Premiere Educandum: Jurnal Pendidikan Dasar dan Pembelajaran
Volume 15 (1) 49 – 59 2025
ISSN: 2088-5350 (Print) / ISSN: 2528-5173 (Online)
Doi: 10.25273/pe.v15i1.25370
The article is published with Open Access at: http://e-journal.unipma.ac.id/index.php/PE

The effect of steam learning based on project-based learning (pjbl) assisted by assemblr edu on elementary school students' creative thinking skills

Rezki Ungki Yanna Opsari, Universitas PGRI Madiun
Parji✉, Universitas PGRI Madiun
Marheny Lukitasari, Universitas PGRI Madiun

✉ *parji@unipma.ac.id*

Abstract: Creative thinking is one of the essential 21st-century skills that should be developed in elementary school students to enhance problem-solving abilities and generate innovative ideas. However, preliminary observations in Grade V of SDN Sugihwaras 2 indicated that students' creative thinking skills were still relatively low. This study aimed to examine the effect of Science, Technology, Engineering, Arts, and Mathematics (STEAM) learning based on Project-Based Learning (PjBL) assisted by Assemblr Edu on students' creative thinking skills. A quantitative pre-experimental method with a One-Group Pretest–Posttest Design was employed. The participants were 20 fifth-grade students selected through purposive sampling. Data were collected using a creative thinking test covering fluency, flexibility, originality, and elaboration. Data were analyzed using descriptive statistics, the Shapiro–Wilk normality test, and the Paired Sample *t*-test. The findings indicate that STEAM-based Project-Based Learning (PjBL) assisted by Assemblr Edu effectively enhanced elementary school students' creative thinking skills. The integration of project-based activities with immersive augmented reality learning experiences encouraged students to generate original ideas, explore multiple problem-solving strategies, and elaborate their ideas more creatively. These results support the view that authentic, technology-enhanced STEAM learning environments foster higher-order thinking and creativity in elementary education.

Keywords: Creative Thinking Skills; STEAM Learning Approach; Project-Based Learning; Assemblr Edu Platform; Elementary School Students

Received 14 November 2025; **Accepted** 15 May 2026; **Published** 27 July 2026

Citation: Opsari, R.U.Y., Parji, P., Lukitasari, M. (2025). The effect of steam learning based on project-based learning (pjbl) assisted by assemblr edu on elementary school students' creative thinking skills. *Premiere Educandum : Jurnal Pendidikan Dasar dan Pembelajaran*, *15*(2), 49 – 59. Doi.org/10.25273/pe.v15i1.25370

Published by Universitas PGRI Madiun. This work is licensed under the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License.

INTRODUCTION

The rapid advancement of technology in the era of the Industrial Revolution 4.0 and Society 5.0 has transformed educational practices worldwide. Elementary education is no longer merely oriented toward knowledge acquisition but also emphasizes the development of 21st-century competencies, including creativity, critical thinking, communication, collaboration, and digital literacy. Among these competencies, creative thinking is considered one of the essential skills because it enables students to generate original ideas, solve problems innovatively, and adapt to various real-life situations. Consequently, elementary school learning should be designed to provide meaningful learning experiences that encourage exploration, creativity, and problem-solving (Bedar & Al-Shboul, 2020; Utomo et al., 2020; Wahyudi et al., 2024).

However, the development of creative thinking skills among elementary school students remains far from optimal. Preliminary observations conducted in Grade V of SDN Sugihwaras 2 indicated that students experienced difficulties in generating diverse ideas, providing original responses, and elaborating ideas while completing learning tasks. The pretest results further revealed that the average creative thinking score was only 35.45, indicating a relatively low level of creative thinking ability. This condition is closely related to teacher-centered instructional practices, routine learning activities, and the limited use of innovative learning media that actively engage students in knowledge construction (Nurfadilah & Siswanto, 2020; Wiyoko, 2019).

Science, Technology, Engineering, Arts, and Mathematics (STEAM) has been widely recognized as an interdisciplinary learning approach capable of fostering students' creativity and higher-order thinking skills. STEAM integrates multiple disciplines into authentic learning experiences, allowing students to investigate problems, design solutions, and apply knowledge in meaningful contexts. The implementation of STEAM becomes more effective when integrated with Project-Based Learning (PjBL), which provides opportunities for students to design, create, test, and evaluate products collaboratively. Through project-based activities, students are encouraged to demonstrate fluency, flexibility, originality, and elaboration as the primary indicators of creative thinking (Priantari et al., 2020; Prasetyawati & Astuti, 2025; Wahyudi et al., 2024).

In addition to instructional approaches, interactive digital media play an important role in supporting innovative learning environments. One promising platform is Assemblr Edu, an Augmented Reality (AR)-based application that enables teachers and students to create and visualize interactive three-dimensional learning objects. Assemblr Edu integrates 3D visualization, text, images, audio, video, animation, and AR technology to create immersive learning experiences. Unlike conventional digital media that merely present information, Assemblr Edu allows students to manipulate virtual objects, explore alternative designs, and present project outcomes interactively. These characteristics provide students with greater opportunities to develop original ideas and improve creative thinking skills (Octaviani et al., 2022; Tuta et al., 2022; Sari, 2025).

Previous studies have confirmed that STEAM, Project-Based Learning, and Augmented Reality media positively influence learning outcomes and the development of 21st-century competencies. Nevertheless, these three components have generally been investigated separately. Most studies have focused only on STEAM-based learning, Project-Based Learning, or Assemblr Edu independently, while empirical evidence regarding the integration of these three approaches to improve elementary students' creative thinking skills remains limited. Therefore, a significant research gap still exists concerning the effectiveness of integrating STEAM, Project-Based Learning, and Assemblr Edu into a single instructional framework (Dywan & Airlanda, 2020; Prasetyawati & Astuti, 2025; Yanuarto & Prakosa, 2025).

Based on this research gap, the present study proposes an instructional strategy that integrates STEAM, Project-Based Learning, and Assemblr Edu within a single learning process to facilitate the development of students' creative thinking skills, particularly in terms of fluency, flexibility, originality, and elaboration. This integrated approach is expected to provide a more authentic, interactive, and technology-supported learning experience than approaches that apply these components separately. Therefore, this study aims to analyze the effect of STEAM-based Project-Based Learning assisted by Assemblr Edu on elementary school students' creative thinking skills. Specifically, this study addresses the following research question: Does STEAM-based Project-Based Learning assisted by Assemblr Edu significantly improve elementary school students' creative thinking skills? The findings are expected to contribute empirical evidence to the development of innovative instructional practices and provide practical recommendations for elementary school teachers in integrating digital technology to foster students' 21st-century skills (Damayanti & Putra, 2024; Wahyudi et al., 2024).

METHODS

Research Design

This study employed a quantitative approach using a pre-experimental method with a One Group Pretest–Posttest Design. The research design was developed to systematically evaluate the effectiveness of STEAM-based Project-Based Learning (PjBL) assisted by Assemblr Edu in improving elementary school students' creative thinking skills. The implementation consisted of three consecutive stages: (1) measuring students' initial creative thinking skills through a pretest, (2) implementing STEAM-based Project-Based Learning integrated with Assemblr Edu as the instructional treatment, and (3) measuring students' creative thinking skills after the intervention through a posttest. The comparison between the pretest and posttest results was used to determine the effectiveness of the instructional intervention.

Participant

The study was conducted in an Indonesian public elementary school during the second semester of the 2025/2026 academic year. The participants consisted of 20 fifth-grade students selected through purposive sampling. This sampling technique was employed because the participants exhibited relatively low levels of creative thinking skills based on preliminary classroom observations and initial assessments. All participants received the same instructional treatment throughout the study.

TABLE 1. *Characteristics of participants*

Characteristics	Description
School Characteristics	Public elementary school implementing the national curriculum and integrating digital learning media in classroom instruction
Grade	Fifth Grade
Age Range	10–11 years
Student Characteristics	Students demonstrated relatively low creative thinking skills during the preliminary assessment and had limited prior experience with STEAM-based learning and Augmented Reality applications.
Sampling Technique	Purposive Sampling
Research Design	One Group Pretest–Posttest
Learning Material	Indonesian Map

Material and Instrument

The research instrument consisted of an essay test designed to measure students' creative thinking skills after participating in STEAM-based Project-Based Learning assisted by Assemblr Edu. The instrument was developed based on the four dimensions of creative thinking proposed by Torrance, namely fluency, flexibility, originality, and elaboration. Each dimension was operationalized into specific observable indicators to ensure that the instrument comprehensively measured students' creative thinking skills.

TABLE 2. *Indicators of creative thinking instrument*

Dimension	Operational Indicators	Description
Fluency	Generating multiple ideas	Students are able to produce several relevant ideas or alternative solutions to a given problem.
	Providing various answers	Students give more than one possible answer or solution to the assigned task.
	Expressing ideas smoothly	Students communicate their ideas fluently without significant hesitation.
Flexibility	Using different strategies	Students solve problems using various approaches or methods.
	Viewing problems from different perspectives	Students are able to change viewpoints and consider alternative solutions.
	Classifying ideas	Students organize ideas into different categories based on their characteristics.
Originality	Producing unique ideas	Students generate uncommon or novel ideas that differ from those of their peers.
	Creating innovative solutions	Students propose original solutions to solve the given problem.
	Combining concepts creatively	Students integrate different concepts to produce new ideas or products.
Elaboration	Developing ideas in detail	Students enrich their ideas by adding relevant details and explanations.
	Refining solutions	Students improve or modify their initial ideas to make them more complete.
	Presenting comprehensive explanations	Students explain their ideas systematically and thoroughly.

Before being administered to the participants, the instrument was subjected to empirical validity and reliability testing to ensure its appropriateness for measuring students' creative thinking skills. The validity of the instrument was examined using the Pearson Product Moment correlation test, and all ten essay items met the validity criteria with significance values below 0.05. Consequently, all items were retained for data collection. The reliability of the instrument was evaluated using Cronbach's Alpha coefficient through IBM SPSS Statistics version 25. As presented in Table 3, the instrument obtained a Cronbach's Alpha coefficient of 0.836, indicating high reliability. These results demonstrate that the instrument was both valid and reliable for assessing elementary school students' creative thinking skills.

TABLE 3. *Instrument reliability*

Variable	Cronbach's Alpha	Number of Items	Interpretation
Creative Thinking Test	0.836	10	Reliable

As presented in Table 3, the instrument obtained a Cronbach's Alpha coefficient of 0.836, indicating high internal consistency. This value exceeds the commonly accepted reliability threshold of 0.70, suggesting that the instrument consistently measured the four dimensions of creative thinking, namely fluency, flexibility, originality, and elaboration. Therefore, the instrument was considered reliable and appropriate for use in assessing elementary school students' creative thinking skills throughout the study.

Procedure

The research was conducted in four sequential stages: preparation, pretest, treatment, and posttest. During the preparation stage, the researcher developed the lesson plans, creative thinking test instrument, student worksheets, and learning media using Assemblr Edu. Prior to implementation, the research instrument was subjected to validity and reliability testing to ensure that it accurately measured students' creative thinking skills. After the preparation phase, all participants completed a pretest to identify their initial level of creative thinking before receiving the learning intervention. The pretest assessed four dimensions of creative thinking, namely fluency, flexibility, originality, and elaboration.

The treatment phase involved the implementation of STEAM-based Project-Based Learning (PjBL) assisted by Assemblr Edu during the Indonesian Map learning topic. The learning activities followed six phases of the Project-Based Learning model: determining the essential question, designing the project plan, developing the project schedule, monitoring project progress, assessing project outcomes, and evaluating the learning experience. Throughout the learning process, students worked collaboratively in small groups to investigate the characteristics of the Indonesian archipelago and design a three-dimensional Indonesian map using Assemblr Edu. The STEAM approach was integrated by encouraging students to apply scientific inquiry in identifying geographical characteristics, utilize digital technology through the Assemblr Edu platform, design and construct virtual three-dimensional map models, incorporate artistic elements into the visualization of their projects, and apply mathematical concepts such as scale, distance, and spatial relationships. During project implementation, the teacher acted as a facilitator by guiding group discussions, monitoring students' progress, providing feedback, and encouraging creative problem-solving and collaborative learning.

At the end of the intervention, each group presented its completed project using the Augmented Reality (AR) visualization feature available in Assemblr Edu and received feedback from both the teacher and their peers. Reflection activities were subsequently conducted to encourage students to evaluate their learning experiences and identify possible improvements to their project outcomes. Finally, all participants completed the posttest using the same instrument administered during the pretest. The comparison between the pretest and posttest scores was used to determine the effectiveness of STEAM-based Project-Based Learning assisted by Assemblr Edu in improving elementary school students' creative thinking skills.

Data Analysis

The collected data were analyzed using IBM SPSS Statistics version 25 through descriptive and inferential statistical techniques. Descriptive statistics were first employed to summarize students' creative thinking performance before and after the implementation of the learning intervention. The descriptive analysis included the calculation of the minimum score, maximum score, mean, and standard deviation for both the pretest and posttest. These statistics were used to provide an overview of the distribution of students' creative thinking scores and to identify changes in performance following the implementation of STEAM-based Project-Based Learning assisted by Assemblr Edu.

Prior to hypothesis testing, the data were examined to ensure that they satisfied the assumptions required for parametric statistical analysis. The normality of the pretest and posttest scores was assessed using the Shapiro–Wilk test because the number of participants was fewer than 50, making this test appropriate for small sample sizes. A significance value (p) greater than 0.05 indicated that the data were normally distributed and therefore met the assumptions for further parametric testing. Establishing the normality of the data was an essential step to ensure the validity and accuracy of the subsequent statistical analysis.

Following the confirmation of normality, the research hypothesis was tested using a Paired Samples *t*-test with a significance level of $\alpha = 0.05$. This statistical test was selected because it is appropriate for comparing two related sets of scores obtained from the same participants before and after an instructional intervention. The null hypothesis (H_0) stated that there was no significant difference between students' pretest and posttest creative thinking scores, whereas the alternative hypothesis (H_1) stated that a significant difference existed after the implementation of the learning intervention. The null hypothesis was rejected when the significance value was less than 0.05, indicating that the treatment produced a statistically significant improvement in students' creative thinking skills.

To complement the hypothesis testing, the magnitude of the treatment effect was determined by calculating Cohen's *d* effect size. Unlike the significance test, which only indicates whether a difference exists, the effect size provides information about the practical importance of the intervention. The interpretation of Cohen's *d* followed the commonly accepted criteria, where values of 0.20 indicate a small effect, 0.50 a medium effect, and 0.80 or higher a large effect. By combining descriptive statistics, assumption testing, inferential analysis, and effect size estimation, this study provided a comprehensive evaluation of the effectiveness of STEAM-based Project-Based Learning assisted by Assemblr Edu in improving elementary school students' creative thinking skills.

RESULTS

This section presents the findings of the study regarding the effect of STEAM-based Project-Based Learning (PjBL) assisted by Assemblr Edu on elementary school students' creative thinking skills. The results are organized into four parts: descriptive statistics, normality testing, hypothesis testing, and effect size analysis. These analyses provide comprehensive evidence of the effectiveness of the implemented learning approach in improving students' creative thinking skills.

Descriptive Statistics

Descriptive statistical analysis was conducted to describe students' creative thinking skills before and after the implementation of STEAM-based Project-Based Learning assisted by Assemblr Edu. The analysis included the number of participants, mean scores, and standard deviations for both the pretest and posttest.

TABLE 4. *Descriptive statistics of creative thinking scores*

Test	N	Mean	Standard Deviation
Pretest	20	23.80	6.246
Posttest	20	45.25	3.712

As shown in Table 4, students' average creative thinking score increased considerably after the learning intervention. The mean score improved from 23.80 in the pretest to 45.25 in the posttest, representing an increase of 21.45 points. Moreover, the standard deviation decreased from 6.246 to 3.712, indicating that students' learning outcomes became more consistent after participating in the learning activities. These findings provide preliminary evidence that the implemented learning model positively influenced students' creative thinking performance.

Normality Test

Prior to hypothesis testing, the assumption of data normality was examined using the Shapiro–Wilk test because the number of participants was fewer than fifty. The normality test was performed separately for the pretest and posttest scores.

TABLE 5. *Results of the shapiro–wilk normality test*

Data	Statistic	Sig.	Interpretation
Pretest	0.913	0.072	Normal
Posttest	0.934	0.181	Normal

According to Table 5, the significance values for both the pretest (0.072) and posttest (0.181) exceeded the significance level of 0.05. Therefore, the data were considered normally distributed, indicating that the assumptions for parametric statistical analysis were satisfied. Based on these results, the Paired Samples t-test was selected to examine the research hypothesis.

Hypothesis Testing

The effectiveness of STEAM-based Project-Based Learning assisted by Assemblr Edu was evaluated using the Paired Samples t-test. This analysis was conducted to determine whether there was a statistically significant difference between students' creative thinking scores before and after the implementation of the learning model.

TABLE 6. *Results of the Paired Samples t-test*

Comparison	Mean Difference	t	Sig. (2-tailed)
Pretest–Posttest	-21.450	-14.523	<0.001

As presented in Table 6, the analysis produced a significance value of less than 0.001, which was lower than the predetermined significance level of 0.05. Therefore, the null hypothesis was rejected, indicating a statistically significant difference between students' creative thinking skills before and after the intervention. The negative mean difference reflects that posttest scores were substantially higher than pretest scores, suggesting that the implementation of STEAM-based Project-Based Learning assisted by Assemblr Edu effectively improved students' creative thinking skills.

Effect Size Analysis

In addition to statistical significance testing, the practical significance of the treatment was evaluated using Cohen's d effect size. This analysis was conducted to determine the magnitude of the influence of the implemented learning model on students' creative thinking skills.

TABLE 7. *Effect size analysis*

Effect Size	Value	Category
Cohen's *d*	3.247	Large Effect

As shown in Table 7, the calculated Cohen's d value was 3.247, which falls within the large effect category according to Cohen's interpretation criteria. This finding indicates that the improvement in students' creative thinking skills was not only statistically significant but also educationally meaningful. The large effect size demonstrates that integrating STEAM, Project-Based Learning, and Assemblr Edu provided a substantial contribution to enhancing students' ability to generate ideas, think flexibly, produce original solutions, and elaborate their ideas during the learning process.

DISCUSSION

The findings of this study demonstrate that STEAM-based Project-Based Learning (PjBL) assisted by Assemblr Edu significantly improved elementary school students' creative thinking skills. This finding is supported by the significant increase in the mean score from 23.80 in the pretest to 45.25 in the posttest, as well as the results of the Paired Samples *t*-test, which indicated a statistically significant difference between students' creative thinking skills before and after the intervention. Furthermore, the effect size analysis yielded a Cohen's *d* value of 3.247, indicating that the implemented learning approach had a very large practical effect on students' creative thinking development.

The improvement in creative thinking skills can be explained by the characteristics of the STEAM approach, which integrates science, technology, engineering, arts, and mathematics into authentic problem-solving activities. Rather than emphasizing memorization of concepts, STEAM encourages students to investigate problems, develop multiple ideas, evaluate alternative solutions, and construct meaningful products. This learning process promotes higher-order thinking skills because students are required to connect knowledge from different disciplines while solving real-world problems. STEAM learning also creates meaningful learning environments that encourage innovation, collaboration, inquiry, and independent learning, thereby supporting the development of students' creative thinking skills (Bedar & Al-Shboul, 2020; Utomo et al., 2020; Wahyudi et al., 2024).

Another factor contributing to the improvement was the implementation of the Project-Based Learning (PjBL) model. During the learning process, students actively participated in identifying problems, designing projects, developing solutions, and presenting their final products. These activities encouraged students to generate multiple ideas (fluency), examine problems from different perspectives (flexibility), produce unique solutions (originality), and refine their work in detail (elaboration). Such collaborative and project-oriented learning experiences provide students with opportunities to actively construct knowledge while solving authentic problems, thereby enhancing their creative thinking skills (Annisa et al., 2019; Dywan & Airlanda, 2020; Prasetyawati & Astuti, 2025).

The significant improvement observed in this study was also influenced by the use of Assemblr Edu as an Augmented Reality (AR)-based learning medium. Assemblr Edu enables students to visualize abstract concepts through interactive three-dimensional objects while integrating text, images, animation, audio, and AR technology. Unlike conventional digital media, Assemblr Edu allows learners to manipulate virtual objects, modify project designs, and present their work in an immersive environment. Such learning experiences provide students with greater opportunities to explore ideas, strengthen conceptual understanding, and improve their creative performance through interactive visualization (Damayanti & Putra, 2024; Octaviani et al., 2022; Tuta et al., 2022; Sari & Sari, 2025; Yanuarto & Prakosa, 2025).

The contribution of Assemblr Edu became evident across all four indicators of creative thinking. The visualization of three-dimensional learning objects enabled students to generate more ideas during project planning, thereby improving fluency. Collaborative project activities encouraged students to evaluate problems from multiple perspectives, resulting in greater flexibility. Furthermore, the freedom to design unique AR-based learning products supported originality, while the opportunity to continuously revise and improve project outcomes strengthened elaboration. These findings reinforce constructivist learning theory, which suggests that meaningful learning occurs when students actively construct knowledge through exploration, collaboration, and authentic experiences.

Compared with previous studies, this research offers a novel contribution by integrating three instructional components simultaneously, namely the STEAM approach, the Project-Based Learning model, and Assemblr Edu as an Augmented Reality platform.

Previous studies generally investigated these components separately, whereas this study demonstrates that combining all three creates a more interactive, collaborative, and technology-rich learning environment that significantly enhances students' creative thinking skills. This integrated learning model may therefore serve as an effective instructional alternative for elementary school teachers seeking to foster twenty-first-century skills through technology-supported project-based learning (Damayanti & Putra, 2024; Prasetyawati & Astuti, 2025; Wahyudi et al., 2024).

CONCLUSION

This study concludes that STEAM-based Project-Based Learning (PjBL) assisted by Assemblr Edu has a significant positive effect on elementary school students' creative thinking skills. The integration of interdisciplinary STEAM learning, project-based activities, and Augmented Reality technology created meaningful learning experiences that enabled students to actively construct knowledge, generate original ideas, solve problems from multiple perspectives, collaborate with peers, and develop innovative learning products. These findings indicate that combining pedagogical approaches with interactive digital technology provides an effective learning environment for fostering creative thinking and supporting the development of twenty-first-century competencies among elementary school students. Furthermore, this study contributes to the existing body of knowledge by providing empirical evidence that integrating STEAM, Project-Based Learning, and Assemblr Edu within a single instructional framework offers a more comprehensive approach to developing creative thinking skills than implementing each component independently.

In addition to its practical contribution, this study also provides theoretical implications for technology-enhanced learning in elementary education. The findings reinforce the constructivist perspective that creative thinking develops more effectively when students actively engage in authentic problem-solving, collaborative project activities, and the creation of meaningful learning products. The integration of STEAM, Project-Based Learning, and Assemblr Edu demonstrates that interdisciplinary learning supported by Augmented Reality technology creates a synergistic learning environment that stimulates students to think creatively, explore multiple perspectives, and elaborate their ideas through interactive learning experiences. From a practical perspective, these findings encourage elementary school teachers to integrate technology-supported project-based learning into classroom instruction to create more engaging, student-centered, and authentic learning environments. The use of Assemblr Edu may also serve as an effective digital learning medium for facilitating conceptual understanding, increasing student participation, and promoting creativity through collaborative learning activities.

Despite these contributions, this study has several limitations. The research employed a One Group Pretest–Posttest Design without a comparison group, making it difficult to attribute improvements exclusively to the intervention. In addition, the relatively small number of participants from a single educational setting limits the generalizability of the findings to broader contexts. Therefore, future studies are recommended to employ quasi-experimental or true experimental designs involving larger and more diverse samples, different educational levels, and various learning topics to obtain stronger empirical evidence regarding the effectiveness of STEAM-based Project-Based Learning assisted by Augmented Reality technology. Future research may also explore the long-term impact of this integrated instructional approach on other twenty-first-century competencies, such as critical thinking, collaboration, communication, and digital literacy.

ACKNOWLEDGMENTS

The author would like to express sincere gratitude to the principal, teachers, and fifth-grade students who participated in this study for their valuable cooperation throughout the research process. The author also extends appreciation to the lecturers of the Master's Program in Elementary Education, Universitas PGRI Madiun, for their valuable guidance, constructive feedback, and academic support during the completion of this study. Special thanks are also addressed to everyone who contributed to the implementation of the research and the preparation of this manuscript.

REFERENCES

1. Al-Zahra, H. S., & Handayani, S. L. (2025). Empowering student creativity through problem-based learning assisted by Assemblr Edu: A study on metamorphosis in primary science. *Journal of Educational Sciences, 9*(4), 2967–2976. https://doi.org/10.31258/jes.9.4.p.2967-2976
2. Ambar Ningsih, W. S., Suana, W., & Maharta, N. (2018). Pengaruh penerapan blended learning berbasis Schoology terhadap kemampuan berpikir kritis siswa. *Konstan: Jurnal Fisika dan Pendidikan Fisika, 3*(2), 85–93. https://doi.org/10.20414/konstan.v3i2.16
3. Annisa, R., Effendi, M. H., & Damris, D. (2019). Peningkatan kemampuan berpikir kreatif siswa dengan menggunakan model Project Based Learning berbasis STEAM pada materi asam dan basa. *Journal of the Indonesian Society of Integrated Chemistry, 10*(2), 14–22. https://doi.org/10.22437/jisic.v10i2.6517
4. Apriliana, M. R., Ridwan, A., Hadinugrahaningsih, T., & Rahmawati, Y. (2018). Pengembangan soft skills peserta didik melalui integrasi pendekatan Science, Technology, Engineering, Arts, and Mathematics (STEAM). *JRPK: Jurnal Riset Pendidikan Kimia, 8*(2), 42–51. https://doi.org/10.21009/JRPK.082.05
5. Bedar, R. A. H., & Al-Shboul, M. (2020). The effect of using STEAM approach on developing computational thinking skills among high school students in Jordan. *International Journal of Interactive Mobile Technologies, 14*(14), 80–94. https://doi.org/10.3991/ijim.v14i14.14719
6. Damayanti, L. S. A., & Putra, G. M. C. (2024). Development of augmented reality media based on Assemblr Edu to enhance learning outcomes. *Research and Development in Education (RaDEn), 4*(2), 924–939. https://doi.org/10.22219/raden.v4i2.34160
7. Dywan, A. A., & Airlanda, G. S. (2020). Efektivitas model pembelajaran Project Based Learning berbasis STEM terhadap kemampuan berpikir kritis siswa. *Jurnal Basicedu, 4*(2), 344–354. https://doi.org/10.31004/basicedu.v4i2.353
8. Lestari, S. (2021). Pengembangan orientasi keterampilan abad ke-21 pada pembelajaran fisika melalui pembelajaran PjBL-STEAM berbantuan Spectra-Plus. *Ideguru: Jurnal Karya Ilmiah Guru, 6*(3), 272–279. https://doi.org/10.51169/ideguru.v6i3.243
9. Mayuni, K. R., Rati, N. W., Putrini, L. P., & Mahadewi. (2019). Pengaruh model pembelajaran Project Based Learning terhadap hasil belajar IPA. *Jurnal Ilmiah Pendidikan Profesi Guru, 2*(2), 183–193.
10. Nurfadilah, S., & Siswanto, J. (2020). Analisis kemampuan berpikir kreatif pada konsep polimer dengan pendekatan STEAM bermuatan ESD. *Media Penelitian Pendidikan, 14*(1), 45–51. https://doi.org/10.26877/mpp.v14i1.5543

11. Octaviani, L., Harta, J., & Winarta, G. Y. (2022). Development of Assemblr Edu-assisted augmented reality learning media on the topic of reaction rate. *Journal of Chemistry Education Research, 6*(1), 58–71. https://doi.org/10.26740/jcer.v6n1.p58-71
12. Prasetyawati, A. N., & Astuti, A. P. (2025). Implementation of Project Based Learning–STEAM on students' creative thinking skills in Indonesia: A bibliometric review. *Journal of Lesson Study and Teacher Education, 4*(1), 66–75. https://doi.org/10.51402/jlste.v4i1.158
13. Priantari, I., Prafitasari, A. N., Kusumawardhani, D. R., & Susanti, S. (2020). Improving students' critical thinking through STEAM-PjBL learning. *Bioeducation Journal, 4*(2), 95–103.
14. Sari, N. N., & Sari, P. M. (2025). Development of augmented reality learning media based on Assemblr Edu to improve students' creativity abilities. *Jurnal Paedagogy, 12*(4). https://doi.org/10.33394/jp.v12i4.16817
15. Tuta, B. B., Harta, J., & Purwasih, S. S. (2022). Development of Assemblr Edu-assisted augmented reality learning media on the topic of surface area and temperature on reaction rate. *Journal of Chemistry Education Research, 6*(1), 44–57. https://doi.org/10.26740/jcer.v6n1.p44-57
16. Utomo, A. P., Hasanah, L., Hariyadi, S., Narulita, E., Suratno, & Umamah, N. (2020). The effectiveness of STEAM-based biotechnology module equipped with flash animation for biology learning in high school. *International Journal of Instruction, 13*(2), 463–476. https://doi.org/10.29333/iji.2020.13232a
17. Wahyudi, A. B. E., Salimi, M., Hidayah, R., Zainnuri, H., & Fajari, L. E. W. (2024). The improvement of students' creative and collaborative thinking skills by applying STEAM-integrated Project-Based Learning. *Jurnal Iqra': Kajian Ilmu Pendidikan, 9*(1). https://doi.org/10.25217/ji.v9i1.4438
18. Yanuarto, W. N., & Prakosa, I. P. (2025). Development of STEM-based Assemblr Edu learning media to improve students' creative thinking skills and performance. *Desimal: Jurnal Matematika.* https://doi.org/10.24042/djm.v9i2.31271
19. Zubaidah, S. (2019). STEAM (Science, Technology, Engineering, Arts, and Mathematics): Pembelajaran untuk memberdayakan keterampilan abad ke-21. *Seminar Nasional Pendidikan Biologi.*
20. Ainsworth, S. (2021). The educational value of multiple representations in science learning. *Educational Psychology Review, 33*(2), 467–491.
21. Ibáñez, M. B., & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review. *Computers & Education, 123*, 109–123.
22. Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review. *Educational Research Review, 20*, 1–11.
23. Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education. *Education and Information Technologies, 25*(2), 835–861.