Journal Evaluation in Education (JEE)
Vol. 7, No. 1, January 2026, pp. 282~290
ISSN: 2716-4160, DOI: 10.37251/jee.v7i1.2378

Research Article

Ethno-STEM Innovation in Science Learning: Developing Scientific Literacy Using the Local Context of "*Dawet Jabung*"

Muhammad Naqqi Imani[1,*], Wahono Widodo[2], Sukarmin[3], Muhammad Satriawan[4]
[1] Department of Magister Science Education, Universitas Negeri Surabaya, Jawa Timur, Indonesia
[2] Department of Natural Sciences Education, Universitas Negeri Surabaya, Jawa Timur, Indonesia
[3] Department of Chemistry Education, Universitas Negeri Surabaya, Jawa Timur, Indonesia
[4] Department of Physics Education, Universitas Negeri Surabaya, Jawa Timur, Indonesia

Article Info

Article history:

Received Nov 22, 2025
Revised Dec 23, 2025
Accepted Jan 20, 2026
OnlineFirst Jan 31, 2026

Keywords:

Dawet Jabung
Ethno-STEM
Local Wisdom
Scientific Literacy
STEM Learning

ABSTRACT

Purpose of the study: This study aims to analyze the effectiveness of a locally contextualized STEM-based learning device, "*Dawet Jabung*," in improving students' scientific literacy at MA Darul Huda.

Methodology: A quasi-experimental posttest non-equivalent control group design was used. The experimental class (n = 16) learned using a STEM-based "Dawet Jabung" learning device, while the control class (n = 16) used traditional materials. Quantitative data were collected through a scientific literacy questionnaire and analyzed using descriptive statistics, independent-samples t-test, and N-Gain scores with SPSS 21. Qualitative data from interviews supported the quantitative findings.

Main Findings: The experimental class showed higher scientific literacy, with 75% categorized as "good" and 25% as "very good" (M = 68), compared with the control class, which was dominated by the "poor" category (50%) with an average score of 58. The t-test revealed a significant difference (t = 9.297 > t-table = 2.036). The N-gain score of 0.65 indicated moderate effectiveness. Interview results indicated increased engagement, curiosity, and conceptual understanding among students who used the STEM tool.

Novelty/Originality of this study: This study introduces a unique Ethno-STEM learning device integrating local wisdom "Dawet Jabung," bridging scientific concepts with cultural practices. The innovation advances existing STEM literature by demonstrating that integrating cultural context enhances scientific literacy more effectively than conventional STEM alone. This work contributes a new pedagogical model aligned with the Merdeka Belajar curriculum's emphasis on contextual and culturally responsive learning.

Corresponding Author:
Muhammad Naqqi Imani,
Department of Magister Science Education, Universitas Negeri Surabaya,
Lidah Wetan, Kec. Lakarsantri, Surabaya, Jawa Timur, 60213, Indonesia
Email: 24030795014@mhs.unesa.ac.id

1. INTRODUCTION

The world in the 21st century is experiencing rapid technological and scientific developments, marked by the transition to Society 5.0, which combines the real and virtual worlds through advanced technologies such as the Internet of Things (IoT) and Artificial Intelligence (AI) [1]-[4]. This transformation requires every country to prepare adaptive, creative, and high-quality human resources. Therefore, global education now focuses on improving the quality of human resources to compete internationally [5]-[7]. In this context, scientific literacy is a crucial 21st-century life skill because it is an indicator of national progress and key to improving people's quality of life. Scientific literacy skills enable individuals to think scientifically and analyze social, environmental, health, and technological issues, making assessment of students' scientific literacy skills crucial [8]-[11]. This situation is clarified by the World Economic Forum, which places scientific literacy as one of the six Foundational Literacies that students must master to adapt to the complex challenges of the 21st century. However, this reality is not yet fully reflected in educational practices in Indonesia.

Pre-research results at MA Darul Huda revealed a misalignment between learning methods and student expectations. The majority of students (85%) assessed that science learning was still theoretical, lacked practical experience, and lacked contextualization, making it difficult for them to connect scientific concepts to everyday life. They explicitly expressed the need for more interactive, applicable, and technology-supported learning, such as simulations and 3D visual media. These findings align with numerous studies confirming that contextual, experiment-based, and technology-integrated learning is highly effective in increasing motivation and learning outcomes [12]-[14]. Furthermore, the use of problem-solving and technology-based learning strategies has been shown to encourage students to think critically and apply their knowledge in real-life situations [15]-[17]. The mismatch between the still-dominant traditional learning and students' need for practical, contextual, and problem-solving-based learning creates a gap in motivation and understanding, ultimately contributing to low scientific literacy outcomes.

Empirically, students' scientific literacy skills at MA Darul Huda Ponorogo are categorized as low, with an average score of 47.32. Similar findings were seen in other schools in the surrounding area, such as Madiun, which recorded an average score of 43.15, and research in East Java at the MA/SMA level showed an average percentage of around 58%, categorized as low. This data confirms a significant gap between global demands and students' actual abilities in mastering scientific literacy. Efforts to improve this situation can be achieved through student-centered learning that integrates various disciplines to deepen conceptual understanding, one example of which is the STEM approach [18]-[22]. STEM connects science, technology, engineering, and mathematics through authentic problem-solving activities, making it ideal for developing essential 21st-century skills [23]-[25]. This approach can be enhanced with innovative problem-solving-based learning strategies, which have been shown to improve scientific literacy and are particularly effective when integrated with STEM [26]-[28].

Nationally, scientific literacy is a strategic mandate in the Independent Curriculum, which emphasizes strengthening literacy and numeracy as the foundation of learning. Phase E of the Independent Curriculum in Biology mandates mastery of science process skills and local issue-based problem-solving [29], [30]. Therefore, utilizing the surrounding environment as a learning resource has proven effective in improving scientific literacy, particularly in the subject of Biodiversity. In its implementation, learning tools function as systematic guides that provide students with an active role, with teachers acting as facilitators [31]-[33]. Thus, learning tools that integrate STEM in local contexts, such as Dawet Jabung, have the potential to meaningfully improve science literacy by linking scientific concepts with students' cultural realities.

Based on a comprehensive analysis, three main research gaps underlie the urgency of this research. First, students' scientific literacy achievement remains low due to the dominance of conventional methods that fail to meet the demands of practical, contextual, and problem-solving learning. Second, although local contexts like Dawet Jabung have great potential as media for contextual learning, there has been no development of STEM-based science learning tools that specifically integrate this local wisdom. Third, existing learning tools have not been designed with an integrated STEM framework and do not explicitly facilitate the science process skills mandated by the Independent Curriculum. Interviews with biology teachers at MA Darul Huda reinforced these gaps: the tools used are still printed textbooks with material summaries and questions, there are no STEM-based tools, and teachers are not yet thoroughly familiar with the STEM approach despite recognizing the need for innovation.

Previous studies have also shown a gap in effectiveness between pure STEM and Ethno-STEM models. The ethnoscience approach has been shown to improve science literacy significantly [34], [35], with moderate to high N-gain, whereas pure STEM produced only a moderate N-gain [36]. Meanwhile, Ethno-STEM achieved a high N-gain. This demonstrates that integrating local context is crucial for the success of STEM-based learning. However, no research has used the local context of Ponorogo, namely *Dawet Jabung*, as the basis for developing STEM-based science learning tools. The lack of research examining this context presents a crucial research gap to be filled. Based on the background, empirical conditions, and research gaps.

2. RESEARCH METHOD

The researcher's research design is quantitative, using a quasi-experimental posttest non-equivalent control group design. It was done to investigate causal hypotheses by comparing one or more experimental groups that received treatment with a comparison group that did not. This research design was applied because it aligns with the research objectives, which aim to determine whether STEM-based learning devices can affect students' scientific literacy. This study uses descriptive statistics (mean, min, and max) and inferential statistics. The inferential statistic used is the independent-samples t-test.

Tabel 1. Posttest Non-Equivalent Control Group Design

Group	Pretest	Treatment	Posttest
Experimental	O_1	Using the STEM-Based Learning Tool "*Dawet Jabung*"	O_1
Control	O_2	Traditional Learning Tools	O_2

This study was conducted at MA Darul Huda Ponorogo with a total of 32 students in class X. There were 16 students in the experimental class and 16 students in the control class. The experimental class used the STEM-Based Learning Tool "*Dawet Jabung*," while the control class used traditional learning tools. The sample collection technique used was purposive sampling. Purposive sampling is a sampling technique based on the researcher's criteria [37].

In this study, the first step in the data collection process was to provide interventions only to the experimental class using the STEM-Based Learning Tool "*Dawet Jabung*." In contrast, the control class received traditional learning tools. The results of the scientific literacy assessment were then compared between students who used the STEM-Based Learning Tool "*Dawet Jabung*" and those who did not. The instrument used was a scientific literacy questionnaire and interviews supported the quantitative findings. The science literacy questionnaire uses a 4-point Likert scale for positive statements. Strongly Disagree has a score of 1, Disagree has a score of 2, Fair has a score of 3, Agree has a score of 4, and Strongly Agree has a score of 5. For negative statements, Strongly Disagree has a score of 5, Disagree has a score of 4, Fair has a score of 3, Agree has a score of 2, and Strongly Agree has a score of 1.

Below are the categories of science literacy, including very good, good, fair, not good, and very not good, as in Table 2.

Table 2. Categorization of scientific literacy

Category	Interval
Very Good	40.0 – 50.0
Good	50.1 – 60.0
Not Good	60.1 – 70.0
Very Not Good	70.1 – 80.0

And category for n-gain in Tabel 3.

Table 3. N-Gain Category

N-Gain	Category
$G > 0.7$	High
$0.3 < G < 0.7$	Moderate
$G < 0.3$	Low

All data obtained from the science literacy questionnaire in the control and experimental classes were collected, then calculated and analyzed using SPSS 21. Descriptive statistics were used to calculate the frequency, percentage, mean, minimum, and maximum for the control and experimental groups. In this study, quantitative data were analyzed using parametric statistics, including the independent-samples t-test. An independent-samples t-test was conducted to examine the effect of science literacy on STEM-based learning devices. This study used SPSS 21 at a significance level of 0.05. and Qualitative used miles and Huberman.

3. RESULTS AND DISCUSSION

This section describes the research findings on students' scientific literacy abilities. The results of Category, Mean, Min, Max, and Percentage on the posttest, showing the impact of the STEM-based learning device "*Dawet Jabung*" on scientific literacy among MA Darul Huda students, are presented as follows.

Table 4. Gaps in Students' Science Literacy Ability Scores

	Interval Range	Interval Category	Interval Total	Mean	Min	Max	%
Class Experiment	40.0 – 50.0	Not very good	0	68	64	78	0.0
	50.1 – 60.0	Not good	0				0.0
	60.1 – 70.0	Good	12				75.0
	70.1 – 80.0	Very good	4				25.0
TOTAL			16				100
	Range	Category	Total	Mean	Min	Max	%
Class Control	40.0 – 50.0	Not very good	2	58	48	72	12.5
	50.1 – 60.0	Not good	8				50.0
	60.1 – 70.0	Good	6				37.5
	70.1 – 80.0	Very good	0				0.0
TOTAL			16				100

From table 4, which comes from 16 respondents from MA Darul Huda students, it is categorized as good in the experimental class, and after being processed and the results obtained using the SPSS 21 program application, it is obtained that the scientific literacy in the experimental class has a good category of 50.0% for 12 students from 16 total students, and very good 25% for 4 students from 16 total students. Of the 16 students, the Mean is 68, the Maximum is 78, and the Minimum is 64. Then in the control class which comes from 16 respondents, the dominant category is not good, and after being processed and the results obtained using the SPSS 21 program application, it is obtained that the scientific literacy of students in the control class has a bad category of 50% for 8 students from 16 total students, good 37.5% for 6 students from 16 total students, very bad 12.5% for 2 students from 16 total students. The 16 students had a mean score of 58, a maximum score of 72, and a minimum score of 48.

This comparison indicates that traditional learning is unable to meet students' needs for scientific literacy. At the same time, the "*Dawet Jabung*" STEM device provides a more contextual, applicable, and problem-solving-based learning experience, thus encouraging improved student academic performance.

Table 5. Independent sample t-test for scientific literacy

	t	df	Mean	Std.Deviation	*95% confidence interval* Lower	*95% confidence interval* Upper
Literacy Scientific	9.297	32	3.1972	.14321	8.134	.6120
	9.297	8.167	2.6148	.20015	7.885	.8615

From table 5 it can be seen that the value is obtained (t count) with the t table value. The t-table value can be found in the t table with a significance value of 0.05 (2-sided test) with degrees of freedom (df) 32. In this study, the results for the t table are 2.036933. While for the t count value can be seen in table 5 (t column) which is 9.297. The criteria for testing the hypothesis is the value of rejection of H0. So, it can be concluded that there is a significant difference in students' scientific literacy between the control class taught with traditional learning tools and the experimental class using the STEM-based learning tool "*Dawet Jabung*". It can be seen from table 5 that the average value of student literacy scientific is 3.1972, which means it can improve students' scientific literacy. To emphasize these results, the n-gain value is obtained as in table 6.

Tabel 6. N-Gain Results

N-gain Score	Decision
0.65	Moderate

The effectiveness of the STEM-based learning device "*Dawet Jabung*" is evident from the N-gain scores in Table 6. The average value is 0.65. This means that the effectiveness of the STEM-based learning device "*Dawet Jabung*" in learning is included in the moderate category, or the interpretation category is quite effective. This moderate category indicates that the device functions optimally, but still has room for further development to reach the high category.

In-depth interviews with subject teachers and student representatives supported the quantitative findings regarding improved scientific literacy in the experimental class. The experimental class teacher reported that the use of the "*Dawet Jabung*" STEM kit resulted in significant changes in student engagement patterns. The teacher stated that students demonstrated increased initiative in asking questions, participating in discussions, and conducting independent explorations during the lab activities. According to the teacher, the kit "provides more concrete and relevant learning experiences to students," making scientific concepts related to mixtures, the properties of substances, and the processes of changes of state easier to understand. The teacher also emphasized that the local context-based activities helped students connect theoretical concepts with phenomena they encounter every day.

Similar responses emerged in interviews with students in the experimental class. The majority of students reported that learning using "*Dawet Jabung*" improved their understanding of the material because they were directly involved in the scientific process, rather than simply listening to explanations. One student stated that the lab activities made it "easier to remember and re-explain scientific concepts, because they had seen and experienced the process themselves." Other students reported that hands-on learning made them more interested in solving problems and in exploring other scientific phenomena outside the classroom. This increase in motivation and curiosity is consistent with the high proportion of "good" and "very good" scores in scientific literacy in the experimental class.

In contrast, interviews with students and teachers in the control class revealed challenges in traditional learning. Teachers acknowledged that student engagement was relatively low and that some students struggled to understand the material because the presentation still relied heavily on lectures and abstract explanations. Students in the control class stated that they often "couldn't visualize the scientific process just from the text," making them less confident in answering scientific literacy-based questions. This condition aligns with quantitative findings, which showed lower average scores and a predominance of "poor" scores in scientific literacy in the control class. Overall, the interview results strengthen the quantitative evidence that the "*Dawet Jabung*" STEM learning toolkit can improve scientific literacy through a more contextual, applicable, and problem-solving-oriented learning experience. Interviews indicated that the tool not only improved conceptual understanding but also increased student engagement, curiosity, and motivation. The integration of qualitative and quantitative perspectives confirms the toolkit's effectiveness in developing scientific literacy more comprehensively than traditional learning.

The study's results indicate that the use of the locally context-based STEM learning tool "*Dawet Jabung*" significantly improved students' scientific literacy at MA Darul Huda. In the experimental class, 75% of students achieved the "good" category, and 25% achieved the "very good" category, with an average score of 68. In contrast, the control class was dominated by the "poor" category (50%), with only 37.5% achieving the "good" category, and the average score was 58. The results of the independent-samples t-test supported this finding, with the calculated t-value of 9.297 exceeding the t-table value of 2.036, indicating a significant difference between the two groups. These findings align with previous research suggesting that STEM learning can improve students' conceptual understanding, critical thinking, and problem-solving skills [38]-[41]. Still, this study adds a new dimension by integrating local wisdom, a topic that has not been widely explored in Indonesian STEM literature.

Pedagogically, the effectiveness of this learning tool can be explained by the characteristics of STEM learning: integrative, contextual, and prioritizing authentic problem-solving. Through the STEM approach, students connect the concepts of science, technology, engineering, and mathematics to real phenomena, thereby strengthening conceptual understanding and scientific literacy [42], [43]. The integration of local wisdom "*Dawet Jabung*" further enriches the learning process by teaching scientific concepts through activities that are close to students' lives and culture. Empirical evidence shows that local context can increase student relevance, motivation, and engagement in learning. Thus, it is not surprising that students in the experimental class showed higher scientific literacy, as they learned through meaningful, culturally appropriate experiences.

Qualitative findings from interviews corroborate the quantitative evidence. Teachers reported that students appeared more active in asking questions, grasped concepts more easily, and displayed high levels of enthusiasm during the practicum. Students also reported that learning became more engaging because they could directly observe scientific processes, such as changes in the state of materials, changes in physical properties, and reactions that occur during the making of "*Dawet Jabung*." These findings are consistent with the view that hands-on science learning can improve scientific literacy by developing scientific process skills such as observation, analysis, and decision-making [44]-[46]. This activity aligns with the OECD-PISA scientific literacy framework, which emphasizes students' ability to apply scientific knowledge to real-world situations.

The N-gain value of 0.65, in the moderate category, indicates that the "*Dawet Jabung*" learning tool is quite effective in improving scientific literacy, though there is still room for improvement. These results are consistent with findings that STEM learning often results in moderate to high increases in scientific literacy. This moderate category is likely influenced by the heterogeneity of students' initial abilities, the level of teacher preparedness, and the complexity of the activities, which can still be optimized. To achieve a high N-gain, refining the activity design, using more varied technologies, and providing further teacher training are essential for optimal implementation of the tools.

Overall, this study's findings confirm that integrating STEM and local wisdom is a powerful strategy for improving students' scientific literacy. The use of "*Dawet Jabung*" not only creates contextual and applicable learning but also develops scientific thinking skills relevant to everyday life. This research expands the evidence that locally context-based learning tools can strengthen the understanding of scientific concepts in a more meaningful way [47]-[51]. Furthermore, these tools have the potential to be replicated and developed in other local contexts in Indonesia, thereby improving the quality of science education nationwide.

The novelty of this research lies in the unique integration of the STEM approach and the local wisdom of "*Dawet Jabung*," which has not been widely explored in scientific literacy studies. Unlike conventional STEM research, which emphasizes only cognitive aspects, this study demonstrates that STEM learning grounded in local culture can improve scientific literacy while strengthening students' cultural identity. This approach presents a new pedagogical model that integrates science and technology with local values as a source of scientific learning. The implications of this research are significant for teachers, schools, and curriculum developers. For teachers, this toolkit can serve as an example of a learning strategy that can effectively improve science literacy through authentic, culturally based activities. For schools and Islamic schools (madrasahs), this research demonstrates the importance of integrating science content with local culture as an innovation to address low national science literacy. For policymakers, these findings support the development of locally context-based education policies incorporated into the Merdeka Belajar curriculum.

A limitation of this research lies in the limited sample size of a single madrasah, so generalizations of the findings should be made with caution. The relatively short intervention period also limits the researchers' ability to measure long-term impacts on science literacy. Furthermore, this study did not delve deeply into the affective and socio-cultural aspects that may arise from integrating local wisdom into learning. Given these limitations, recommendations for future research include expanding the sample to include other madrasahs and schools with different characteristics, conducting longitudinal studies to assess the sustainability of the toolkit's impact, and developing similar tools for other local contexts, such as traditional foods, crafts, or regional cultural practices. Future research is also recommended to combine quantitative and qualitative methods to gain a more comprehensive understanding of changes in students' scientific literacy. Furthermore, tool development could focus on integrating digital technologies, such as simulations, augmented reality, and STEM-based applications, to enhance learning effectiveness and appeal.

4. CONCLUSION

The findings of this study demonstrate that the expectations outlined in the introduction namely the need for contextual, problem-solving-oriented, and culturally relevant learning were successfully achieved through the implementation of the STEM-based "*Dawet Jabung*" learning device. The experimental class achieved significantly higher scientific literacy scores than the control class, supported by both quantitative data ($t = 9.297$; N-gain = 0.65) and qualitative evidence showing improved engagement, curiosity, and conceptual understanding. The integration of STEM with local wisdom proved effective in connecting scientific concepts to students' real-life experiences, making learning more meaningful and culturally relevant. This confirms that Ethno-STEM approaches can strengthen scientific literacy and address gaps found in traditional learning methods. The prospects of this research include expanding the development of similar local-context STEM tools across different regions and subjects, aligning with the Merdeka Belajar curriculum. Future studies can explore long-term impacts, wider populations, and integration with digital technologies such as AR/VR-based STEM applications. This research therefore contributes not only to improving scientific literacy but also to promoting culturally grounded science education in Indonesia.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to all parties who contributed to the completion of this research.

AUTHOR CONTRIBUTIONS

MNI was responsible for the research design, data collection, data analysis, and manuscript preparation. WW, S, and MS, contributed to conceptual development, research methodology guidance, and critical review of the manuscript. All authors have read and approved the final version of the manuscript.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

REFERENCES

[1] D. Mourtzis, J. Angelopoulos, and N. Panopoulos, "A literature review of the challenges and opportunities of the transition from industry 4.0 to Society 5.0," *Energies*, vol. 15, no. 17, pp. 6276, 2022, doi: 10.3390/en15176276.

[2] M. C. Tavares, G. Azevedo, and R. P. Marques, "The challenges and opportunities of era 5.0 for a more humanistic and sustainable society—a literature review," *Societies*, vol. 12, no. 6, pp. 149, 2022, doi: 10.3390/soc12060149.

[3] R. Ziatdinov, M. S. Atteraya, and R. Nabiyev, "The fifth industrial revolution as a transformative step towards society 5.0," *Societies*, vol. 14, no. 2, pp. 19, 2024, doi: 10.3390/soc14020019.

[4] S. S. Hamedani, S. Aslam, B. A. M. Oraibi, Y. B. Wah, and S. S. Hamedani, "Transitioning towards tomorrow's workforce: Education 5.0 in the landscape of society 5.0: A systematic literature review," *Education Sciences*, vol. 14, no. 10, pp. 1041, 2024, doi: 10.3390/educsci14101041.

[5] M. K. Budiarto, A. Rahman, and A. Efendi, "Proposing information and communication Technology (ICT)-Based Learning transformation to create competitive human resources: A theoretical review," *Multidisciplinary Reviews*, vol. 7, no. 4, pp. 2024076-2024076, 2024 doi: 10.31893/multirev.2024076.

[6] S. Rana, S. Verma, M. M. Haque, and G. Ahmed, "Conceptualizing international positioning strategies for Indian higher education institutions," *Review of International Business and Strategy*, vol. 32, no. 4, pp. 503-519, 2022, doi: 10.1108/RIBS-07-2021-0105.

[7] M. Moshtari, and A. Safarpour, "Challenges and strategies for the internationalization of higher education in low-income East African countries," *Higher Education*, vol. 87, no. 1, pp. 89-109, 2024, doi: 10.1007/s10734-023-00994-1.

[8] D. Fortus, J. Lin, K. Neumann, and T. D. Sadler, "The role of affect in science literacy for all," *International Journal of Science Education*, vol. 44, no. 4, pp. 535-555, 2022, doi: 10.1080/09500693.2022.2036384.

[9] M. P. Virtič, "Teaching science & technology: components of scientific literacy and insight into the steps of research," *International Journal of Science Education*, vol. 44, no. 12, pp. 1916-1931, 2022, doi: 10.1080/09500693.2022.2105414.

[10] H. Suwono, N. L. Rofi'Ah, M. Saefi, and R. Fachrunnisa, "Interactive socio-scientific inquiry for promoting scientific literacy, enhancing biological knowledge, and developing critical thinking," *Journal of Biological Education*, vol. 57, no. 5, pp. 944-959, 2023, doi: 10.1080/00219266.2021.2006270.

[11] V. Kumar, S. K. Choudhary, and R. Singh, "Environmental socio-scientific issues as contexts in developing scientific literacy in science education: A systematic literature review," *Social Sciences & Humanities Open*, vol. 9, pp. 100765, 2024, doi: 10.1016/j.ssaho.2023.100765.

[12] J. Chang, and D. Liu, "Optimising learning outcomes: A comprehensive approach to virtual simulation experiment teaching in higher education," *International Journal of Human–Computer Interaction*, vol. 41, no. 4, pp. 2114-2134, 2025, doi: 10.1080/10447318.2024.2314825.

[13] A. R. Fitria, N. Hasnunidah, N. Fadiawati, and A. Suyatna, "Enhancing scientific argumentation through the integration of argument-driven inquiry and STEM in E-Worksheets for secondary science education," *Jurnal Penelitian Pendidikan IPA*, *11*(7), 263-272, 2025, doi: 10.29303/jppipa.v11i7.11603.

[14] B. T. Cahyono, H. Wibawanto, M. K. Budiarto, T. S. Qodr, F. Sukmawati, and R. Prihatin, "Utilizing ICT-Based learning resources to enhance creativity and innovation for pre-service students of vocational education," *Journal on Efficiency and Responsibility in Education and Science*, vol. 18, no. 4, pp. 282-292, 2025, doi: 10.7160/eriesj.2025.180404.

[15] K. M. I. Rosyida, and B. K. Prahani, "Enhancing students' critical thinking skills in physics: Exploring problem-based learning and mobile technology integration in rotational dynamics education," *Advances in Mobile Learning Educational Research*, vol. 5, no. 1, pp. 1301-1313, 2025, doi: 10.25082/AMLER.2025.01.006.

[16] J. Tang, "The impact of smart learning technologies on students' cognitive competence: enhancing critical thinking," *Education and Information Technologies*, vol. 30, no. 8, pp. 10073-10089, 2025, doi: 10.1007/s10639-024-13250-5.

[17] S. N. Ajid, D. A. Kusumaningtyas, K. Ratih, and S. Lava, "Strategies for integrating problem-based learning, teaching modules, and formative assessments to enhance learning outcomes and critical thinking skills," *Indonesian Journal on Learning and Advanced Education (IJOLAE)*, vol. 7, no. 2, pp. 218-232, 2025, doi: 10.23917/ijolae.v7i2.8612.

[18] R. Capone, "Blended learning and student-centered active learning environment: A case study with STEM undergraduate students," *Canadian Journal of Science, Mathematics and Technology Education*, vol. 22, no. 1, pp. 210-236, 2022, doi: 10.1007/s42330-022-00195-5.

[19] K. H. D. Tang, "Student-centered approach in teaching and learning: What does it really mean?," *Acta Pedagogia Asiana*, vol. 2, no. 2, pp. 72-83, 2023, doi: 10.53623/apga.v2i2.218.

[20] A. M. Al-Ansi, and A. Al-Ansi, "Enhancing student-centered learning through introducing module for STEM development and assessment," *International Journal of STEM Education for Sustainability*, vol. 3, no. 1, pp. 22-27, 2023, doi: 10.53889/ijses.v3i1.114.

[21] H. Y. Hong, P. Y. Lin, B. Chen, and N. Chen, "Integrated STEM learning in an idea-centered knowledge-building environment," *The Asia-Pacific Education Researcher*, vol. 28, no. 1, pp. 63-76, 2019, doi: 10.1007/s40299-018-0409-y.

[22] W. Shumar, J. Silverman, A. E. Moyer, M. Casino, B. Condon, D. Murasko, and J. S. Stanford, "Use of a professional development course to promote student-centered teaching in large STEM courses," *College teaching*, vol. 73, no. 3, pp. 145-159, 2025, doi: 10.1080/87567555.2023.2246618.

[23] S. Fajrina, L. Lufri, and Y. Ahda, "Science, technology, engineering, and mathematics (STEM) as a learning approach to improve 21st century skills: A review," *International Journal of Online & Biomedical Engineering*, vol. 15, no. 7, 2020, doi: 10.3991/ijoe.v16i07.14101.

[24] R. A. Ali, "Enhancing 21st century skills through integrated STEM education using project-oriented problem-based learning," *Geo Journal of Tourism and Geosites*, vol. 53, no. 2, pp. 421-430, 2024, doi: 10.30892/gtg.53205-1217.

[25] S. M. Stehle, and E. E. Peters-Burton, "Developing student 21st Century skills in selected exemplary inclusive STEM high schools," *International Journal of STEM education*, vol. 6, no. 1, pp. 1-15, 2019, doi: 10.1186/s40594-019-0192-1.
[26] S. R. Muzana, I. Wilujeng, B. E. Yanto, and A. A. Mustamin, "E-STEM project-based learning in teaching science to increase ict literacy and problem solving," *International Journal of Evaluation and Research in Education*, *10*(4), 1386-1394, 2021, doi: 10.11591/ijere.v10i4.21942.
[27] O. Karamustafaoğlu, and H. M. Pektaş, "Developing students' creative problem solving skills with inquiry-based STEM activity in an out-of-school learning environment," *Education and Information Technologies*, vol. 28, no. 6, pp. 7651-7669, 2023, doi: 10.1007/s10639-022-11496-5.
[28] L. Chen, Y. Taniguchi, A. Shimada, and M. Yamada, "Exploring behavioral and strategic factors affecting secondary students' learning performance in collaborative problem solving-based STEM lessons," *Sage Open*, vol. 14, no. 2, pp. 21582440241251641, 2024, doi: 10.1177/21582440241251641.
[29] M. Maesaroh, E. Kartikawati, M. Elvianasti, I. Irdalisa, and S. Murwitaningsih, "Study of science process skills in lesson plan by prospective biology teachers based on merdeka curriculum," *AL-ISHLAH: Jurnal Pendidikan*, vol. 15, no. 3, pp. 2866-2873, 2023, doi: 10.35445/alishlah.v15i3.2600.
[30] J. S. Hornejas, and J. A. A. Guntalidad, "Project-based learning approach on content mastery and cognitive skills: a pedagogical model for senior high school biology students," *Sapienza: International Journal of Interdisciplinary Studies*, vol. 5, no. 2, 2024, doi: 10.51798/sijis.v5i2.763.
[31] T. Tanti, W. Utami, D. Deliza, and M. Jahanifar, "Investigation in vocation high school for attitude and motivation students in learning physics subject," *Journal Evaluation in Education (JEE)*, vol. 6, no. 2, pp. 479-490, 2025, doi: 10.37251/jee.v6i2.1452.
[32] R. Dumasari, A. Sutisna, P. Hadiyanti, and M. Mawardi, "Evaluating technical guidance in the functional role of learning facilitators: A multidimensional approach to enhancing educational outcomes," *Journal of Nonformal Education*, vol. 10, no. 1, pp. 135-146, 2024, doi: 10.15294/jone.v10i1.255.
[33] N. Mansour, "Students' and facilitators' experiences with synchronous and asynchronous online dialogic discussions and e-facilitation in understanding the Nature of Science," *Education and Information Technologies*, vol. 29, no. 12, pp. 15965-15997, 2024, doi: 10.1007/s10639-024-12473-w.
[34] L. Herayanti, F. Fuaddunnazmi, and B. A. Sukroyanti, "Development of ethnoscience-based teaching materials to improve students' scientific literacy," *Jurnal Kependidikan: Jurnal Hasil Penelitian dan Kajian Kepustakaan di Bidang Pendidikan, Pengajaran, dan Pembelajaran*, vol. 11, no. 1, pp. 365-374, 2025, doi: 10.33394/jk.v11i1.13429.
[35] I. N. Tika, and P. Artawan, "The effect of ethnoscience-based problem-based learning on energy literacy and learning outcomes in high school," *Jurnal Penelitian Pendidikan IPA*, vol. 11, no. 8, pp. 353-361, 2025, doi: 10.29303/jppipa.v11i8.12330.
[36] N. Andrina, L. Nazli, M. A. Pratiwi, M. S. Sitepu, and D. S. Putri, "The effect of using napier stem media on students'understanding of mathematical concepts," *Journal of Authentic Research on Mathematics Education (JARME)*, vol. 7, no. 1, pp. 52-63, 2025, doi: 10.29303/jppipa.v11i8.12330.
[37] S. K. Ahmed, "How to choose a sampling technique and determine sample size for research: A simplified guide for researchers," *Oral Oncology Reports*, vol. 12, pp. 100662, 2024, doi: 10.1016/j.oor.2024.100662.
[38] A. L. Tan, Y. S. Ong, Y. S. Ng, and J. H. J. Tan, "STEM problem solving: Inquiry, concepts, and reasoning," *Science & Education*, vol. 32, no. 2, pp. 381-397, 2023, doi: 10.1007/s11191-021-00310-2.
[39] K. Adhelacahya, S. Sukarmin, and S. Sarwanto, "The impact of problem-based learning electronics module integrated with STEM on students' critical thinking skills," *Jurnal Penelitian Pendidikan IPA*, vol. 9, no. 7, pp. 4869-4878, 2023, doi: 10.29303/jppipa.v9i7.3931.
[40] Z. Zulfawati, T. Mayasari, and J. Handhika, "The effectiveness of the problem-based learning model integrated STEM approach in improving the critical thinking skills," *Jurnal Penelitian Fisika Dan Aplikasinya (JPFA)*, vol. 12, no. 1, pp. 76-91, 2022, doi: 10.26740/jpfa.v12n1.p76-91.
[41] A. Rasyid, R. Rinto, and M. Susanti, "Project-based learning through the STEM approach in elementary schools: How to improve problem-solving ability," *Journal of Education For Sustainable Innovation*, vol. 1, no. 1, pp. 1-8, 2023, doi: 10.56916/jesi.v1i1.477.
[42] S. Purnomo, Y. S. Rahayu, and R. Agustini, "Effectiveness of adi-stem to improve student's science literacy skill," *IJORER: International Journal of Recent Educational Research*, vol. 4, no. 5, pp. 632-647, 2023, doi: 10.46245/ijorer.v4i5.382.
[43] M. Nasir, C. Cari, W. Sunarno, and F. Rahmawati, "The effect of STEM-based guided inquiry on light concept understanding and scientific explanation," *EURASIA Journal of Mathematics, Science and Technology Education*, vol. 18, no. 11, pp. 2175, 2022, doi: 10.29333/ejmste/12499.
[44] B. Almeida, M. Santos, and R. Justi, "Aspects and abilities of science literacy in the context of nature of science teaching," *Science & Education*, vol. 32, no. 3, pp. 567-587, 2023, doi: 10.1007/s11191-022-00324-4.
[45] M. Istyadji and S. Sauqina. (2023). Conception of scientific literacy in the development of scientific literacy assessment tools: A systematic theoretical review. *Journal of Turkish Science Education*, *20*(2), 281-308, 2023, doi: 10.36681/tused.2023.016.
[46] W. Bangun, I. N. S. Degeng, H. Praherdhiono, and S. R. Lestari, "The effect of blended project-based learning for enhancing student's scientific literacy skills: An experimental study in University," *Pegem Journal of Education and Instruction*, vol. 13, no. 1, pp. 223-233, 2023, doi: 10.47750/pegegog.13.01.24.
[47] I. Deveci, and I. Karteri, "Context-based learning supported by environmental measurement devices in science teacher education: A mixed method research," *Journal of Biological Education*, vol. 56, no. 5, pp. 487-512, 2022, doi: 10.1080/00219266.2020.1821083.

[48] B. A. Gungor, S. Saracoglu, and M, Metin, “Perspective of teachers to context-based learning and its use in science education,” *Canadian Journal of Science, Mathematics and Technology Education*, vol. 23, no. 1, pp. 27-47, 2023, doi: 10.1007/s42330-023-00266-1.

[49] C. E. Mundy, and B. K. Nokeri, “Investigating the effects of a context-based laboratory exercise for meaningful learning,” *Journal of Chemical Education*, vol. 101, no. 8, pp. 3118-3125, 2024, doi: 10.1021/acs.jchemed.3c01260.

[50] A. I. Oladejo, T. T. Olateju, P. A. Okebukola, R. Sanni, H. Akintoye, F. Onowugbeda, and U. Adam, “Breaking barriers to meaningful learning in STEM subjects in africa: A systematic review of the culturo-techno-contextual approach,” *Sustainability*, vol. 17, no. 5, pp. 2310, 2025, doi: 10.3390/su17052310.

[51] R. Ramli, R. Razali, A. N. Gadeng, N. Diana, and J. Hariadi, “Integrating local knowledge into higher education: A qualitative study of curriculum innovation in Aceh, Indonesia,” *Education Sciences*, vol. 15, no. 9, pp. 1214, 2025, doi: 10.3390/educsci15091214.