ISSN 2807-9329 (Print) ISSN 2807-9167 (Online)

Journal of Mathematics, Science and Computer Education (JMSCEdu)

https://ppjp.ulm.ac.id/journals/index.php/jmsc-edu

The Use of Augmented Reality-Based Stem Approach on Self-Efficacy and Science Problem-Solving Ability of Elementary Students

Siti Sahronih[1]*, Wirda Hanim[2], and Reza Rachmadtullah[3]

[1]Elementary School Teacher Education, Institut Prima Bangsa, Cirebon, Indonesia

[2]Psychology, Faculty of Psychology Education, Universitas Negeri Jakarta, Jakarta, Indonesia

[3]Elementary School Teacher Education, Universitas PGRI Adi Buana Surabaya, Surabaya, Indonesia

*sahronihsiti@gmail.com

Received: 24 December 2024 **Accepted:** 14 January 2025 **Published:** 15 January 2025

DOI: https://doi.org/10.20527/jmscedu.v4i2.14410

Abstract

Learning in the 21st century has shifted to using technology and various approaches that facilitate students' ability to solve problems independently. One substitute method for assessing students' scientific problem-solving skills and self-efficacy was an AR-based STEM approach. This study aimed to determine the effect and correlation between self-efficacy and students' problem-solving skills in learning science using AR. A quasi-experiment with a pretest-posttest non-equal control group design model was employed. The number of samples in this study consisted of 50 students spread across the experimental (VA) and control (VB) classes. The results of the value of the problem-solving ability in the control class were 58 on the pretest and 77 on the post-test, while the experimental class yielded 61 on the pretest and 82 on the post-test. The average self-efficacy of the control class was 53 on the pretest and 60 on the post-test, while the experimental class yielded 56 on the pretest and 79 on the post-test. The study's results showed that using the AR-based STEM approach affected self-efficacy and problem-solving ability, with a percentage of 21%. The T-test score obtained by tcount>ttable (3.630 > 2.010) indicates a significant correlation between self-efficacy and students' problem-solving ability. Students with higher levels of self-efficacy were better at solving problems, as shown by the regression value for every 1% increase in the self-efficacy variable, contributing 64.13 to the problem-solving ability. Thus, there was a significant correlation between self-efficacy and problem-solving ability in science learning using the AR-based STEM approach.

Keywords: augmented reality; elementary students; problem-solving skills; self-efficacy; STEM

How to cite: Sahronih, S., Hanim, W., & Rachmadtullah, R., (2024). The use of augmented reality-based stem approach on self-efficacy and science problem-solving ability of elementary students. *Journal of Mathematics, Science, and Computer Education,* 4(2), 185-196.

INTRODUCTION

Science learning in the 21st century is inextricably linked to the learning process that is integrated with technology. Technology use in education is also inseparable from the learning process integrated with science and engineering (Dare et al., 2021; Pregowska et al., 2021; Yang & Baldwin, 2020). STEM (Science, Technology, Engineering, and Mathematics) is implemented in this instance. STEM is highly appropriate in the current Society 5.0 era (Baran et al., 2021; Broo et al., 2022; Burbules et al., 2020) and facilitates the evolution of the times. STEM's significance has increased significantly in the 21st century, with one of its primary objectives being to develop high-quality human resources. In the present era, the learning process necessitates output in order for individuals to engage in the development of cooperation, creativity, innovation, and problem-solving.

STEM, a problem-based learning method that integrates four disciplines, is ideal for evaluating students' problem-solving abilities. In STEM approaches, students can enhance their ability to conduct a case study. The implementation of STEM in education necessitates the integration of technology that facilitates learning activities. For instance, the science learning process necessitates the implementation of technology in the form of Augmented Reality (AR) to assist students in comprehending the concepts presented in scientific materials (Chen et al., 2016; Lai et al., 2019; Yoon et al., 2017). Technology in the form of AR has features that are particularly well-suited for the compilation of teaching materials, particularly for the comprehension of concepts by students. For instance, the science learning process necessitates an understanding of specific concepts in accordance with the teaching materials studied (Dargan et al., 2023).

AR is a type of technology that integrates a variety of digital content from a computer with the actual environment in real time (Arena et al., 2022; Kesim & Ozarslan, 2012; Sungkur et al., 2016). Learning materials containing specific concepts can be described in real life through AR technology, which facilitates students' comprehension of the material. AR has introduced a new dimension to the education field, underscoring that educational innovation is advancing and evolving. AR can address all of the learning challenges of the 21st century by presenting a creative and innovative learning process. In other words, the utilization of AR in the learning process, which can be implemented in a classroom setting, can potentially reduce students' misunderstandings regarding the teaching materials, particularly those pertaining to the concept of science. This is further bolstered by the inclusion of 3D features in the application of AR, which can also provide more detailed visualizations in the form of animations of specific objects.

Integrating STEM approaches with AR perfectly matches learning in this era. When integrated with AR technology, STEM can be an engaging alternative to traditional teaching and learning methods (Jesionkowska et al., 2020; Lee et al., 2024; Mystakidis et al., 2022). Nevertheless, teachers must provide guidance in elementary education, as elementary school students are still in the developmental stage and require adult guidance. This pertains to elementary school students' motivation and personality traits and their ability to complete specific tasks or challenges. Self-efficacy is one of the factors involved. Self-efficacy is an individual's belief in their capacity to organize and accomplish specific tasks. Self-efficacy in the learning process is associated with the completion of tasks that are required of individuals. Consequently, this is founded on the necessity of a student's ability to solve societal problems 5.0.

The ability to resolve scientific issues is crucial during the science learning process, as comprehending concepts is one of the components of science learning. This scientific problem-solving ability is essential for acquiring scientific knowledge. It is closely associated with self-efficacy, which refers to specific constraints on students' ability to complete tasks. The strategy for problem-solving is comprised of several stages, including comprehension of the problem, development of a problem-solving plan, execution of the plan, and evaluation of the implementation of the plan.

Previous research related to self-efficacy and STEM, namely, learning using STEM with self-efficacy in students, makes the learning process produce good outputs (Blackmore et al., 2021). Furthermore, research with the same theme states that STEM learning processes and outcomes are significantly influenced by self-efficacy (Han et al., 2021). Researchers have also previously conducted several studies in the form of AR related to character education in 2022 and associated with several learning models in 2023. Previously, researchers have conducted numerous studies on using AR in character education in 2022 and its association with various learning models in 2023. The researcher believes that the research must be conducted due to the current unrestricted use of the internet, which has resulted in a demoralization of character in elementary school students (Sahronih et al., 2022, 2023). Other research related to STEM and self-efficacy shows that strengthening the STEM approach can support student self-efficacy (Rusmansyah et al., 2023). Furthermore, the use of STEM significantly impacted students' problem-solving abilities (Rahman et al., 2023), critical thinking skills (Hartini et al., 2020; Pahrudin et al., 2021) and higher-order thinking skills (Saputri et al., 2023) during the learning process.

The background of this research is intended to further examine the problems in the field, namely related to the function of using AR in the learning process combined with STEM approaches, which are, in the current era of the Internet of Things, one of the appropriate approaches to be applied in the learning process, especially in science subjects. This research was conducted to determine students' problem-solving ability in science subjects in elementary school and to measure students' self-efficacy. This study is significant because previous research has not found a correlation between the use of AR technology and self-efficacy. Additionally, self-efficacy is a theory present in numerous psychological theory references and is associated with the capacity to organize in order to solve specific problems. This is particularly relevant to the variable of students' problem-solving ability in completing tasks.

The formulation of the problem from this study is: (1) Does the AR-based STEM approach affect the self-efficacy and problem-solving ability of elementary school students? (2) How does self-efficacy correlate with elementary school students' problem-solving ability in science learning? Thus, the purpose of this study is (1) to determine the effect of using an AR-based STEM approach on the self-efficacy and problem-solving ability of elementary school students and (2) to describe the correlation between self-efficacy and problem-solving ability of elementary school students in science learning.

METHODS

This study employed a quasi-experimental research model pretest-posttest non-equivalent control group design. It was located at SDN Taman Kalijaga Permai, Cirebon City, using the purposive sampling area method. The population in this study included all grade V students of SDN Taman Kalijaga Permai for the 2024/2025 school year, totalling 59 students, 33 male students and 26 female students.

The sample in this study was selected using a purposive sampling technique with the criteria that students who can operate gadgets independently and from the student's parents are allowed to use mobile phones for the application of AR media during the learning process. 9 students did not meet the sample criteria in the study, so the total sample in this study was 50 students who were divided into experimental classes, namely class 5A and control classes, namely class 5B.

This study's data collection techniques included tests, surveys, interviews, observations, and documentation. Tests measured problem-solving ability, while questionnaires with pretest and post-test questions determined self-efficacy.

The data analysis test employed homogeneity, normality, and hypothesis tests using SPSS 30. A homogeneity test was used to prove the distribution of homogeneous population variants. The normality test was used to prove whether the sample was normally distributed, while the hypothesis test was used for hypothesis testing.

The initial and final questionnaires were used with modifications of self-efficacy questionnaire scale-type instruments to measure self-efficacy data analysis techniques. The instrument was designed concerning three aspects based on Wood and Bandura's theory: level, strength, and generality (Bandura, 1969, 2023). Then, the data to measure problem-solving ability used a test instrument for questions with problem-solving ability indicators.

A parametric statistical test was conducted using covariance analysis (ANCOVA) to analyze self-efficacy and problem-solving ability data. An independent T-test is employed to evaluate the STEM approach with the assistance of AR media. The decision-making technique ensures that if the Sig < 0.05, Ho is rejected, and Ha is accepted. If the Sig > 0.05, then Ho is accepted, and Ha is rejected.

RESULTS AND DISCUSSION

The implementation of the research was carried out for six weeks, with 4x face-to-face meetings in the science learning process in the classroom using Ecosystem materials, including time to conduct observations and interviews and collect student questionnaire data. Observations, interviews, and pretest activities were carried out in the first week. In the second to fifth weeks, the learning process was carried out by providing treatment in the experimental class, using a STEM approach assisted by learning media in the form of AR in the science learning process. The sixth week was carried out with post-test activities.

Self Efficacy

Figure 1 illustrates the outcomes of the initial and final self-efficacy scores of SDN Taman Kalijaga Permai students in grade V in the control and experimental classes. The experimental and control classes exhibited identical data and did not exhibit a significant difference in the average of their initial self-efficacy scores. However, the experimental class and the control class were compared after the control class underwent treatment, specifically the learning process using the AR-based STEM. The results of the recapitulation of questionnaire data on the level of self-efficacy in the experimental class and control class as in Figure 1.

The average score of the control class's pretest and post-test self-efficacy level was 53 to 60, with sufficient interpretation. In the experimental class, the score increased from 56 to 79, with an acceptable interpretation. Thus, there is a difference between the control class and the experiment after being given treatment, namely in the experimental class using an AR-based STEM approach.

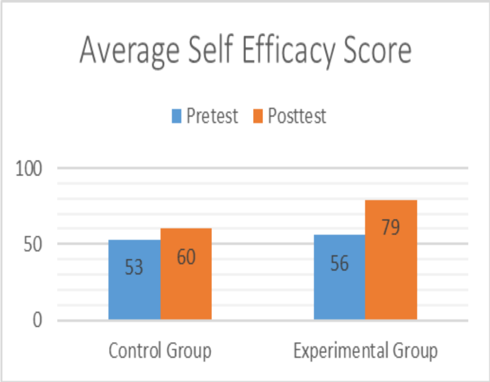

Figure 1 Average pretest and post-test self-efficacy scores

The results of the ANKOVA analysis test of self-efficacy are shown in Table 1.

Table 1 ANKOVA results of self-efficacy data

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4679.016[a]	2	2339.508	41.515	<0.001
Intercept	7479.31	1	7479.31	132.7	<0.001
Pretest	51.796	1	51.796	.919	.343
Self Efficacy	4399.292	1	4399.29	78.066	<0.001
Error	2648.60	47	56.353		
Total	250511.00	50			
Corrected Total	7327.62	49			

a. R Squared = .639 (Adjusted R Squared = .623)

The results from ANKOVA in Table 1 show that there is a significant difference between the control class and the experimental class after the F test. The results can be seen in the table, namely $F_{count} > F_{table}$ (78.066>3.19); thus, it can be concluded that the application of the AR-based STEM approach is significantly different from the self-efficacy for students. Thus, there is a significant difference between the group of students who learn using the AR-based STEM approach and those who do not use the AR-based STEM approach in terms of self-efficacy.

The aspects measured in self-efficacy in this study consist of level, strength, and generality. The three aspects are rearranged in Figure 2.

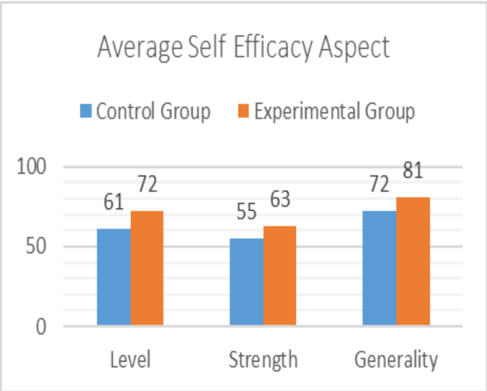

Figure 2 Average score of self-efficacy aspect

The results of each aspect of self-efficacy in the control and experimental classes are distinct. The experimental class achieves higher results than the control class, as illustrated in Figure 2. The greatest score is in the general aspect, as evidenced by the results.

The experimental class achieved a higher average result than the control class in terms of level. This is because the experimental classroom's learning process, which STEM facilitates, can resolve issues (Idawati et al., 2019).

The experimental class exhibited a higher average strength in the self-efficacy results than the control group. The average self-efficacy score in the experimental class is higher because using AR media in conjunction with a learning process based on the STEM approach gives students the confidence to complete the task during the learning process. This is due to the research that has been carried out by Tirka (2021), which states that STEM can increase self-efficacy and influence each other.

The experimental class exhibits a higher generality aspect than the control class, which results in higher average results when compared to other aspects. This is because all forms of assessment in the generality aspect, which includes activities and learning process activities, are heavily represented in learning activities that utilize a STEM approach. This approach provides students with the opportunity to develop critical thinking skills and processes for addressing a variety of tasks and challenges. Additionally, the STEM approach, facilitated by AR media to comprehend concepts in elementary school science material, is closely aligned with the science learning process that is dependent on the capacity to think logically. Furthermore, using STEM in the educational process can generate an enjoyable learning experience and inspire students to solve various problems (Alfika et al., 2019).

Problem-Solving Ability

Pretest and post-test data from the recapitulation of science problem-solving skills of Class V students of SDN Taman Kalijaga Permai in the experimental and control classes are shown in Figure 3.

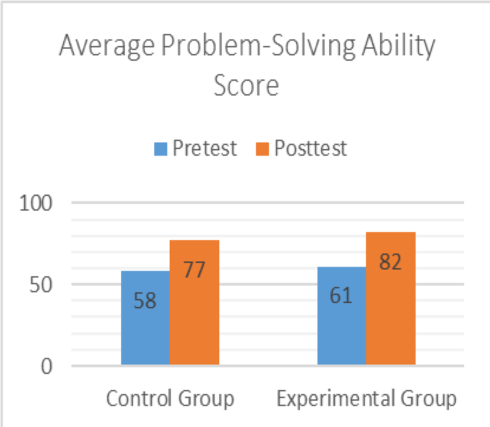

Figure 3 Average score of pretest and post-test problem-solving ability

Figure 3 shows that the average problem-solving ability between the control and experimental classes at the pretest did not show a significant difference or was in a low category, namely in the control class of 58, while in the experimental class, it was 61. However, after treatment, there was a significant difference between the experimental and control classes, with scores of 77 for the control and 82 for the experimental classes, respectively. Thus, there is a significant difference between students who learned using the

AR-based STEM approach and those who learned without using the AR-based STEM approach in terms of problem-solving skills in science subjects.

Table 2 shows the average pretest and post-test scores of students' science problem-solving skills using the ANKOVA analysis test. The experimental class scored the highest in the post-test with problem-solving skills, scoring 82.

Table 2 ANKOVA results problem-solving ability data

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	568.926[a]	2	284.463	12.293	<0.001
Intercept	7160.41	1	7160.41	309.4	<0.001
Pretest	271.246	1	271.2	11.7	0.001
Problem_ Solv_Ability	227.447	1	227.447	9.829	0.003
Error	1087.55	47	23.139		
Total	317828.000	50			
Corrected Total	1656.480	49			

a. R Squared = .343 (Adjusted R Squared = .316)

The results of Table 2 show a significant difference between the experimental and control classes after the F-test. Namely, the results show that with the value of $F_{count} > F_{table}$ or 9.829 > 3.19, thus it can be concluded that the use of STEM assisted by AR media significantly differs from students' problem-solving skills in science learning.

The Correlation of Self-Efficacy and Problem-Solving Ability

After data processing using SPSS 30, data was obtained as a correlation between variables, namely the relationship between self-efficacy and problem-solving ability. The results obtained through the correlation test show this. The following are the results of the correlation data in Table 3.

Table 3 Correlation test results

		Self_Efficacy	Problem_Solv Ability
Self_ Efficacy	Pearson Correlation	1	.464**
	Sig. (1-tailed)		<0.001
	N	50	50
Problem_ Solv_Ability	Pearson Correlation	.464**	1
	Sig. (1-tailed)	<0.001	
	N	50	50

**. Correlation is significant at the 0.01 level (1-tailed).

The correlation test was obtained between self-efficacy and problem-solving ability, namely the calculation > the table (0.464 > 0.235). Self-efficacy and the ability of student learning outcomes have a positive correlation at a moderate level. For the significance value, it is also known that 0.001 < 0.05; thus, it can be continued to calculate the T-test so that the effect between variables can be known to each other in this study.

Based on the t-test, it was obtained that the $t_{count} > t_{table}$ (3,630 > 2,010), so it can be concluded that self-efficacy and problem-solving ability have a significant correlation. The following are the results of the t-test in Table 4.

Table 4 T-test Results

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	64.133	4.303		14.905	<0.001
	Self_ Efficacy	.221	.061	.464	3.630	<0.001

a. Dependent Variable: Problem-Solving Ability

Figure 4 illustrates the regression between the two variables, which serves as a predictor of the variable self-efficacy's influence on problem-solving ability.

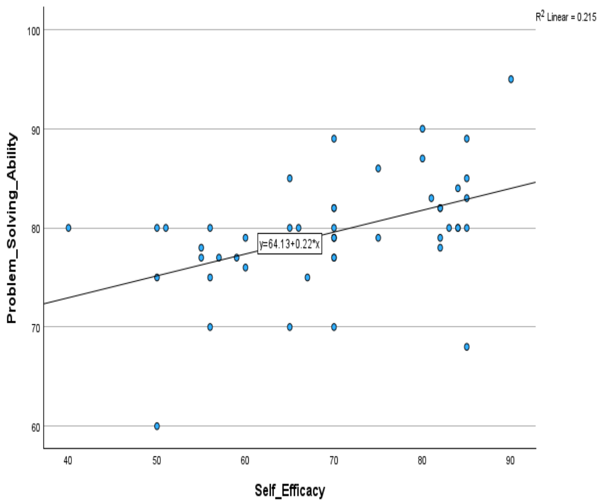

Figure 4 Regression between self-efficacy and problem-solving ability

The average score of self-efficacy is 62, and the average score of problem-solving ability is 70, so a scatter diagram is formed in the form of a regression line of the equation y = 0.22x + 64.13. Based on this equation, it is obtained that if the self-efficacy score (X) is equal to 0, then the problem-solving ability (Y) has a score of 64.13, which means that low self-efficacy for students has a low problem-solving ability of 64.13. On the other hand, if the student's self-efficacy score is high, he will also obtain high problem-solving skills. If students have self-efficacy with a maximum score of 100, then their problem-solving skills will increase by a score of 85. In other words, every 1% increase in variable self-efficacy contributes 64.13 to problem-solving ability. The determination coefficient (R2) has a score value of 0.215, which shows that variable x in the form of a STEM approach assisted by AR media affects the problem-solving ability of students in science learning by 21%, the rest is 79% influenced by other factors that are not analyzed in this study.

Students must possess internal cognitive and motivational factors in order to engage in the problem-solving process. The motivational factor fosters confidence and the ability to solve problems completely, while the cognitive factor pertains to the degree to which students can think positively about the success of problem-solving (Allanta & Puspita, 2021). Students' self-efficacy is comprised of these two components. The STEM approach to learning involves activities that aid in developing students' cognitive abilities and motivation.

Students may implement environmental problem-solving activities in the actual world, provided they possess sufficient self-efficacy. These in-learning activities can be incorporated with STEM approaches that offer students a comprehensive comprehension of scientific concepts (Putri et al., 2024).

The study's results indicate that self-efficacy is a significant factor in the learning process and is associated with problem-solving abilities. This is also influenced by the learning process, which is facilitated by using AR media designed with a STEM approach. In accordance with the research conducted by Han et al. (2021), the learning process using STEM is significantly influenced by self-efficacy and problem-solving skills. The use of AR media provides interesting insights for students learning science, along with supporting concepts in the form of STEM approaches. Therefore, the existence of good self-efficacy for students will improve problem-solving skills during the learning process (Rusmansyah et al., 2023). Furthermore, self-efficacy can foster students' cognitive curiosity and nurture learning motivation as a means of encouragement for resolving learning problems and challenges. The more self-efficacy students possess, the greater their curiosity and capacity to solve problems in learning activities. This is consistent with prior research, which has demonstrated that integrating STEM into the learning process can benefit learning outcomes (Blackmore et al., 2021).

The study's results also indicate that implementing an AR-based STEM approach impacts students' self-efficacy and problem-solving abilities. One of the skills that students must possess in the 21st century is the capacity to solve various problems in a manner conducive to the student's creative process (González-Pérez & Ramírez-Montoya, 2022). Furthermore, students' self-efficacy significantly impacts their character, a component of their other abilities. The maximum score in this study is at the generality level, as per Bandura's theory of self-efficacy, which comprises three components: level, strength, and generality. In theory, the degree of generality correlates with an individual's conviction that they should only complete specific related and generalized tasks (Bandura, 1978). The 21st-century learning process necessitates students to independently construct knowledge from the environment to comprehend scientific concepts by relying on self-efficacy for students, specifically their confidence to complete specific tasks as a form of challenge.

The use of technology in education can have a positive and significant impact based on the results of this study. However, the reality is that not all schools have implemented technology in their teaching practices due to the limitations of facilities and infrastructure, as well as the digital literacy skills of their teachers. Consequently, it is imperative to conduct ongoing training. Furthermore, the implementation of suitable methodologies during the learning process is essential for the attainment of learning objectives that are consistent with the relevant curriculum output targets. Consequently, all stakeholders in the education sector must adopt a proactive approach to enhancing the capabilities of teachers in order to enhance student motivation and self-efficacy in the learning process.

Several limitations were identified after conducting research and data processing related to the implementation of AR with a STEM approach. One of these limitations is that this research was conducted exclusively in one of the elementary schools in Cirebon City, necessitating additional samples to enhance the next research. In addition, the restricted investigation time is only adjusted to the theme of the science subject in a limited number of meetings in accordance with the subject being taught. In addition to reflection, recommendations for additional research development may be implemented in additional subjects at the elementary and secondary levels, including junior high and high school.

CONCLUSION

The results of the study indicated that implementing the STEM approach, which was facilitated by augmented reality media, impacted the self-efficacy and problem-solving skills of students studying material about ecosystem balance. The deployment of the AR-based STEM approach showed a significant correlation between students' self-efficacy and problem-solving skills in this study. This is evidenced by the t-test value that the $t_{count} > t_{table}$ is 3,630 > 2,010. The higher the self-efficacy, the higher the problem-solving ability possessed by students. Consequently, elementary school teachers in Indonesia can participate in a variety of training sessions in order to enhance the learning process by recommending the appropriate approach, such as STEM, and enhancing the capabilities of teachers in the use of technology in the form of AR. One of the concrete solutions to enhance students' self-efficacy in problem-solving is the implementation of AR-based STEM. A data collection process can be conducted with a broader sample and varying levels of education to refine the findings related to the application of AR-based STEM for further research.

REFERENCES

Alfika, Z. A., Mayasari, T., & Kurniadi, E. (2019). Modul STEM berbasis pemecahan masalah dengan tema rumah dome. *Jurnal Pendidikan Fisika*, *7*(1), 93–105.

Allanta, T. R., & Puspita, L. (2021). Analisis keterampilan berpikir kritis dan self efficacy peserta didik: Dampak PjBL-STEM pada materi ekosistem. *Jurnal Inovasi Pendidikan IPA*, *7*(2), 158–170.

Arena, F., Collotta, M., Pau, G., & Termine, F. (2022). An overview of augmented reality. *Computers*, *11*(2), 28.

Bandura, A. (1969). *Psikologi perkembangan*. PT. Gramedia Widiasarana Indonesia.

Bandura, A. (1978). Self-efficacy: Toward a unifying theory of behavioral change. *Advances in behaviour research and therapy*, *1*(4), 139–161.

Bandura, A. (2023). *Social cognitive theory: An agentic perspective on human nature*. John Wiley & Sons.

Baran, M., Baran, M., Karakoyun, F., & Maskan, A. (2021). The ınfluence of project-based STEM (PjbL-STEM) applications on the development of 21st century skills. *Journal of Turkish Science Education*, *18*(4), 798-815.

Blackmore, C., Vitali, J., Ainscough, L., Langfield, T., & Colthorpe, K. (2021). A review of self-regulated learning and self-efficacy: The key to tertiary transition in science, technology, engineering and mathematics (STEM). *International Journal of Higher Education*, *10*(3), 169–177.

Broo, D. G., Kaynak, O., & Sait, S. M. (2022). Rethinking engineering education at the age of industry 5.0. *Journal of Industrial Information Integration*, *25*, 100311.

Burbules, N. C., Fan, G., & Repp, P. (2020). Five trends of education and technology in a sustainable future. *Geography and sustainability*, *1*(2), 93–97.

Chen, C. H., Chou, Y. Y., & Huang, C. Y. (2016). An augmented-reality-based concept map to support mobile learning for science. *The Asia-Pacific Education Researcher*, *25*, 567-578.

Dare, E. A., Keratithamkul, K., Hiwatig, B. M., & Li, F. (2021). Beyond content: The role of STEM disciplines, real-world problems, 21st century skills, and STEM careers within science teachers' conceptions of integrated STEM education. *Education Sciences*, *11*(11), 737.

Dargan, S., Bansal, S., Kumar, M., Mittal, A., & Kumar, K. (2023). Augmented reality: A comprehensive review. *Archives of computational methods in engineering*, *30*(2), 1057–1080.

González-Pérez, L. I., & Ramírez-Montoya, M. S. (2022). Components of Education 4.0 in 21st century skills frameworks: systematic review. *Sustainability*, *14*(3), 1493.

Han, J., Kelley, T., & Knowles, J. G. (2021). Factors influencing student STEM learning: Self-efficacy and outcome expectancy, 21st century skills, and career awareness.

Journal for STEM Education Research, *4*(2), 117–137.

Hartini, S., Mariani, I., Misbah, M., & Sulaeman, N. F. (2020). Developing of students worksheets through STEM approach to train critical thinking skills. *Journal of Physics: Conference Series*, 1567(4), 042029. IOP Publishing.

Idawati, I., Muhardjito, M., & Yuliati, L. (2019). *Authentic learning berbasis inquiry dalam program STEM terhadap literasi saintifik siswa berdasarkan tingkatan kemampuan pemecahan masalah siswa*. State University of Malang.

Jesionkowska, J., Wild, F., & Deval, Y. (2020). Active learning augmented reality for STEAM education—A case study. *Education Sciences*, *10*(8), 198.

Kesim, M., & Ozarslan, Y. (2012). Augmented reality in education: Current technologies and the potential for education. *Procedia-social and behavioral sciences*, *47*, 297–302.

Lai, A. F., Chen, C. H., & Lee, G. Y. (2019). An augmented reality-based learning approach to enhancing students’ science reading performances from the perspective of the cognitive load theory. *British Journal of Educational Technology*, *50*(1), 232-247.

Lee, T., Wen, Y., Chan, M. Y., Azam, A. B., Looi, C. K., Taib, S., Ooi, C. H., Huang, L. H., Xie, Y., & Cai, Y. (2024). Investigation of virtual & augmented reality classroom learning environments in university STEM education. *Interactive learning environments*, *32*(6), 2617–2632.

Mystakidis, S., Christopoulos, A., & Pellas, N. (2022). A systematic mapping review of augmented reality applications to support STEM learning in higher education. *Education and Information Technologies*, *27*(2), 1883-1927.

Pahrudin, A., Misbah, M., Alisia, G., Saregar, A., Asyhari, A., Anugrah, A., & Susilowati, N. E. (2021). The effectiveness of science, technology, engineering, and mathematics inquiry learning for 15-16 years old students based on k-13 indonesian curriculum: the impact on the critical thinking skills. *European Journal of Educational Research*, *10*(2), 681-692.

Pregowska, A., Masztalerz, K., Garlińska, M., & Osial, M. (2021). A worldwide journey through distance education—from the post office to virtual, augmented and mixed realities, and education during the COVID-19 pandemic. *Education sciences*, *11*(3), 118.

Putri, M. O. S., Putra, P. D. A., & Ridlo, Z. R. (2024). Pengembangan modul IPA berbasis STEM untuk meningkatkan keterampilan pemecahan masalah bagi siswa SMP. *Jurnal Pendidikan MIPA*, *14*(1), 289–297.

Rahman, A., Suharyat, Y., Ilwandri, I., Santosa, T. A., Sofianora, A., Gunawan, R. G., & Putra, R. (2023). Meta-Analisis: Pengaruh pendekatan STEM berbasis etnosains terhadap kemampuan pemecahan masalah dan berpikir kreatif siswa. *Innovative: Journal of social science research*, *3*(2), 2111–2125.

Rusmansyah, R., Rahmah, S. A., Syahmani, S., Hamid, A., Isnawati, I., & Kusuma, A. E. (2023). The implementasi model PjBL-STEAM konteks lahan basah untuk meningkatkan kemampuan berpikir kritis dan self-efficacy peserta didik. *JINoP (Jurnal inovasi pembelajaran)*, *9*(1), 44–57.

Sahronih, S., Ismuwardani, Z., Suanto, A., & Shofari, M. R. (2022). Pengembangan media pembelajaran edugame augmented reality bermuatan pendidikan karakter pada siswa sekolah dasar. *Tematik*, *9*(2), 128–133.

Sahronih, S., Suryono, T., Maemuna, S., & Hasanah, D. (2023). Integrasi teknologi augmented reality berbasis model samr (substitution, augmentation, modification, redefinition) dalam pembelajaran ipa sekolah dasar. *Prima magistra: Jurnal ilmiah kependidikan*, *4*(4), 619–629.

Saputri, D. F., Wahyudi, W., Nurhayati, N., Nurussaniah, N., & Misbah, M. (2023). Development of electronic modules based on science, technology, engineering and mathematical (stem) approaches in vibration and wave courses. *Jurnal Pendidikan Fisika dan Keilmuan (JPFK)*, *9*(1), 53-65.

Sungkur, R. K., Panchoo, A., & Bhoyroo, N. K. (2016). Augmented reality, the future of contextual mobile learning. *Interactive Technology and Smart Education*, *13*(2), 123-146.

Tirka, R. A. (2021). *Pengaruh PjBL (project based learning) dengan pendekatan STEM (science, technology, engineering and mathematics) terhadap keterampilan berpikir kritis dan self efficacy peserta didik*. UIN raden intan lampung.

Yang, D., & Baldwin, S. J. (2020). Using technology to support student learning in an integrated STEM learning environment. *International Journal of Technology in education and science*. *4*(1), 1-11.

Yoon, S., Anderson, E., Lin, J., & Elinich, K. (2017). How augmented reality enables conceptual understanding of challenging science content. *Journal of Educational Technology & Society*, *20*(1), 156-168.