

# Investigating the Correlation Between STEAM-Based PjBL Supported by Augmented Reality and the Enhancement of 21st-Century Skills in Senior High School Students

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## Key Words:

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Life and career skills

## Abstract:

This research investigates the correlation between STEAM-based Project-Based Learning (PJBL) enhanced by Augmented Reality and the development of 21st-century skills among students. The study employs a quantitative descriptive approach, utilizing a one-shot case study design. The sample was obtained through a cluster random sampling method. Data were analyzed using percentage analysis techniques and Kendall's tau-b test at a 5% significance level. The results from Kendall's tau-b test demonstrated a significant correlation between STEAM-based PJBL supported by Augmented Reality and enhancing students' 21st-century skills, with a correlation coefficient of 0.798 and a significance level of 0.000. Furthermore, observational data indicated that the average achievement of 21st-century skills was 77%, which is considered good. The study concludes that STEAM-based PJBL supported by Augmented Reality is significantly linked to improving students' 21st-century skills and effectively fosters these skills. These findings imply that integrating STEAM-based PJBL with Augmented Reality technology such as Assemblr Edu can be an effective strategy for educators to enhance 21st-century skills in secondary education settings.

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### Introduction

The younger generation faces significant challenges in adapting and competing quickly amid changes in various aspects of life, especially in the era of globalization and the fourth industrial revolution. To deal with the complexity and dynamics of the modern world, education needs to develop 21st-century skills, including learning and innovation skills, information, communications, technology skills, and life and career skills ([Öksüzoglu & Tünkler, 2022](#)).

Learning difficulties in students can be influenced by several factors, such as their aspirations, implemented learning patterns, level of intelligence, self-confidence, ability to process and remember information, concentration, and attitudes ([Yusuf, 2022](#)). The role of educators, learning facilities, evaluation policies, social conditions in the school environment, and curriculum are external elements that contribute to the education process. The quality of education has decreased because the number of implementations of creative teaching methods that involve active student participation is minimal ([Syofiani et al., 2024](#)). Failure to understand the underlying learning activities of a particular topic is often attributed to low student achievement, where the use of less effective methods, such as traditional learning, is still widely implemented in schools with the intention that students 21st-century skills can be developed ([Vyas & Vidyavihar, 2023](#)).

An uncertain future must prepare students to have 21st-century skills, including learning and innovation, information, communications, technology, and increasingly important life and career skills ([Thornhill-Miller et al., 2023](#)). To facilitate this need, a practical learning approach is needed. Project-based learning (PjBL) is an interesting approach because, through real projects linked to everyday life, students can be actively involved in learning activities ([Nilada et al., 2024](#)).

The STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach enriches PjBL by integrating diverse disciplines into one learning project ([Ichsan et al., 2024](#)). STEAM bridges theory and practice, giving students hands-on experience. Adding arts in STEAM adds a crucial dimension of creativity to the learning activity ([Nieto-Isidro & Martínez-Abad, 2024](#)). This approach aims to develop students' problem-solving, creativity, and collaboration skills through interdisciplinary projects ([Mariana & Kristanto, 2023](#)).

Augmented Reality (AR) technology, such as Assembler Edu, offers significant innovation in the context of STEAM-based learning. AR can create a more interactive and immersive learning experience by allowing students to interact with 3D models and complex visualizations. In biology learning, especially in the material of cells in animals and plants, AR technology can simplify abstract concepts and make them easier to understand ([Raja & Subramanian, 2024](#)). 3D visualization of biological structures can help students understand the relationship between parts of organs and systems in a more real and engaging context. Augmented Reality (AR) technology also has the potential to increase student engagement in learning activities, making learning more interesting and meaningful ([Afnan & Puspitawati, 2024](#)). Lifelong learning is essential for teachers to stay current and effective, especially in the 21st century with rapid technological changes worldwide. Technological advancements are reshaping how students learn, as evidenced by the rise of online PDFs, virtual

classrooms, smart boards, and digital tools replacing traditional classrooms and materials (Mopara & Sanrattana, 2023).

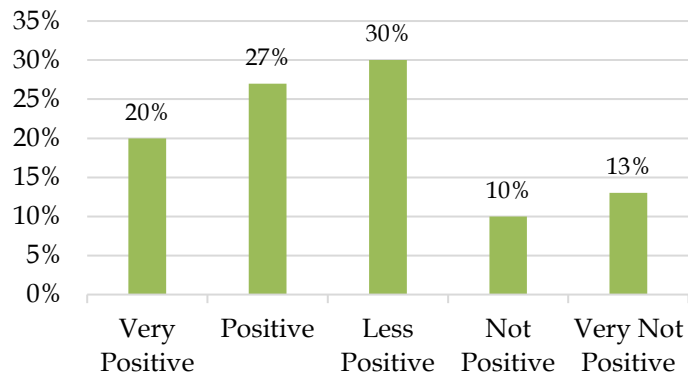
According to the literature, the significance of this research lies in addressing the disparity between traditional teaching methodologies and the necessity for more engaging and meaningful learning experiences that align with the demands of the 21st century. STEAM-PjBL promotes teamwork and communication skills, which are essential for success in both academic and professional settings (Ferawati Artauli Hasibuan & Tetti Hasibuan, 2023). Studies indicate that students exhibit improved fluency, flexibility, originality, and elaboration in their creative outputs when engaged in STEAM-PjBL activities (Papilaya & Salhuteru, 2024). The topic of cells in biology is inherently abstract and often poses visualization challenges for students. Many students struggle to comprehend biological cell structures due to their abstract and microscopic characteristics. Consequently, implementing a STEAM-based Project-Based Learning (PjBL) approach, supported by Augmented Reality, offers an interdisciplinary and visual strategy that can enhance student comprehension. This integration not only fosters deeper conceptual learning but also aligns with the requirements of 21st-century skills development. Applying STEAM-based PjBL, facilitated by Assemblr Edu, is anticipated to bridge this gap by enabling interdisciplinary and visual learning that simultaneously enhances students' conceptual understanding and skills (Rosidin et al., 2024). Furthermore, although the advantages of STEAM-PjBL and Augmented Reality (AR) have been explored, studies integrating both, particularly with Assemblr Edu in high school biology classrooms, remain limited, especially within the Indonesian context. Therefore, this study is crucial in providing empirical evidence on the relationship between STEAM-based PjBL, assisted by Augmented Reality, and the enhancement of students' 21st-century skills.

## Research Method

This research implements descriptive quantitative methods with the intention that a detailed description of a phenomenon can be provided. Data obtained from descriptive research is generally analyzed using descriptive techniques such as descriptive statistics, tables, and graphs. The research design implemented in this study is a one-shot design, which only measures variables at one specific time, often used in correlational research. All grade XI students at SMA Budi Luhur Samarinda were used as the population in this study, and the researcher implemented the cluster random sampling technique for sampling so that 30 students from class XI-1 were obtained as the sample. The instruments used refer to the Battelle for Kids P21 Framework for 21st Century Skills (Battele for Kids, 2019), which includes student 21st-century skills observation sheet, student response questionnaire to STEAM-based learning with PjBL method using Augmented Reality through the Assemblr Edu platform, and student 21st-century skills questionnaire, all of which have gone through validity and reliability tests before being implemented on the sample. To analyze the data and see the relationship between the two variables, the Kendalls Tau-b technique was used, considering that the data analyzed were ordinal scales.

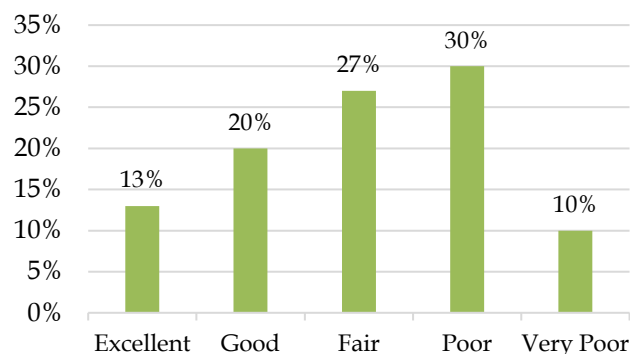
## Results and Discussion

The data obtained from the questionnaire were systematically organized into tables, and the responses from students were analyzed based on the value scores assigned to each answer. To assess the extent of the relationship between STEAM-based learning, utilizing a Project-Based Learning (PjBL) approach combined with Augmented Reality facilitated by Assemblr Edu platform, and the development of students' 21st-century skills, the author employed a questionnaire distributed to a randomly selected sample of 30 students.



**Figure 1. Graph depicting the percentage outcomes of the response questionnaire completed by students of Class XI-1**

Figure 1 illustrates that six learners, constituting 20%, expressed a very positive or highly satisfied and enthusiastic attitude towards the learning activities. Conversely, eight learners, accounting for 27%, were categorized as positive, indicating that while they provided favorable feedback, there remains room for improvement in several areas. Additionally, nine learners, or 30%, were classified as moderately positive, suggesting moderate satisfaction with the learning experience. In contrast, three learners, representing 10%, were categorized as not positive, as they did not respond well to the learning and felt inadequately supported. Lastly, four learners, comprising 13%, were classified in the very non-positive category, as they were dissatisfied with the teaching and perceived the implemented method as ineffective.



**Figure 2. Graph Depicting the Percentage Outcomes of the 21st Century Skills Questionnaire Completed by Students in Class XI-1**

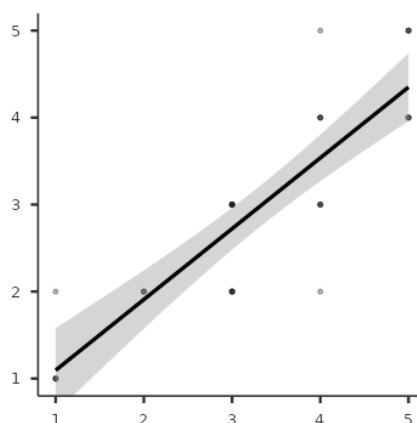
Figure 2 provides a comprehensive overview of learners' proficiency levels in 21st-century skills. The data reveals that 13% of the cohort, equivalent to four learners,

demonstrate exceptional proficiency in these skills. Additionally, 20% of the learners, or six individuals, are assessed as possessing a good level of proficiency, though there remains potential for improvement in specific areas. Furthermore, 27% of the learners, corresponding to eight individuals, have sufficient proficiency, indicating an adequate but not optimal understanding of the skills. In contrast, 30% of the learners, or nine individuals, are identified as lacking, facing considerable challenges in mastering these skills. Finally, 10% of the learners, or three individuals, are considered deficient, as they have not yet acquired the requisite 21st-century skills and require more intensive support.

**Table 1. Kendall's tau-b test of STEAM-based PJBL learning assisted by Augmented Reality with Students 21st Century Skills**

Correlations			X	Y
Kendall's tau-b	X	Correlation Coefficient	1.000	.798
		Sig. (2-tailed)	.	.000
		N	30	30
	Y	Correlation Coefficient	.798	1.000
		Sig. (2-tailed)	.000	.
		N	30	30

Table 1 presents the results of Kendall's tau-b test examining the relationship between the STEAM-based Project-Based Learning (PJBL) approach combined with Augmented Reality facilitated by the Assemblr Edu platform and students' 21st-century skills. The analysis reveals a correlation coefficient of 0.798 with a significance level (Sig. 2-tailed) of 0.000, below the 0.05 threshold, indicating a strong and significant positive relationship between the two variables. According to Cohen's classification, this is considered a robust correlation (Cohen, 2013), confirming that as the quality of the Augmented Reality-assisted STEAM-PJBL learning experience increases, so does the development of students' 21st-century skills. Consequently, there is a close and significant relationship between STEAM-based PJBL facilitated by Augmented Reality and students' 21st-century skills, whereby an increase in one variable corresponds with an increase in the other.



**Figure 3. Plot Correlation Matrix Kendall's tau-b test**

Figure 3 illustrates the visual analysis of the relationship between variable X (Augmented Reality-assisted STEAM-based PJBL learning) and variable Y (students' 21st-century skills). The plot features a regression line that ascends from the lower left to the upper right, signifying a positive correlation between these variables. The shaded region around the regression line indicates the confidence interval within which most data points are located, suggesting that the observed relationship is consistently maintained. The upward trend in the plot indicates a consistently positive relationship, further supported by the narrow confidence interval suggesting stable data distribution.

**Tabel 2. Description of Observation Results of Student Activities During Learning Activities**

No	Indicator	Meetings			Average	%
		I	II	III		
1	Critical Thinking and Problem Solving	23	25	30	26.000	86.67%
2	Creativity and Innovation	17	22	27	22.000	73.33%
3	Collaboration and Communication	22	23	27	24.000	80.00%
4	Information Literacy	23	21	24	22.667	75.56%
5	Media Literacy	21	24	29	24.667	82.22%
6	ICT Literacy	21	20	29	23.333	77.78%
7	Flexibility and Adaptability	28	28	29	28.333	94.44%
8	Self-Management	18	21	26	21.667	72.22%
9	Social and Cultural Interaction	29	28	25	27.333	91.11%
10	Productivity and Accountability	28	20	28	25.333	84.44%
11	Leadership and Responsibility	17	20	22	19.667	65.56%
Total		247	252	296	256	883.33
Average		77				

Table 2 presents the observations of students' 21st-century skills, indicating an increase in the average achievement across all indicators from 247 points in the first session to 296 points in the third session. This suggests that the implemented pedagogical approach has effectively enhanced students' critical thinking, creativity, collaboration, and literacy skills. The overall average achievement reached 77%, which is categorized as good. The most notable improvements occurred in Critical Thinking and Problem Solving" (86.67%), "Flexibility and Adaptability" (94.44%), and "Social and Cultural Interaction" (91.11%). These are core components of 21st-century competencies as described by the Partnership for 21st Century Skills (Battele for Kids, 2019). This finding demonstrates that students are becoming increasingly proficient in analyzing problems and devising solutions as the learning activities progress.

This research aims to understand more deeply the contribution of STEAM-PJBL supported by Augmented Reality using the Assemblr Edu platform in improving



students' 21st-century skills. Students' experiences were classified into five categories based on their responses to the learning methods used. The categories include Not Positive, Less Positive, Moderately Positive, Positive, and Very Positive. Each category has a different influence on students' 21st-century skills development. The results of this study are in line with previous research, which found that project-based learning and Augmented Reality (AR) significantly improved students' critical thinking, collaboration, communication, and creativity (Hanham & Hendry, 2024; Tang et al., 2022). Several previous studies have examined the effectiveness of the STEAM-PJBL approach in improving 21st-century skills. Previous research shows that students' critical thinking and problem-solving skills can be improved by implementing project-based learning in the context of STEAM (Pasca Emilidha & Waluya, 2024). Similar findings also state that STEAM-based PJBL can improve students' collaborative skills through more active project-completion interaction (Rahma, 2024). In addition, studies have shown that AR technology in education increases student engagement and helps students understand abstract concepts more effectively (Rosidin et al., 2024). This supports the study's findings that using Assemblr Edu as an AR-based learning platform helps students understand Biology learning concepts with cell material in a more visual and interactive way.

In the Not Positive and Less Positive learning categories (Figure 1), this study confirms the results of previous research showing that a lack of understanding of STEAM concepts and minimal engagement in projects can hinder students' development of 21st-century skills (Mulyani et al., 2023). Students' difficulty accessing technology and low motivation to learn are also factors identified in various studies as significant barriers to implementing project-based learning methods. Students in the Moderately Positive and Positive categories experienced improvements in critical thinking and problem-solving as they became more familiar with project-based learning methods and technology (Issa & Khataibeh, 2021). On the other hand, other research confirms that the use of AR in learning can increase student motivation and understanding, as reflected in the findings of this study in the Positive and Very Positive categories (Utama et al., 2024). Finally, the Very Positive category in this study corroborates the research findings, showing that integrating advanced technology in project-based learning can significantly improve students' leadership skills, creativity, and innovation (Rahayu et al., 2024). Students in this category have shown high independence in completing projects and can adapt to technological changes and new learning methods. Overall, this study strengthens the evidence that the Assemblr Edu-assisted STEAM-PJBL approach has great potential to improve students' 21st-century skills, especially if implemented with the right strategies to overcome obstacles that may arise during learning activities.

The more positive the students experience participating in STEAM-PJBL-based learning assisted by Augmented Reality, the higher the 21st-century skills they achieve. STEAM-PJBL learning is proven in previous research to affect students' cognitive learning outcomes (Palennari & Mf, 2024). Students who actively participate in technology-based projects tend to be better able to develop learning skills, think innovatively, master information, media, and technology, and build life and career

skills. In contrast, students who rarely have engaging and meaningful learning experiences are less developed in these aspects.

It is important to note that the presence of 30% of students in the "poor" category and 10% in the "inferior" category for 21st-century skills mastery indicates that while the approach is practical, it may not be uniformly successful for all learners (Figure 2). Utilizing digital tools allows for varied pacing and difficulty levels, which is particularly beneficial for students with limited prior exposure to technology (Estaiteyeh & DeCoito, 2023). Mastery of 21st-century skills improves as students progress through their education (Aizenkot & Ben David, 2023).

This finding highlights the potential of STEAM-based PjBL supported by Augmented Reality in facilitating holistic student development. The learning model allows students to engage in real-world problem-solving tasks, integrating multiple disciplines and creative thinking. Integrating arts into STEAM (Science, Technology, Engineering, Arts, and Mathematics) significantly enhances Project-Based Learning (PjBL) by fostering imagination and self-expression, which are often neglected in traditional science education. This approach enriches the learning experience and cultivates essential creative thinking skills among students. Integrating arts with science encourages a more comprehensive educational experience, bridging gaps between disciplines and fostering innovative thinking (Musa et al., 2023). The STEAM-PjBL approach has been shown to improve students' scientific creativity, with significant increases in imaginative thinking and problem-solving abilities (Candra Yulia et al., 2024). Projects that combine artistic elements with scientific inquiry help students relate their learning to real-life contexts, enhancing engagement and understanding (Papilaya & Salhuteru, 2024).

The high percentage in indicators like "Flexibility and Adaptability" (Tabel 2) suggests that students can effectively respond to diverse tasks and shift roles in group collaboration. This adaptability is increasingly recognized as a critical skill in modern education, particularly in collaborative learning environments. This aligns with findings from research that indicate that students possess high levels of adaptability, which is essential for navigating complex group dynamics and problem-solving scenarios (M. Liwanag & C. Lunar, 2023). Adaptability enables students to make quick judgments and respond to new challenges, fostering resilience and creativity in collaborative tasks (Cheng & Zhang, 2024). Educational institutions should enhance curricula to further develop students' adaptability and collaboration skills through cross-disciplinary activities and experiential learning opportunities (M. Liwanag & C. Lunar, 2023).

Integrating Project-Based Learning (PjBL) with Augmented Reality (AR) significantly enhances the development of 21st-century skills among students. This educational approach fosters critical thinking, collaboration, creativity, and communication, often called the 4Cs, by engaging students in immersive, hands-on learning experiences. PjBL encourages students to tackle real-world problems, promoting analytical reasoning and innovative solutions (Rosita et al., 2024). AR provides interactive simulations that enhance understanding of complex concepts, improving critical thinking skills (Prananta et al., 2024). Collaborative projects in PjBL require students to work in teams, enhancing their ability to communicate effectively



and share ideas (Masruri et al., 2024). AR tools facilitate group discussions and joint problem-solving, further strengthening collaborative skills (Indriani et al., 2024). PjBL allows students to express their creativity through project design and execution, while AR adds an engaging visual element that captivates learners (Burhanudin, 2021). Additionally, Assemblr Edu's AR features, by enabling 3D object manipulation and visual simulation of biological cell structures, help clarify complex abstract concepts, which directly contributes to improved conceptual understanding and media literacy (Raja & Subramanian, 2024; Afnan & Puspitawati, 2024).

Integrating Assembler Edu in educational settings significantly enhances the development of 21st-century skills among students. This digital platform fosters critical competencies such as argumentation, perseverance, and curiosity, particularly in physics. The use of e-modules has shown a marked improvement in these areas, with studies indicating a 42.2% enhancement in argumentation skills and a 47.6% increase in perseverance among students (Astalini et al., 2024). Furthermore, Assembler Edu supports project-based learning (PjBL), which is crucial for cultivating creativity, critical thinking, and collaboration skills, as evidenced by positive feedback from teachers and students involved in PjBL training (Nugrohadi & Anwar, 2022; Seth et al., 2015).

Project-focused learning allows students to complete complex tasks both independently and in collaboration. This method contributes to the development of analytical thinking, creativity in problem-solving, and adaptability skills to new challenges that arise during project implementation. This finding aligns with previous research showing that project-based learning supported by modern technology can increase students' learning motivation, encourage independence in completing tasks, and improve problem-solving skills more effectively (Philosophy et al., 2024).

This study revealed that implementing the STEAM-based PJBL method supported by Assembly Edu significantly improved students' 21st-century skills, particularly in critical thinking, creativity, digital literacy, leadership, and initiative. Students who experienced a positive learning process tended to show better skills than those who did not have a meaningful experience. These results are consistent with previous research, emphasizing that effective technology integration in learning can significantly improve students' digital literacy and 21st-century skills essential for facing future challenges (Sabila & Hadi, 2024).

Observer observations during learning activities as supporting data in this study showed a significant increase in students' 21st-century skills from the first to the third meeting. This increase shows that the more students engage in project-based learning, the more their 21st-century skills develop. Consistent with previous research, these findings highlight how Project Learning (PjBL) encourages greater student engagement in solving real-world problems, leading to improved critical thinking and problem-solving skills (Rehani & Mustofa, 2023). Research also reinforces this by showing that the STEAM approach can accelerate the development of student's cognitive and creative skills (Pitaloka & Sinaga, 2023).

The combination of quantitative data and observational insights confirms that STEAM-based PJBL, assisted by Assemblr Edu, significantly supports the development of 21st-century competencies. These results reinforce the call for

integrating interdisciplinary, technology-supported learning designs into the mainstream education system. The model's adaptability, visual support, and student-centered nature offer a robust framework for educational transformation in the digital age.

## Conclusion

The study's findings indicate a significant correlation between the implementation of STEAM-based Project-Based Learning (PJBL), facilitated by Augmented Reality, and the enhancement of students' 21st-century skills. The significance value of 0.000, derived from Kendall's tau-b test, which is below the threshold of 0.05, indicates a meaningful association between STEAM-based PJBL learning, supported by Augmented Reality using Assemblr Edu platform, and the advancement of students' 21st-century skills. Furthermore, the analysis reveals that the correlation coefficient between STEAM-based PJBL learning and students' 21st-century skills is 0.798, signifying a strong positive relationship between these variables. With an average achievement of 77%, the observations of student activities demonstrate a notable improvement in 21st-century skills, categorized as good. Based on the results of Kendall's tau-b test and observations, it can be concluded that STEAM-based PJBL, supported by Augmented Reality using the Assemblr Edu platform, has a significant relationship with students' 21st-century skills and is effective in enhancing these skills. This suggests that schools and educators should consider integrating AR-based learning and interdisciplinary project designs as part of curriculum innovation to foster essential 21st-century competencies in students.

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