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The Effect of Project-Based Learning Integrated with the SAMR Model (Substitution, Augmentation, Modification, Redefinition) on Student Learning Outcomes

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To improve student engagement and learning results, the use of technology in biology education necessitates a suitable pedagogical strategy. Nonetheless, traditional teaching approaches still predominate in classrooms, with little use of technology. The purpose of this study was to examine how using Project-Based Learning (PjBL) in conjunction with the Substitution, Augmentation, Modification, and Redefinition (SAMR) model affected students' learning results regarding the respiratory system. This study employed a non-equivalent control group design and a quasi-experimental methodology. Purposive sampling was used to pick 68 11th graders from a South Tangerang public high school for the research sample. Pretests and posttests with multiple-choice items that had undergone validity and reliability testing were used to gather data. Normalized gain (N-Gain) computation, the Shapiro-Wilk normality test, Levene's homogeneity test, and the Mann-Whitney test were used to analyze the data. According to the findings, the experimental class's average posttest score was roughly 29 points higher than the control class's. The experimental class's N-Gain value was 84.50%, or ($_2g^2 = 0.845$) (high category). The Asymp. Sig. (2-tailed) value for the Mann-Whitney test was 0.000 (<0.05). These findings showed that using PjBL in conjunction with the SAMR model significantly improved students' learning outcomes.

Keywords: Project-Based Learning, SAMR, Learning Outcomes, Respiratory System, Biology

INTRODUCTION

The advancement of digital technology has significantly altered many facets of society, including education. Through access to a greater variety of learning resources, more diversified material presentations, and more dynamic learning interactions, the use of technology in the learning process presents chances to enhance the quality of the learning experiences. Technology integration promotes the development of a more creative and efficient learning process (Dheni & Damas, 2020). The development of 21st-century abilities, including critical thinking, creativity, communication, and teamwork, is greatly aided by the use of educational technology (Juanda et al., 2021). Teachers need to possess the competence to integrate technology into the learning process to ensure that learning activities become more relevant to scientific and technological advancements (Sinaga & Firmansyah, 2024) .

Although the use of technology has great potential to improve the quality of learning, its implementation in school settings still faces several challenges. The learning process in many schools is still dominated by conventional, teacher-centered approaches, meaning that student engagement in learning remains suboptimal (Suprijono, 2010). The use of technology in learning is often limited to basic functions, such as presenting materials through digital media, without being accompanied by more innovative changes in learning strategies (Dheni & Damas, 2020). The success of technology integration in learning depends not only by the availability of technological devices, but also by the pedagogical approaches used by teachers in designing and implementing learning activities (Juanda et al., 2021).

The SAMR model (Substitution, Augmentation, Modification, and Redefinition), developed by Ruben Puentedura, is one of the most popular conceptual frameworks for assessing the degree of technology integration in education. According to Hamilton, E. R., Rosenberg, J. M., & Akcaoglu (2016), the SAMR model is a framework that explains the phases of technology use in education, from using technology as a replacement for conventional learning tools to the stage of learning transformation that permits the development of new learning activities. In order to ensure that technology is not only utilized as a tool but also as a way to improve the caliber of students' learning activities, the SAMR model can assist educators in creating technology-based learning more methodically (Aprinaldi et al., 2018). Teachers can use the SAMR model as a guide to create more creative technology-integrated teaching methods (Niswatin & Zainiyati, 2021).

The SAMR model comprises four levels of technology integration that describe the resulting level of learning transformation. The substitution stage describes the use of technology as a replacement for traditional learning tools with no significant changes in learning activities (Hamilton, E. R., Rosenberg, J. M., & Akcaoglu, 2016) . In the augmentation stage, technology is used to enhance learning functions, thereby making learning activities more effective (Muktiarni, 2021). The modification stage allows for significant changes in instructional design through the use of technology (Bauder, D. K., Cooper, K. M., & Simmons, 2020). Meanwhile, the redefinition stage enables the creation of new learning activities that would otherwise be difficult to implement without technological support (Aprinaldi et al., 2018) .

In addition to technology integration, learning models that emphasize active student engagement are also key factors in enhancing learning quality. One model widely used in modern education is Project-Based Learning. It is a learning model that emphasizes learning through the completion of projects related to real-world problems. Through this approach, students are encouraged to actively engage in the processes of exploration, investigation, and collaboration, which fosters a deeper conceptual understanding (Kokotsaki, D., Menzies, V., & Wiggins, 2016). Project-Based Learning can enhance students’ critical thinking skills and problem-solving abilities (Elisabet et al., 2019). Implementing can increase students’ learning motivation, as it provides opportunities for them to participate actively in learning activities (Zainuddin et al., 2023). Learning biology often involves abstract concepts, which requires a more innovative learning approach to ensure students can understand them optimally. The use of technology in biology education can help students understand concepts through visualization and more interactive digital media (Cartono, 2022). Project-Based Learning allows students to explore concepts more deeply through scientific investigation activities (Kokotsaki, D., Menzies, V., & Wiggins, 2016).

Various studies have shown that Project-Based Learning (PjBL) contributes positively to improve learning outcomes through collaborative and contextual learning activities, rendering learning more meaningful by connecting concepts to students' experiences (Hentje H. Umbunan et al., 2025) . Furthermore, prior research indicates that integrating technology into learning through the SAMR model can enhance learning quality, particularly at the augmentation, modification, and redefinition stages, which lead to improved learning performance, conceptual understanding, and students' critical thinking skills (Nair & Chuan, 2021). Consistent with these findings, Hou (2024) found that the application of SAMR in Project-Based Learning also has the potential to improve critical thinking and collaboration skills, although it is still limited to the context of Mandarin language learning within the International Baccalaureate (IB) curriculum.

Although numerous studies have examined the effectiveness of PjBL and the SAMR model separately or within specific contexts, empirical evidence specifically integrating these two approaches into a single systematic pedagogical framework remains limited. More importantly, previous literature did not explore the application of PjBL integration with the SAMR model in biology teaching, especially concerning the Human Respiratory System curriculum in the secondary school level. Therefore, there is a need for a learning strategy that will focus on the process of constructing knowledge using project activities and transforming learning through technology.

This research gap is significant because the integration of PjBL and SAMR model has the potential to create synergy between strengthening experience-based pedagogy and optimizing technology use to enhance students' learning outcomes. This study aims to address this gap by examining the impact of integrating Project-Based Learning with the SAMR model (Substitution, Augmentation, Modification, and Redefinition) on students' learning outcomes in the Human Respiratory System unit within biology education.

METHOD

Research Design

This study used a quasi-experimental approach to conduct a quantitative investigation. Two sample groups were used in the study: a control group that used PjBL without SAMR integration as a comparison, and an experimental group that used the Project-Based Learning (PjBL) model integrated with SAMR (Sugiyono, 2016). The independent variable (X) and the dependent variable (Y) were the two variables used in this investigation. Students' learning outcomes were the dependent variable (Y), while the application of the Project-Based Learning model combined with SAMR was the independent variable (X).

Setting and Participants

The sampling technique adopted was purposive sampling, whereby the sample was selected based on certain criteria that were necessary for the purpose of the study in the Private School in South Tangerang, Indonesia. Criteria considered for selecting the sample include Grade 11 students studying the Human Respiratory System, and presence of facilities and infrastructure necessary for implementing the SAMR model.

Instruments

The instrument used in this study was a test designed to measure students' level of understanding of the learning material. This test consisted of a set of questions or exercises used to assess students' knowledge and skills.

Table 1. Pre-Test and Post-Test Instrument Outline

No	Main Topic	Indicator	Taxonomy						Number Questions
			C1	C2	C3	C4	C5	C6	
1	Basic concepts of respiration	Identifying the basic concepts of respiration		1					1
2	Structure and function of the human respiratory system	Identifying human respiratory organs from pictures/models and explaining their functions		3, 5, 6, 7, 8	2,4				7
3	Respiratory mechanisms	Comparing chest and abdominal breathing mechanisms		9. 14	13	10: 15			5
4	Respiratory air volume	Identifying the different types of respiratory air volume			16				1
5	Factors affecting respiratory rate	Analyzing the effect of activity on respiratory rate				11, 12, 17, 18			4

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The test instrument should have been pretested on respondents not within the sample population. The outcome of the testing was thereafter analyzed to assess the validity, reliability, difficulty and discriminative nature of the test instrument to determine its appropriateness for use with the aid of SPSS. The validated test instrument contained 18 items with a reliability of 0.792. This was an indication that the test instrument was highly reliable and thus appropriate for use in collecting data in the research.

Data Collection

In this case, the data collection method used test procedure which involved pretest and posttest. Pretest was done before the instruction in order to know their initial level of ability, and the posttest was performed after the instructions were taught to measure the results. The test procedure had eighteen questions which were given to both the experimental and control groups. These questions were created in accordance to the revised bloom’s taxonomy and matched the biology syllabus of Human Respiratory System.

Data Analysis

The IBM SPSS Statistics program was used to process the data. The measurement of learning gains, which involved comparing the students' performance before and after the instruction process, was used to produce the normalized N-Gain scores (Sukarelawa, M. I.; Indratno, T. K.; Ayu, 2024). The degree of gains realized during the learning process was measured using the N-Gain scores from both the experimental and control groups. In accordance with R. Hake's (1998) classification of N-Gain scores, the scores were divided into three categories: high ($\geq g^2 > 0.7$), medium ($0.3 \leq \langle \leq 0.7$), and low (; < 0.3). The classification was used to assess how well the chosen learning strategy worked.

It was evident that the pretest and posttest data for the experimental and control groups were not regularly distributed after the normality test. Consequently, the Mann-Whitney test—a non-parametric test—was employed in place of the t-test in the hypothesis test. This test was designed to determine whether learning outcomes for two independent samples alter when either or both samples are not regularly distributed.

RESULTS AND DISCUSSION

Research results were provided to fulfill the research objectives and hypotheses on how the application of the Project-Based Learning model with the use of SAMR would affect the learning results of students on the Human Respiratory System. Results were processed through IBM SPSS Statistics Version 26 considering the pre-test and post-test results, N-Gain computation, prerequisites of data analysis (normality and homogeneity test), and inter-group differences test (Mann-Whitney). The results of the N-Gain of the experimental and control class are shown on Table 2.

Table 2. N-Gain Results for the Experimental and Control Classes

Statistics	N-Gain Score for the Experimental Class	N-Gain Score for the Control Class
Sample Size	35	33
Mean	84.50	55.36
Minimum Value	0	0
Maximum Value	100	100
Standard Deviation	28.298	34.330
Category	High	Medium

According to Table 2, the experimental class included 35 students while the control class had 33 students. The N-Gain calculations show that the average N-Gain for the experimental class was 84.50% ($\langle g \rangle = 0.845$) which belongs to the high level ($\langle g \rangle > 0.7$). In its turn, the control class demonstrated the average N-Gain score of 55.36% ($\langle g \rangle = 0.554$) belonging to the medium category ($0.3 \leq \langle g \rangle \leq 0.7$) (R. Hake, 1998). It means that the learners in the experimental group gained more knowledge in comparison with the control class. There were also differences in the value of standard deviations where the value for the control class was higher (34.330) than the one for the experimental class (28.298).

This finding indicates that there was more heterogeneity of improvement among the control group learners than those in the experimental group. This means that the lower variance of improvement in the experimental group has made it clear that not only did the use of the SAMR model in PjBL increase the learning achievement of the learners, but it also brought about uniformity in the distribution of learning achievements among the learners. In conclusion, the N-Gain findings further confirm that technology integration using the SAMR model in PjBL has a more significant impact on increasing the learning achievements of students than PjBL without technology integration.

Data Analysis Prerequisite Tests

The results of the normality test and homogeneity test can be seen in Table 3.

Table 3. Results of the Normality Test and Homogeneity Test

Statistical Data	Experimental Class		Control Class	
	Pre-test	Posttest	Pre-test	Posttest
Sig.	0.000	0.000	0.033	0.000
Conclusion	Not normally distributed	Not normally distributed	Not normally distributed	Not normally distributed
Levene's Statistic	1.533 (Sig. 0.220) Homogeneous			

Based on Table 3, all significance values (Sig.) in the pretest and posttest data for both the experimental and control classes were below 0.05, namely 0.000; 0.000; 0.033; and 0.000. Referring to the decision criteria for the normality test, if the Sig. value is < 0.05, the data were deemed not normally distributed. It can be concluded that the pretest and posttest data in both classes did not satisfy the normality assumption.

This indicated that the distribution of student learning outcomes in the Project-Based Learning (PjBL) integrated with the SAMR model in the experimental class, as well as in the PjBL without SAMR integration in the control class, was not normally distributed. This might occur due to students' varying initial abilities, differences in their grasp of the material, and variations in their responses to the implementation of Project-Based Learning combined with technology through the SAMR model. This non-normality of the data also indicated that some students experienced substantial high improvement in learning outcomes, some showed moderate improvement, and others showed no improvement. This variation reflected the influence of the implementation of SAMR-integrated PjBL on student learning outcomes, where not all students responded to the treatment equally.

Meanwhile, the Levene's test yielded a significance value of 0.220. Since this value was greater than 0.05 (0.220 > 0.05), H_0 wass accepted. Thus, it can be concluded that the variances in learning outcomes between the experimental and control classes was homogeneous.

Hypothesis Testing

After conducting a normality test on the pretest and posttest data for the experimental and control classes, the results showed that the data were not normally distributed. Therefore, the hypothesis test was conducted using a nonparametric test as an alternative to the t-test, specifically the Mann–Whitney test (see Table 4). The Mann–Whitney test was used to determine whether there was a difference in learning outcomes between two independent sample groups when one or both groups were not normally distributed.

Table 4. Results of the Mann-Whitney Hypothesis Test

Statistics	Results
Mann-Whitney	203.000
Wilcoxon W	764,000
Z	-4.917
Asymp. Sig. (2-tailed)	0.000
Conclusion	H_0 Rejected / H_1 Accepted

Based on the results of the Mann–Whitney test, the Asymp. Sig. (2-tailed) value was 0.000. Since this value was less than 0.05 (0.000 < 0.05), H_1 was accepted and H_0 was rejected. This indicated that there was a significant difference in learning outcomes between the experimental and control classes. The Z-value of −4.917 confirmed that the difference in learning outcomes between the two groups was statistically significant. This finding demonstrated that the implementation of Project-Based Learning (PjBL) integrated with the SAMR model had a significant impact on improving students' learning outcomes in the Human Respiratory System curriculum (see Table 6.).

The improvement in learning outcomes in the experimental class was influenced by the integration of each stage of Project-Based Learning with the SAMR stages applied during the learning process. This integration ensured that learning focused not only on project completion but also on transforming how students understood concepts through digital technology. According to Crompton & Burke (2020), the SAMR model was hierarchical, where technology was categorized into Substitution, Augmentation, Modification, and Redefinition, so that each level had a different impact on the quality of learning.

The implementation of the SAMR model contributed to the development of students' critical thinking skills and enhanced conceptual understanding through technology-based learning (Nair & Chuan, 2021). SAMR-based learning enriched the learning experience through the optimal use of technology and provided students with access to various digital learning resources (Alfiana et al., 2022).

In the early stages of Project-Based Learning, the use of virtual reality (VR) at the Modification level provided an immersive learning experience of the concept of the Human Respiratory System. Students not only received verbal explanations but also observed the structure of organs and respiratory mechanisms in three dimensions. This transformed learning from static representations into a more concrete visual experience (Wang et al., 2024), thereby strengthening students' understanding of abstract concepts (Fitrianto & Saif, 2024) and enhancing the quality of the digital learning experience (Tkachov et al., 2023).

Table 6. SAMR Model Levels and Their Impact on the Learning Process

SAMR Levels	Implementation in the Study	Impact on Learning
Substitution	Students used Google Docs to replace manual note-taking when gathering information about the Human Respiratory System. Material previously written in notebooks was transferred to digital media.	The learning process still served the same as in conventional learning, but students began to get used to utilizing digital technology in their learning activities.
Augmentation	Students utilized digital features in Google Docs, such as inserting images of the respiratory system, accessing online learning resources, and collaborating on document editing.	Technology enhanced learning by enabling students to collaborate more effectively, receive feedback more quickly, and enrich their materials with visuals and additional information sources.
Modification	Students studied the structure of organs and the mechanisms of the Human Respiratory System using virtual reality (VR). Through VR, students can observe respiratory organs in three dimensions and interactively.	There had been a significant shift in instructional design. Conceptual understanding became more concrete because students did not merely view images in a textbook but gained a more realistic and interactive visual experience, thereby enhancing conceptual comprehension.
Redefinition	Students created educational videos about the Human Respiratory System related to the dangers of smoking, air pollution, and other respiratory disorders, then published these videos to make them more widely accessible and receive broader feedback.	Technology enabled the creation of new learning activities that were previously difficult to implement in conventional learning. Students did not merely complete assignments from the teacher but produced digital works with an audience, thereby increasing their sense of responsibility and the quality of their understanding of the material.

During the project planning and organization phase, the use of Google Docs at the Augmentation level enhanced collaboration and group work efficiency. Students can draft educational videos simultaneously, add references, and provide real-time feedback (Nair & Chuan, 2021). The distribution of schedules and tasks also became more systematic, thereby improving project management efficiency (Kihoza et al., 2016).

During the project monitoring phase, students reached the Modification level by creating educational videos linking the respiratory system to health issues such as smoking and air pollution. At this stage, technology enabled significant changes in instructional design (Geer et al., 2017). Students did not merely summarized the material but transformed it into complex audiovisual media that required analysis, synthesis, and evaluation of concepts (Beluan et al., 2018). This combination of technology and learning strategies reinforces the learning process (Lobo & Jiménez, 2017). During the evaluation stage, videos were collected through Google Drive as a form of Substitution that enhanced assessment efficiency (Arnold, 2019). Although in the Substitution stage technology still served as a replacement tool, this stage remained crucial as it enabled teachers to evaluate students' understanding more comprehensively through the collected digital products (Nair & Chuan, 2021). Next, in the Redefinition stage, students published videos to digital platforms such as YouTube or other social media, which then created authentic learning with a real audience. This enhanced students' sense of responsibility, motivation, and quality of conceptual understanding, as their work had an impact beyond the classroom.

The use of the Project-Based Learning model was one of the effective learning approaches for developing creative thinking skills and problem-solving abilities (Samodra et al., 2026), while also fostering the higher-order thinking skills required for 21st-century learning (Lubna et al., 2024). PjBL learning encouraged students to construct new knowledge through discussion, reflection, and exploration of relevant information, thereby fostering a deeper understanding (Karvonen, 2025). In practice, the implementation of Project-Based Learning still faced challenges, such as selecting appropriate projects, time and resource constraints, and coordinating project activities (Alarfaj et al., 2024).

According to Hilton, (2016) compared to the TPACK model, SAMR placed greater emphasis on the level of learning transformation achieved through technology use. TPACK focused on the integration of technological, pedagogical, and content knowledge that teachers must possess. Consequently, its success heavily depended on teachers' competence in integrating these three domains effectively. Muslimin et al., (2023) found that high TPACK-SAMR-based digital literacy competencies encouraged educators to integrate technology at the Modification and Redefinition levels. This was important because these two levels enabled learning transformations that were more collaborative, creative, and higher-order thinking-oriented learning transformations. (Demirkol Orak & Alagözlü, 2025)

This study aligned with Mohd & Mohamad (2025), who stated that SAMR was generally at the enhancement level (Substitution–Augmentation), while the greatest impact occured at the transformation level (Modification–Redefinition). Furthermore, the results of this study supported the research by Adulyasas (2021) and Umarova et al. (2025) which indicated that SAMR integration enhanced student performance and engagement. However, unlike and Geer et al. (2017), who stated that the significant impact of technology primarily emerged at the Redefinition stage, this study showed that improvements in learning outcomes began to appear as early as the Augmentation stage and increased gradually up to the Redefinition stage. This indicated that the effectiveness of SAMR was cumulative, not linear.

The most significant difference between the experimental and control classes was observed in the form of the final learning product. In the experimental class, students produced digital educational videos that not only summarized the material but also required the integration of various higher-order cognitive skills. In the process, students had to deeply understand the concepts of the respiratory system, construct a scientific narrative, select appropriate visualizations, process information into audiovisual media, and ensure the accuracy of biological concepts. This product was dynamic and communicative, thereby encouraging students to re-represent concepts in more complex forms (Beluan et al., 2018). Additionally, publishing the video on a digital platform created a real audience, thereby enhancing students' academic responsibility and intrinsic motivation (Shouman & Momdjian, 2019).

Meanwhile, in the control class, the learning product took the form of a manual poster presented in front of the class. Although this activity still involved creativity and group collaboration (Zainuddin et al., 2023) , the characteristics of the product were limited to simple text and image representations. The concept elaboration process tended to be more superficial because students merely summarized the material without having to transform it into complex multimedia forms. Consequently, the level of cognitive processing required was lower compared to the production of educational videos in the experimental class. This difference in product characteristics indicated that the integration of SAMR in the experimental class not only changed the learning medium but also altered the depth of the cognitive processes involved in learning.

The Z-score in the Mann–Whitney test (-4.917) indicated a strong treatment effect, suggesting that the integration of PjBL and SAMR significantly influenced students' conceptual understanding. This integration facilitated collaboration and the use of digital technology in knowledge construction (Tunjera & Chigona, 2020). This aligned with the characteristics of PjBL, which emphasized active learning (Zulfiani et al., 2025) as well as the SAMR stages, which made learning more meaningful (Umarova et al., 2025), thereby leading to improved learning outcomes. The improvement in learning outcomes in this study was also supported by research Khotimah et al., (2026) who found that the integration of digital technology in Project-Based Learning is effective in enhancing students' creativity in terms of originality, fluency, flexibility, and elaboration.

SAMR-integrated PjBL in the experimental class required a deeper conceptual understanding, attention to detail in the material, and the ability to coherently explain biological concepts, resulting in higher learning outcomes compared to PjBL without SAMR integration in the control class. PjBL integrated with the SAMR model was not merely a variation of a learning model but an effective strategy for improving the quality of learning. The appropriate integration of technology can make learning more interactive, meaningful, and aligned with students' learning needs in the digital age.

CONCLUSION

This study aimed to analyze the effect of implementing Project-Based Learning integrated with the SAMR model on students' learning outcomes in the subject of the human respiratory system. Based on the results obtained, the combination of PjBL with SAMR was found to improve the learning outcomes of the learners considerably better than PjBL alone. Indeed, the technology is used not just as an instrument but changes the approach that learners apply in their comprehension of the subject matter through visualizing it in the virtual reality, collaborating via the digital means, and producing educational videos. In addition, technology use allows for engaging in the content more thoroughly and systematically. The disparity in the results achieved by the experimental and control group can be accounted for by the disparity in the cognitive loads applied to the learners in the course of different projects. This study shows that PjBL and the SAMR framework combined to create a successful learning approach that increases the quality of learning outcomes in the field of biology. This kind of research can also be carried out on other topics related to biology, as well as on different levels of education, where the effect of the integration of this pedagogical approach on developing 21st-century skills may be studied further.

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