests designed to measure changes in students' learning outcomes before and after the treatment. The test will consist of 40 multiple-choice questions, covering a broad range of topics relevant to the course material. The pre-test will be administered at the start of the study to assess students' initial understanding, while the post-test will follow the treatment to evaluate the effectiveness of the learning intervention. Both tests will measure the same core content to enable a direct comparison of students' performance.

To ensure the validity of the test instruments, the questions will undergo a rigorous review by experts and instructors. These professionals will evaluate the clarity, relevance, and alignment of the questions with the study's objectives. This process will ensure that the tests accurately measure the desired learning outcomes. The tests will be designed to assess various levels of cognitive complexity, from basic recall to more applied problem-solving skills, to capture the full range of student learning.

In addition to the tests, the researcher will develop product validation instruments to evaluate the learning

materials and tools used in the study, particularly the integration of Augmented Reality (AR) within Cooperative Project-Based Learning (CPjBL). These tools will be assessed for feasibility and practicality by experts to determine whether they effectively enhance student engagement and learning. This comprehensive validation process will ensure the reliability and effectiveness of the data collection instruments.

Data Analysis Techniques

The data collected from the pre-test and post-test will be analyzed using a T-test to determine whether there are significant differences in learning outcomes between the experimental and control groups. The T-test will allow for a comparison of the mean scores of the two groups, helping to identify if the treatment, which involves the integration of Augmented Reality (AR) into Cooperative Project-Based Learning (CPjBL), leads to statistically significant improvements in students' performance. This analysis will provide a clear understanding of the impact of the treatment on student learning. Additionally, product feasibility analysis will be conducted to assess whether the learning tools and materials used in the study align with the standards and objectives set out for the research. This process ensures that the learning product is suitable and effective for educational purposes.

In addition to the T-test and product feasibility analysis, practicality analysis will be performed by gathering feedback from students regarding their experiences with the technology-based learning approach. This will help determine whether the learning product is practical, engaging, and acceptable to students. Moreover, effectiveness analysis will be conducted by comparing the pre-test and post-test results to evaluate how much the learning intervention enhanced students' learning outcomes. These combined analyses—examining feasibility, practicality, and effectiveness—will provide a comprehensive evaluation of the technology-based learning approach. Ultimately, these analyses will guide the researcher in drawing conclusions about the success and impact of the treatment applied in this study.

Data Analysis and Findings

This study evaluates the effectiveness of Cooperative Project-Based Learning (CPjBL) integrated with Augmented Reality (AR) in enhancing student learning outcomes. Both qualitative and quantitative data were analyzed to assess the impact of this integrated approach. The quantitative data, gathered from pre- and post-assessment surveys, show significant improvements in students' academic performance, engagement, and the application of AR in learning. The findings highlight that students who participated in the CPjBL with AR integration exhibited a more substantial increase in knowledge retention, problem-solving skills, and interdisciplinary understanding compared to those in the control group who followed traditional learning methods.

A comparative analysis between the experimental group, which used CPjBL with AR integration, and the control group, which followed the conventional curriculum, demonstrated that the experimental group made more notable progress. Descriptive statistics were applied to the pre-test and post-test scores of both groups to analyze their academic progress. The results show a clear positive shift in the scores of the experimental group, suggesting that the integration of AR with CPjBL significantly enhances students' learning outcomes. The accompanying table summarizes the data, illustrating the effectiveness of the CPjBL-AR approach in improving student performance compared to the traditional learning method. A descriptive analysis was conducted on the pre-test and post-test scores of both groups, and the results of this analysis are summarized in the accompanying table.

RESULTS

Cooperative Project-Based Learning Model Approach

Cooperative Project-Based Learning (CPjBL) is an innovative pedagogical approach that combines teamwork and project-based learning. In this approach, learners are encouraged to work together in groups to design, develop, and complete projects related to their learning. This model not only facilitates a deeper understanding of the material but also enhances collaboration, communication, and problem-solving skills. Figure 1 illustrates the development of a guidebook for implementing the Cooperative Project Based Learning through Augmented Reality.

The Cooperative Project-Based Learning (CPjBL) model is an innovative pedagogical approach that encourages students to collaborate within teams to design, develop, and complete projects that are directly related to their learning. This model facilitates a deeper understanding of academic material by integrating theoretical knowledge with practical application through real-world tasks. It fosters the development of key skills such as collaboration, communication, and problem-solving, all of which are essential in both academic and professional settings. The model emphasizes teamwork, where students work together to achieve a common goal, enhancing their ability to solve complex problems and communicate effectively.

Figure 1. Cooperative Project-Based Learning Handbook

Furthermore, the CPjBL model creates an engaging and interactive learning environment, motivating students to take ownership of their learning process. By working on meaningful projects, students are encouraged to explore topics in depth, apply their knowledge creatively, and learn how to manage and execute tasks collectively. This approach not only boosts students' academic performance but also prepares them for the collaborative nature of modern workplaces. Ultimately, CPjBL supports the development of critical skills needed for the 21st century, ensuring that students are well-equipped for future challenges.

Table 2. Results of the Descriptive Analysis Results for Pre-Test and Post-Test

Group	Mean Pre-Test Score	Mean Post-Test Score
Experiment	54,25	79,38
Control	52,38	58,75

The table shows the descriptive analysis results for the Experiment and Control groups. The Experiment group has a mean pre-test score of 54,25, which increases significantly to a mean post-test score of 79,38. This suggests a notable improvement in the performance of the Experiment group after the intervention. On the other hand, the Control group has a mean pre-test score of 52,38, which increases to a mean post-test score of 58,75. Although the Control group also shows an improvement, the change is more modest compared to the Experiment group, indicating that the intervention had a stronger effect on the Experiment group. Furthermore, the normality test was applied to determine the suitability of the data to inferential tests regarding the degree to which it was normally distributed. The results of the Shapiro-wilk test were used to determine the distribution of the data.

Table 3. Results of the Shapiro-wilk Test

Group	Pre-Test (p-value)	Post-Test (p-value)
Experiment	0,288	0,603
Control	0,893	0,443

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The results show that the data in both groups, for both pre-test and post-test, were normally distributed (p > 0,05). Levene's Test was used to examine the homogeneity of variances between the experiment and control groups.

Table 4. Results of Levene's Test

Variable	F	Sig. (p-value)
Post-Test	0,046	0,831

The analysis indicates that the variances of the experiment group to the control group were similar (p > 0,05) suggesting that the groups could be compared parametrically. To establish the researching hypothesis the two condition Independent Sample T-Test was used to compare the post test results between the experimental and control groups.

Table 5. Results of T-Test

Test Type	Variable	t	Sig. (p-value)	Interpretation
Independent Sample T-Test	Pre-Test vs Post-Test	-7,822	0,000	The experimental group achieved a higher mean post-test score than the control group

The table presents the results of an Independent Sample T-Test comparing the pre-test and post-test scores between the Experiment and Control groups. The t-value is -7,822, and the p-value is 0,000, indicating a statistically significant difference between the two groups. With a p-value much smaller than the typical significance level of 0,05, we can reject the null hypothesis and conclude that there is a significant difference in the post-test scores. Specifically, the Experiment group achieved a higher mean post-test score compared to the Control group, suggesting that the intervention or treatment applied to the Experiment group was effective in improving their performance.

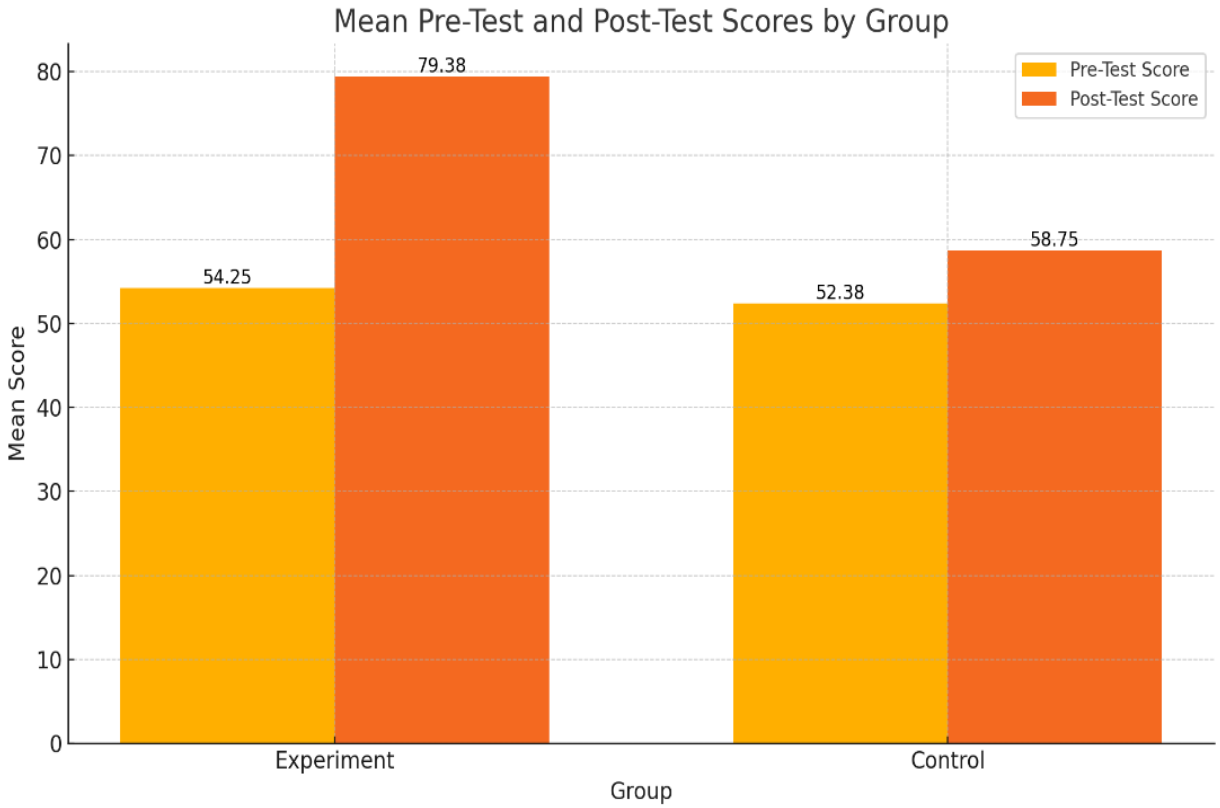

Figure 2. Pre-Test and Post-Test Scores Bar Chart

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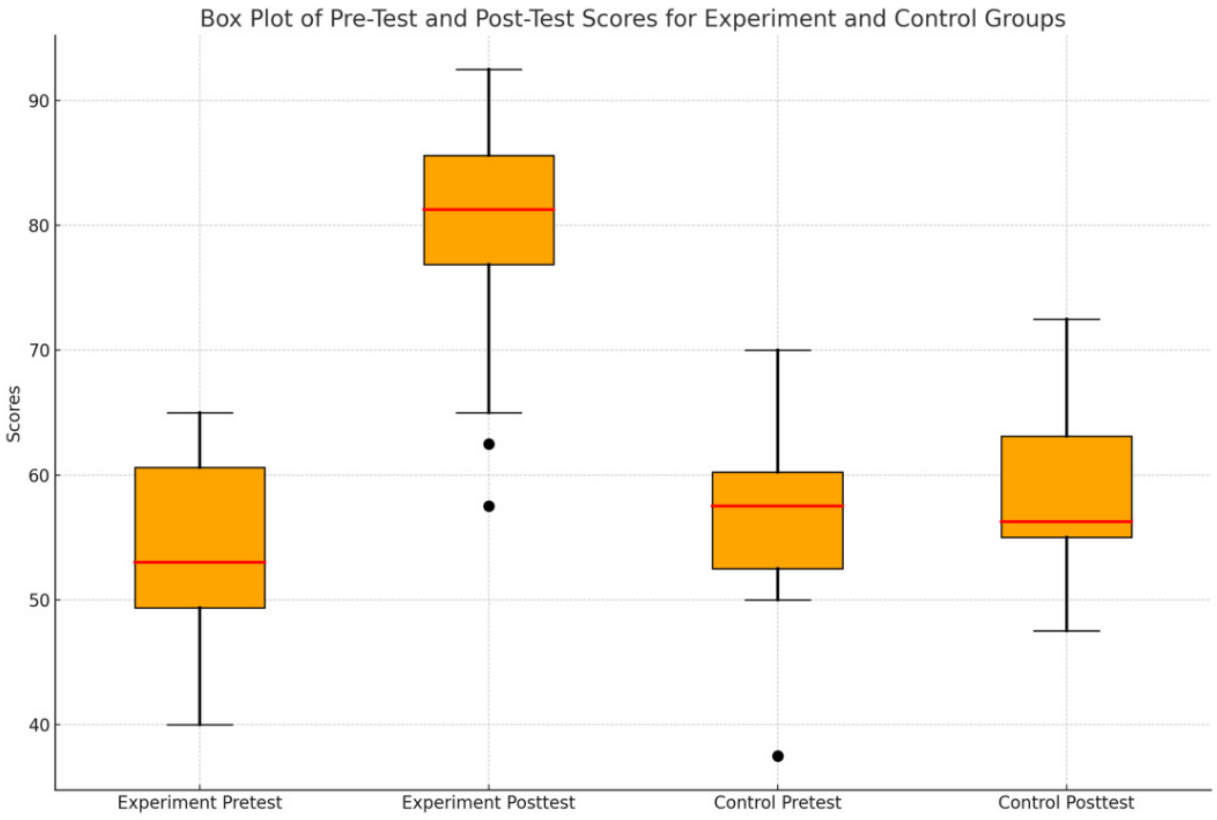

Figure 3. Box Plot Pre-Test and Post-Test Scores

The box plot displays the distribution of pre-test and post-test scores for both the Experiment and Control groups. For the Experiment group, there is a significant increase in the median score from the pre-test (around 55) to the post-test (around 80), with the post-test scores showing a wider spread, suggesting greater variability. The Control group also shows an increase in median score from the pre-test (around 52) to the post-test (around 55), but the change is much more modest. Both groups have some outliers, particularly in the post-test scores. The Experiment group exhibits more variation in scores, while the Control group has a tighter range, indicating more consistency in performance.

DISCUSSION

The results of this study show that combining Cooperative Project-Based Learning (CPjBL) with Augmented Reality (AR) is a good way to help students learn. Comparisons of pre-test and post-test results between the Experiment and Control groups indicate that the Experiment group had substantial enhancements in their scores, corroborating previous findings by Yuen[5], which demonstrated that AR significantly enhances student engagement and information retention. The enhancement in the Experiment group's performance indicates that AR's immersive and interactive characteristics augment the CPjBL framework, affording students a more profound comprehension of intricate subjects.

The findings of this study correspond with those of Richardson[6], who emphasized augmented reality's capacity to deliver a more immersive and concrete educational experience, especially in disciplines such as science and engineering. The implementation of augmented reality enabled pupils to conceptualize abstract ideas, rendering education more dynamic and accessible. This fits with earlier research, like the ones by Fadillah[8], which looked at how AR can help people understand abstract ideas by showing them in pictures that are related to complicated topics. Thus, I believe that the application of augmented reality in education can improve students' understanding of abstract concepts, making learning more interactive, dynamic, and accessible, especially in the fields of science and engineering.

Furthermore, the findings substantiate the efficacy of CPjBL in fostering teamwork, communication, and critical thinking. Students in the experimental group, engaged in AR-based projects, demonstrated enhanced cooperation and problem-solving abilities. This discovery supports the research conducted by Lubis[14], which shown that CPjBL improves cooperation skills, crucial for the workplace. Integrating AR into this framework enabled students to collaborate more efficiently and engage with their learning material in ways that traditional techniques could not do. Thus, I believe that the integration of augmented reality in the CPjBL approach enhances students' cooperation, communication, and critical thinking skills, and prepares them better for the

challenges of the working world with a more interactive and immersive learning experience.

The notable enhancement in the Experiment group's results can be ascribed to heightened motivation and involvement. Prasetya[17] demonstrate that AR technology can enhance learning by providing interactive experiences. In this study, the students in the experimental group engaged with AR-driven information, which likely enhanced their interest and active participation in their assignments. Thus, I believe that augmented reality (AR) technology increases student motivation and engagement by providing a more engaging interactive learning experience, which in turn improves their active participation in tasks.

AR's ability to create an interactive learning environment by letting students explore and change 3D models also helped them understand the material better. Muskhir[3] research from 2024 shows that augmented reality (AR) helps students understand difficult subjects by using advanced visualization techniques that are better than traditional ones. In this study, augmented reality enabled students to engage with learning materials, thereby connecting theoretical knowledge with practical application.

Nonetheless, despite the evident benefits of augmented reality in enhancing student engagement, the study also underscored several limitations in its execution. Stoltz[27] said that technical and logistical problems, such as the need for teacher training and easy access to devices, often make it hard to use AR effectively in education. We must resolve these obstacles to ensure the successful integration of AR in the classroom. In the future, researchers should look into ways to get around these problems, such as making AR solutions that are affordable and giving teachers professional development.

The integration of CPjBL and AR is not simply a trend but a purposeful methodology for equipping students to meet the requirements of the contemporary workforce. Huang[15] contend that the use of technology into collaborative learning settings facilitates the development of essential abilities required in the contemporary job market. This study supports that claim even more by showing that students who did AR-enhanced CPjBL had better problem-solving, critical thinking, and teamwork skills, all of which are skills that employers are increasingly looking for.

The research underscores the significance of hybrid learning environments, enabling students to leverage both conventional and technological resources. Previous research by Xu[10] supports the idea that combining augmented reality with project-based learning could make learning better all around. This study demonstrated that the implementation of augmented reality enabled students to interact with both virtual and physical elements of their projects, thereby enhancing the richness and diversity of their learning experience.

This study enhances the existing literature on technology's role in education, specifically with the incorporation of augmented reality in project-based learning. The results corroborate earlier research demonstrating the beneficial impact of augmented reality in education, especially on student engagement, comprehension of intricate topics, and skill acquisition. Arcade games were effectively included into CPjBL in this research. This further substantiates that such technology advancements can significantly enhance the learning process, rendering it more engaging, beneficial, and aligned with the requirements of the contemporary workforce.

CONCLUSION

The integration of Cooperative Project-Based Learning (CPjBL) with Augmented Reality (AR) has a significant positive impact on student learning outcomes, engagement, and the development of collaboration skills. The comparison between pre-test and post-test scores reveals that the experimental group, which employed CPjBL with AR, showed a substantial improvement in understanding AI concepts compared to the control group using traditional learning methods. These findings align with previous research that emphasizes the effectiveness of AR in enhancing engagement and interaction in educational settings. AR fosters an immersive learning environment that helps students better visualize and comprehend complex concepts. Moreover, the study highlights the development of critical and creative thinking skills, which are essential in the professional world. Overall, this study demonstrates that integrating CPjBL with AR enhances students' academic performance and prepares them with the skills needed for future career success. The integration of these two innovative approaches provides a more engaging and effective learning experience that meets the demands of modern education.

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