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Developing STEAM-Teaching Module in Supporting Students' Literacy Ability in Elementary School

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Abstract

Indonesia's efforts to achieve international education standards and address shortcomings in educational attainment are evident in implementing the Merdeka curriculum. However, a major challenge remains limited learning resources that hinder the curriculum's goals. This research addresses this gap by developing a valid, practical, and potentially impactful STEAM (Science, Technology, Engineering, Art, and Math)-based teaching module designed to enhance elementary school students' literacy skills. The research employs a development research methodology with four stages: definition, design, development, and dissemination. The target population consisted of students from state elementary schools in Bengkulu, Indonesia. Data collection utilized a combination of observation, questionnaires, and literacy tests. Qualitative descriptive statistics were employed for data analysis. The findings demonstrate that the developed STEAM module meets the criteria for validity and high practicality. Additionally, the module exhibits the potential for positively impacting students' literacy abilities. The implication of this research is that the STEAM module, through its engaging activities, can increase student motivation in learning, ultimately leading to improved literacy skills.

Keywords: Design Research, Development Research, Module Teaching, STEAM, Mathematics Literacy

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INTRODUCTION

The 21st century demands a significant transformation across all sectors, including education, to effectively develop the necessary human resources. A successful 21st-century education equips individuals with a range of competencies such as creative thinking, critical thinking and problem-solving, communication, and collaboration skills crucial for success in a globalized society (Maskur et al., 2020; Salim, 2019; Bray et al., 2023). Recognizing the importance of fostering a competitive global workforce, countries worldwide are actively seeking to enhance their educational systems. Indonesia exemplifies this trend, with continuous efforts to improve academic quality through initiatives like raising evaluation assessment standards in alignment with international benchmarks such as the Program for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS).

The Indonesian government's commitment to enhancing educational outcomes is evident through two key initiatives: implementing a minimum competency-based national assessment in 2021 and introducing the Merdeka Curriculum (*Kurikulum Merdeka*). This new curriculum integrates specific learning objectives that emphasize essential skills such as reasoning, problem-solving, communicating mathematical ideas and symbols, making connections between mathematics and real-life applications, and fostering an appreciation for the utility of mathematics (Kemendikbud, 2022). The emphasis on

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these skills in both curriculum and assessment highlights the critical importance of developing students' mathematical literacy.

Mathematical literacy is pivotal as it underpins the development of critical thinking skills and the ability to solve real-world problems (Segers et al., 2015; Pantiwati et al., 2022). It empowers individuals to identify, interpret, formulate, and solve problems effectively (Geiger et al., 2015; OECD, 2013; Adeyemi & Adaramola, 2014). Recognized as a fundamental learning goal at the primary and secondary school levels, mathematical literacy serves as an international indicator of educational quality and alignment with the demands of 21st-century education (Susanta, Sumardi, et al., 2023; Holenstein et al., 2021; Drew, 2012). Strong mathematical literacy skills enable students to relate mathematical concepts to their everyday lives (Fajriyah, 2018; Ojose, 2011).

Despite being a core educational goal in Indonesia, student literacy skills have not demonstrably improved over the past few decades. This is evidenced by consistently low scores in international assessments such as PISA, where Indonesian students' average scores in mathematics fall below the international benchmark (OECD, 2019; Stacey, 2012; Schleicher, 2019). Similarly, elementary school students in Indonesia consistently rank poorly in mathematics on TIMSS (Mullis et al., 2016). National assessments also paint a concerning picture. For instance, on the 2021 and 2022 Minimum Competency Assessments, less than 50% of elementary school students achieved competency. Recent research trends further corroborate these findings. Studies by Susanta et al. (2022) show that even high-achieving students in Indonesia only reach level 3 literacy skills, while Rahmawati et al. (2022) highlight the overall low literacy levels among students.

Achieving desirable learning outcomes in elementary mathematics education remains a significant challenge, as evidenced by national assessment results. For example, an education report at a state elementary school in Bengkulu City displayed concerningly low scores in mathematical literacy (numeracy) during the 2023 national assessment (Pusmendik-Kemendikbud, 2023). These results showed that student mastery across various mathematical content areas remained low, with scores in number (45.05%), geometry (30.32%), algebra (34.56%), and data and uncertainty (45.04%) falling below expectations. Interviews with teachers at state elementary schools in Bengkulu City further highlight classroom challenges. The results of the interview concluded several things, including (1) limited access to learning resources specifically designed to develop mathematical literacy skills and minimal use of technology-integrated teaching materials and assessments were identified as key concerns. (2) The overreliance on paper-based resources restricts students' exposure to more dynamic and engaging learning tools. (3) These findings underscore the urgent need to develop technology-integrated teaching materials that can enhance elementary school students' mathematical literacy skills.

Fostering innovation and creativity in elementary school learning environments is crucial for maintaining student engagement and sparking a lifelong love of learning. The foundation built during these early years is critical for success in higher education (Agnihotri et al., 2021). This period also plays a vital role in shaping students' personalities and developing critical thinking skills. Therefore,

implementing a learning approach that prioritizes these skills is paramount. Mathematics, a subject often characterized by abstract concepts, presents a unique challenge. Here, teacher innovation in designing engaging and effective learning materials becomes particularly important (Susanta, Koto, et al., 2022).

Integrating technology and digitalization in education offers a compelling solution for delivering educational materials in a more engaging and accessible manner. This approach is particularly relevant in the context of Indonesia's independent learning curriculum, where technology can play a crucial role in its effective implementation. By incorporating technology into classroom materials, educators can create a more dynamic and interactive learning experience. Studies have shown that the application of interactive technology, especially in mathematics education, can significantly enhance the quality of learning (Miller, 2018). Integrating and promoting technological innovation within classroom learning is essential, with virtual learning environments emerging as a prominent example (Shafie et al., 2019; Puncreobutr, 2016). Innovations in this area can extend to learning environments that blend technology with real-world experiences, providing students with practical and immersive educational opportunities. A growing body of research underscores the critical role of technology in achieving desired learning outcomes (Wu et al., 2021). The use of digital media and technology has been demonstrably linked to accelerated knowledge acquisition (Wijaya et al., 2016). Furthermore, research by Quigley et al. (2020) and Tran et al. (2021) highlights the positive impact of interactive modules and e-modules on student learning outcomes. Susanta, Sumardi, & Zulkardi (2022) further validate these findings by demonstrating the effectiveness of e-modules in improving students' mathematical literacy skills.

Therefore, to enhance the quality of learning in elementary education, educators should leverage interactive technology in their teaching practices (Yoon & Baek, 2018). Integrating technology into learning materials can significantly improve student outcomes, including literacy skills. In the 21st century, mathematics education demands a focus on Science, Technology, Engineering, and Mathematics (STEM) integration to prepare students for a rapidly evolving world (Beswick & Fraser, 2019). This further emphasizes the importance of technology-based learning. A comprehensive approach that goes beyond STEM by incorporating the Arts in STEAM education. By integrating these five disciplines (Science, Technology, Engineering, Art, and Mathematics), educators can create a more holistic learning experience that facilitates a deeper understanding of concepts within a real-world context (Thingwiangthong et al., 2021).

Empirical evidence underscores the effectiveness of the STEAM model in cultivating essential student skills. Studies have shown that STEAM education can improve students' higher-order thinking skills (Mardlotilla et al., 2020), foster collaboration, communication, and adaptation abilities (Colucci-gray et al., 2019), enhance problem-solving creativity (Wu et al., 2022), and refine critical thinking skills (Martín-Páez et al., 2019). Furthermore, research by (Holmlund et al., 2018) demonstrates the effectiveness of project-based STEAM models in specifically supporting students' creative thinking abilities.

Research has consistently shown that effective learning models can significantly improve student

literacy skills, including mathematical literacy (Jehlička & Rejsek, 2018). For instance, Susanta, Rahimah, et al. (2023) demonstrated that utilizing context-specific course books in coastal regions can enhance students' mathematical abilities. This highlights the potential of well-designed learning models within teaching materials to support and improve literacy skills across disciplines. Empirical evidence further suggests that STEAM-based teaching materials hold particular promise in bolstering mathematical literacy. Studies by Budiyono et al. (2023) and (Annisa et al., 2023) provide compelling evidence of the positive influence of STEAM on students' mathematical literacy skills. These findings collectively point to the value of integrating STEAM into teaching materials to enhance the abilities of elementary school students.

In the context of Indonesia, where mathematical literacy is a critical learning outcome, the use of digital teaching materials incorporating STEAM principles presents a viable solution. While numerous studies have explored the effectiveness of STEAM in learning and the development of supportive teaching materials for improving mathematical literacy (refer to previous citations), this research takes a distinct approach. We aim to integrate STEAM into teaching materials by specifically utilizing local context problem scenarios. The objective of this research is to develop a valid, practical, and impactful STEAM-based teaching module specifically designed to enhance the mathematical literacy skills of elementary school students in Bengkulu.

Research question 1: What is the validity of the STEAM-Teaching module in supporting students' literacy abilities in elementary school?

Research question 2: How practical is the STEAM-Teaching module in supporting students' literacy abilities in elementary school?

Research Question (RQ-3): What is the potential effect of using the STEAM-Teaching module in supporting students' literacy abilities in elementary school?

METHODS

This study adopted a development research methodology following the four-stage 4D model (Thiagarajan et al., 1974). The 4D model offers a systematic framework for developing instructional materials, encompassing four phases: Define, Design, Develop, and Disseminate. We opted for the 4D model due to its well-defined sequential stages that align perfectly with our research objective of creating STEAM-based teaching materials.

This study recruited participants from state elementary schools in Bengkulu, Indonesia. During the needs analysis phase (define stage), data were collected from 24 students and 9 teachers working at these elementary schools. In the development stage, feedback was solicited from 3 subject matter experts. To assess the effectiveness of the teaching module, a small group trial was conducted with 30 fifth-grade students from a Bengkulu elementary school. Finally, a field test involving 76 students from three different state elementary schools in Bengkulu was carried out.

To ensure a comprehensive assessment and validation of the developed STEAM-based teaching module, this study employed a multi-method data collection approach, incorporating observations, questionnaires, and a specifically designed literacy ability test. Before data collection, all instruments underwent rigorous validation and feasibility analyses conducted by two experts with extensive knowledge of elementary school mathematics education. Their feedback was instrumental in refining the questionnaires and the literacy skills test.

Observations were conducted in elementary school classrooms to identify student needs related to mathematical literacy development. Questionnaires were then distributed to teachers to gauge their perceptions of the teaching module's validity and practicality in classroom settings. The literacy skills test focused on key mathematical literacy components outlined by Steen (2001), including mathematical thinking, reasoning, argumentation, problem-solving, representation, symbols, tools and technology, and communication. The test consisted of six original geometry-based questions specifically designed for elementary school students, adhering to established quality standards for instrument development. To ensure the test's validity, two experts assessed the content, and both agreed that each item achieved an Aiken index above .5 (Retnawati, 2014), indicating a strong alignment between the test and the intended learning outcomes. Finally, a field trial involving 24 elementary school students in Bengkulu was conducted to evaluate the instrument's reliability. The Cronbach's Alpha coefficient for the test reached .82, exceeding the threshold for high reliability (>.70).

This study employed descriptive statistics to analyze data collected at various stages of the research process. Needs assessment data, used to inform the development of the teaching materials, was analyzed descriptively to identify key areas for improvement in student mathematical literacy. Following development, the characteristics of the teaching module were evaluated in terms of validity, practicality, and potential impact on students' literacy skills. The Aiken's Index was used to assess the validity of the instructional materials, with a score exceeding 0.5 considered indicative of strong content validity. The practicality of the learning products was evaluated based on user feedback obtained during small-scale trials. A researcher-designed questionnaire, consisting of 10 Likert-scale items (1= strongly disagree, 4 = strongly agree), was used to gather user feedback. Practicality scores were calculated by summing responses across all items, with scores categorized into four ranges: 1.00-1.80 (not practical), 1.81-2.60 (less practical), 2.61-3.40 (practical), and 3.41-4.00 (highly practical). The potential impact of the teaching module on student learning was assessed through student response questionnaires and analysis of their performance on the literacy ability test. Descriptive statistics were used to summarize student literacy scores, with a focus on achieving a high attainment level exceeding 50%. Student literacy levels were categorized into three bands: 0-33 (low), 34-66 (moderate), and 67-100 (high).

RESULTS AND DISCUSSION

Define Stage

The STEAM module developed in this study aligns seamlessly with the learning objectives for mathematics education outlined in the *Kurikulum Merdeka* framework (Adriyawati et al., 2020). These objectives prioritize the development of reasoning skills, problem-solving abilities, effective communication of mathematical ideas and symbols, and the application of these concepts to real-life contexts. To achieve these goals, the module incorporates inquiry-based activities specifically designed to foster reasoning and problem-solving skills. Furthermore, the integration of various STEAM components within the module encourages students to effectively communicate their mathematical ideas and establish meaningful connections between these concepts and their everyday experiences. The development of the STEAM module was informed by a comprehensive needs analysis encompassing three key areas: curriculum content, student needs, and teacher perspectives as facilitators of learning.

Material Analysis

The development of the STEAM teaching module in this research aligns closely with Indonesia's independent curriculum. Attention was given to the core competencies mandated by the curriculum as a guiding principle for designing instructional materials. Each lesson was structured around achieving these competencies effectively. Thematic focus within the STEAM module centers on geometry, specifically targeting the concepts of area and volume calculation for two-dimensional shapes. The intended learning outcomes aim to equip students with the proficiency to construct and deconstruct spatial figures such as cubes and rectangular prisms. Furthermore, the module is designed to enhance students' ability to visualize spatial relationships from various perspectives on geometry.

Analysis of Students.

This analysis aimed to explore information about the use of technological learning resources and the integration of STEAM in classroom learning based on student assessments. Data collection involved distributing questionnaires to 24 students from state elementary schools in Bengkulu, Indonesia. The questionnaire consisted of statements requiring agree or disagree responses in Table 1.

Table 1. Summary of student responses

Item Number	Question items	Percentage (%)
1	Teachers always use textbooks as a learning resource in class	87.50
2	Examples of problems used by the teacher (teaching materials/questions) are familiar/recognized	45.83
3	Teachers have integrated learning with technology, science, engineering, art, and mathematics	29.16

Analysis of Table 1 reveals a heavy reliance on textbook learning resources, with nearly 86.67% of students reporting that their teachers primarily utilize textbooks. This suggests a potential underutilization of alternative resources and a lack of integration with science, technology, and the student's local environment. While 45.83% of teachers incorporate familiar problems or questions into their lessons, a significantly lower percentage (29.16%) actively link learning materials to concepts across Science, Technology, Engineering, Art, and Mathematics (STEAM). This finding underscores the need for the development of STEAM-based teaching materials to address this gap and enhance the learning experience for students.

Analysis of Teacher

To assess the need for developing STEAM-based teaching materials, this study surveyed nine teachers from state elementary schools in Bengkulu. Questionnaires were distributed to these teachers to gather information regarding their current use of STEAM (Science, Technology, Engineering, Arts, and Mathematics) principles and general classroom practices. The data revealed that a significant majority (77.77%) of the teachers already incorporate interactive learning methods into their instruction, utilizing educational media resources such as YouTube videos and online materials. This finding suggests a positive inclination towards technology integration in the classroom. Further interviews with teachers who responded to the questionnaire found that none of the surveyed teachers reported previously implementing the STEAM model specifically for teaching mathematics content. This indicates that current classroom instruction for conveying mathematical concepts may not be fully leveraging the potential of technology, science, art, and engineering to create learning experiences that resonate with students' backgrounds and experiences. These findings align with student assessments, which indicated a heavy reliance on textbooks as the primary resource for delivering mathematical content. Collectively, these results underscore the importance of developing STEAM-based teaching modules. Such modules have the potential to not only enhance student learning outcomes but also to introduce teachers to a more engaging and relevant instructional mode.

Design Stage

Product Description

The developed STEAM module incorporates student activities designed around the core STEAM components. These activities serve as a foundation and springboard for student learning. Based on the needs analysis conducted during the define stage, the module integrates mathematical concepts with relevant science, technology, engineering, math, or art components. To enhance engagement, each stage of the module is presented through instructional videos accessible via QR codes. Students are then required to respond to the video content through a series of activities. These activities, encompassing science, mathematics, and art tasks, are strategically designed to solidify students' understanding of the

target material.

The developed STEAM module is further characterized by its emphasis on student activities embedded within each stage of the STEAM learning process. A key feature of this module is that student activities are designed to complement the learning videos, fostering observation and mastery of the presented concepts. Figure 1 illustrates the introduction of student material and literacy activities within the module.

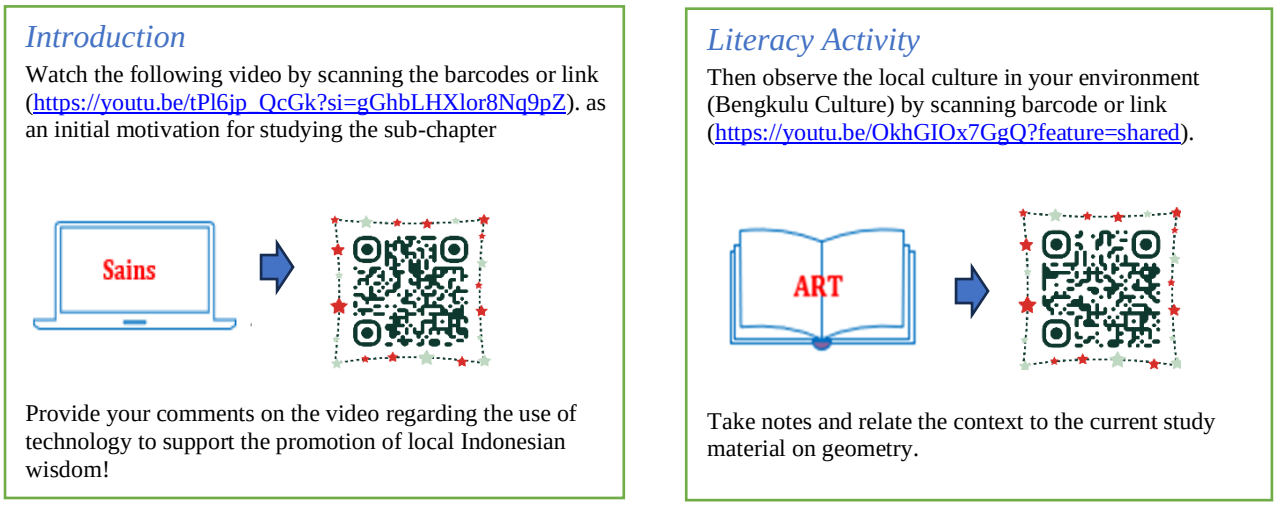


Figure 1. STEAM module design (in English)

Develop Stage

Content Validity Results

The learning handout products that have been developed were evaluated by experts: in the field of mathematics education, media, and language to analyze four aspects: content appropriateness, presentation appropriateness, language usage, and the integration of STEAM and Inquiry-based learning. The assessments by three experts were analyzed using the Aiken index with a criterion of 0.5, as shown in Table 2.

Table 2. Results of the STEAM module expert assessment

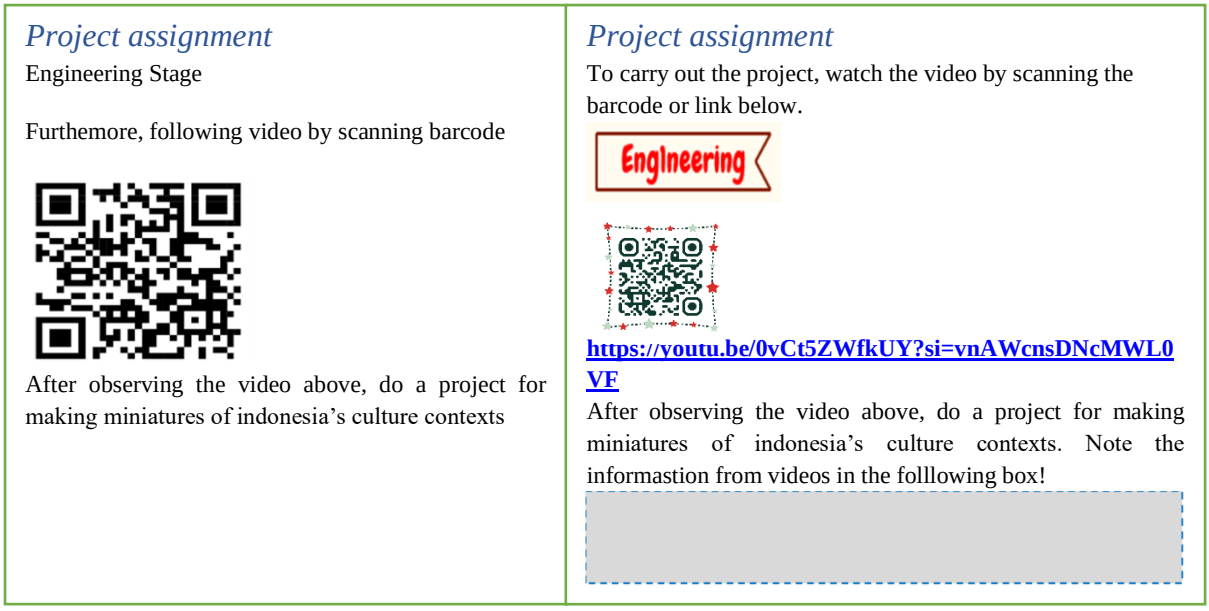
Aspect	Aiken Index	Criterion	Conclusion
Content Appropriateness	0.62	0.5	Valid
Presentation Appropriateness	0.64	0.5	Valid
Language	0.72	0.5	Valid
Use of STEAM components	0.54	0.5	Valid

Table 2 shows that every aspect of the learning product meets the validity criteria in terms of content. Generally, the validators recommended that the presentation of STEAM aspects should be mutually relevant, and the stages of the inquiry should be clearly defined. In summary, some of the suggestions from the validators and the resulting revisions are presented in Table 3.

Table 3. Validator suggestions

Expert	Comment	Revision
Expert 1	The layout of images must be clear and conducive to easy readability, and each barcode should be linked directly to its corresponding video URL	The layout has been fixed, and a video link is included
Expert 2	Assignments should be formulated in a manner that allows for the observation of students' literacy development stages	Literacy questions have been revised to be in descriptive form
Expert 3	When using video presentations to motivate learning, it is crucial that the content aligns closely with the material being taught; for instance, videos on fractions should be pertinent to the lesson context	Video presentations have been revised to align with the specific material, such as adapting technology videos to circle material.

The comments and suggestions provided by the validators served as a crucial reference for improving the research products. When designing STEAM-based teaching materials, it is essential to emphasize each aspect or component of science, technology, engineering, art, and mathematics ensuring relevance to the material being presented. Additionally, there needs to be a focus on student activities facilitated by these STEAM components. To enhance accessibility, besides providing a video barcode, a direct link to the video should be included to ensure easy access for users, as illustrated in Figure 2.



(a) before revision (b) after revision

Figure 2. Access to video before and after revision

Practicality Test Results

To assess the usability of our product, we engaged 30 students as participants to evaluate its practicality. The evaluation focused on their experience using specific modules, with students providing feedback through a questionnaire assessing aspects such as writing clarity, layout, language comprehension, and the effectiveness of instructional videos. A summary of the analysis of student responses is presented in Table 4.

Table 4. Practicality assessment of the module

Rated aspect	Average Score	Criteria
Layout, clarity of symbols and letters, and presentation	3.46	Very Practical
Ease of learning usability	3.30	Practical
Clarity of language for easy comprehension	3.39	Practical
Clarity of instructional videos	3.37	Practical
Average Rating	3.38	Practical

Potential Impact Results

To assess the impact of the developed modules on students' literacy skills, we conducted an effectiveness analysis. A total of 76 students from two elementary schools participated in the testing phase. Following their engagement with the modules, the students underwent a literacy skills assessment to gauge the potential learning gains. The results of the data analysis on student literacy abilities are presented in Table 5.

Table 5. Potential impact on literacy skills

Level	Students (n)	Percentage (%)
Low	12	15.78
Moderate	15	19.74
High	49	64.47

Table 5 presents the distribution of students' literacy skill levels after engaging with the STEAM modules. As shown, a significant majority (64.47%) achieved high-level literacy skills. This finding exceeds a baseline of 50%, indicating the STEAM module's potential to substantially improve student literacy. These results support the notion that integrating STEAM components within learning modules can foster literacy development in students. It can be seen that students who previously had average literacy skills in the low category in the initial survey increased to the high category. This aligns with previous research by Budiyono et al. (2023) who found a positive influence of STEAM on mathematical and scientific literacy in elementary students. Similarly, Annisa et al. (2023) suggest that STEAM learning can address existing gaps in numeracy literacy. Observations during the module implementation revealed high student engagement and motivation in literacy-focused activities. This

reinforces the importance of embedding literacy components across all classroom lessons, as emphasized by Susanta, Sumardi, et al. (2023). This aligns with (Long & Davis, 2017) perspective that STEAM offers a solution to enhance student engagement and promote literacy skills. Furthermore, research suggests that STEAM approaches stimulate student motivation and active participation (Taljaard, 2016; Muzakkir et al., 2024) leading to increased interest in learning (Park, 2021).

Our findings further demonstrate that the designed STEAM activities actively engage students in the learning process. Integrating technological elements, such as learning videos, within the modules further supports student engagement. We observed a positive student response to the technology-integrated learning resources, promoting active discovery of material concepts. This aligns with previous research by Bright et al. (2024) who found a positive impact of technology on mathematics learning. Similarly, Pambudi et al. (2018) suggest that ICT-based learning media supports students' mathematical literacy, and Nurcahyo (2020) highlights the potential of interactive multimedia to enhance students' digital literacy.

Building upon the existing research, Agnihotri et al. (2021) demonstrated the positive impact of incorporating online media through Blended Learning on mathematical literacy. Interactive teaching materials have also been shown to enhance students' visualization literacy, as evidenced by (Alper et al., 2017). Furthermore, Nihayatun and Rusnilawati (2023) highlight the potential of technology integration within teaching modules to create interactive learning experiences. These findings align with the observation that literacy activities within the STEAM framework foster active student participation in classroom learning. We now present several STEAM activities based on the module's framework.

Figure 3. Literacy activities in STEAM

Figure 3 illustrates students actively engaged in STEAM activities, presenting their work aligned with the learning objectives. The results of group discussions showcase student creativity in applying the activities. Furthermore, the module appears to guide students in solving problems by utilizing literacy skills. Figure 4 provides a specific example of a student solution.

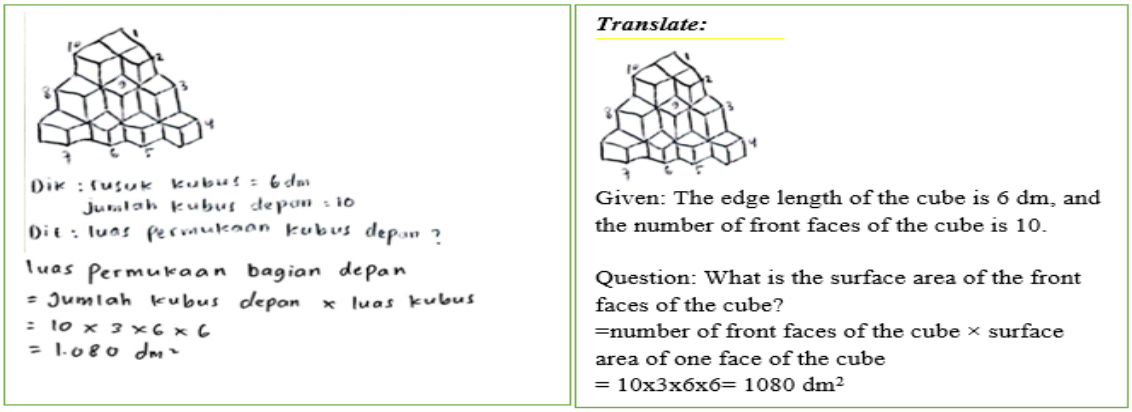


Figure 4. Student literacy process

Figure 4 depicts students solving the area problem of the pictured cube. This solution demonstrates their mastery of several mathematical literacy aspects. Students employ inductive and sequential reasoning (mathematical thinking) while solving heuristically (mathematical argumentation) and utilizing visual aids (modeling, representation). Additionally, their work reflects problem-solving through the application of the cube's surface area formula. These elements highlight the development of various mathematical literacy components during problem-solving, facilitated by the STEAM-inquiry learning module. This aligns with Ozkan and Topsakal (2021) findings, suggesting that STEAM fosters student expression and creativity, leading to a more pronounced display of abilities.

CONCLUSION

This research successfully developed a STEAM module for elementary school students, demonstrating its validity, practicality, and potential to improve their literacy skills. Studies have shown that integrating science, technology, engineering, art, and mathematics (STEAM) into teaching materials can significantly enhance students' literacy development. Furthermore, STEAM modules designed with an inquiry-based approach have been found to effectively support literacy activities in elementary classrooms. However, this research also highlights the importance of considering internet access disparities. Teachers should be mindful of potential limitations in students' home environments when developing interactive learning materials.

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REFERENCES

Adeyemi, O. B., & Adaramola, M. O. (2014). Mathematical literacy as foundation for technological development in Nigeria. *Journal of Research & Method in Education*, *4*(5), 28–31. https://doi.org/10.9790/7388-04562831

Adriyawati, Utomo, E., Rahmawati, Y., & Mardiah, A. (2020). Steam-project-based learning integration to improve elementary school students' scientific literacy on alternative energy learning. *Rning. Univers J Educ Res*, *8*(5), 1863–1873. https://doi.org/10.13189/ujer.2020.080523

Agnihotri, D., Kulshreshtha, K., & Tripathi, V. A. (2021). A study on firms' communication based on artificial intelligence and its influence on customers' complaint behavior in social media environment. *IOP Conf Ser Mater Sci Eng.*, *1116*(1), 012180. https://doi.org/10.1088/1757-899X/1116/1/012180

Alper, B., Riche, N. H., Chevalier, F., Boy, J., & Sezgin, M. (2017). Visualization literacy at elementary school. In Proceedings of the 2017 CHI conference on human factors in computing systems. *In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, 5485–5497. https://doi.org/10.1145/3025453.3025877

Annisa, A. S., Maftukhah, L., Malihatus, S., & Satrio, A. (2023). Study Literature : The Influence of STEAM Learning on Student ' s Literacy-Numeracy Ability. *PRISMA , Prosiding Seminar Nasional Matematika*, *6*, 31–35.

Beswick, K., & Fraser, S. (2019). Developing mathematics teachers' 21st century competence for teaching in STEM contexts. *ZDM Mathematics Education*, *15*, 955–965. https://doi.org/10.1007/s11858-019-01084-2

Bray, D. A., Girvan, D. C., & Chorcora, E. N. (2023). Students' perceptions of pedagogy for 21st century learning instrument (S-POP-21): Concept, validation, and initial results. *Thinking Skills and Creativity*, *49*. https://doi.org/10.1016/j.tsc.2023.101319

Bright, A., Welcome, N. B., & Arthur, Y. D. (2024). The effect of using technology in teaching and learning mathematics on student ' s mathematics performance : The mediation effect of students ' mathematics interest. *Journal of Mathematics and Science Teacher*, *4*(2). https://doi.org/10.29333/mathsciteacher/14309

Budiyono, A., Luthfi, A., & Witarsa, R. (2023). The influence of the STEAM learning model on the science and numeracy abilities of elementary madrasah students [in Bahasa]. *JIKAP PGSD : Jurnal Ilmiah Ilmu Kependidikan*, *7*(2), 197–203. https://doi.org/10.26858/jkp.v7i2.37871

Colucci-gray, L., Burnard, P., Gray, D., & Cooke, C. (2019). A critical review of STEAM (Science , Technology , Engineering , Arts , and Mathematics). In *Oxford Research Encyclopedia of Education* (Issue March). Oxford University Press. https://doi.org/10.1093/acrefore/9780190264093.013.398

Drew, S. V. (2012). Open up the ceiling on the common core state standards: preparing students for 21stcentury literacy-now. *Journal of Adolescent & Adult Literacy*, *56*(4), 321–330. https://doi.org/10.1002/JAAL.00145

Fajriyah, E. (2018). The role of ethnomathematics related to mathematical concepts in supporting

literacy. *In Prisma, Proceedings of the Seminar Nasional Matematika*, *1*, 114–119.

Geiger, V., Goos, M., & Forgasz, H. (2015). A rich interpretation of numeracy for the 21st century: A survey of the state of the field. *ZDM*, *47*(4), 531–548. https://doi.org/10.1007/s11858-015-0708-1

Holenstein, M., Bruckmaier, G., & Grob, A. (2021). Transfer effects of mathematical literacy: An integrative longitudinal study. *European Journal of Psychology of Education*, *36*, 799–825. https://doi.org/https://doi.org/10.1007/s10212-020-00491-4

Holmlund, T., Lesseig, K., & Slavit, D. (2018). *Making sense of " STEM education " in K-12 contexts*. *5*(1), 32. https://doi.org/10.1186/s40594-018-0127-2

Jehlička, V., & Rejsek, O. (2018). A multidisciplinary approach to teaching mathematics and information and communication technology. *EURASIA J Math Sci Tech*, *14*(5), 1705–1718. https://doi.org/10.29333/ejmste/85109

Kemendikbud. (2022). Independent curriculum as an effort to restore Learning [in Bahasa]. *Directorate of Junior High Schools*. https://ditsmp.kemdikbud.go.id/kurikulum-merdeka-sebagai-upaya-pemulihan-pembelajaran/

Long, R. ., & Davis, S. (2017). Using STEAM to increase engagement and literacy across disciplines. *The STEAM Journal*, *3*(1), 1–11. https://doi.org/10.5642/steam.20170301.07

Mardlotilla, A., Suhartono, & Dimyati. (2020). The influence of STEAM learning on high-level thinking skills in grade V students of MI Hidayatul Mubtadi'in Jagalempeni [in Bahasa]. *JPSD (Jurnal Pendidik Sekolah Dasar)*, *7*(2), 157–67.

Martín-Páez, T., Aguilera, D., Perales-Palacios, F., & Vílchez-González, J. (2019). What are we talking about when we talk about STEM education? A review of literature. *Sci Educ*, *103*(4), 799–822. https://doi.org/10.1002/sce.21522

Maskur, R., Sumarno, Rahmawati, Y., Pradana, K., Syazali, M., Septian, A., & Palupi, E. (2020). The effectiveness of problem based learning and aptitude treatment interaction in improving mathematical creative thinking skills on Curriculum 2013. *European Journal of Educational Reseacrh*, *9*(1), 375–383. https://doi.org/10.12973/eu-jer.9.1.375

Miller, T. (2018). Developing numeracy skills using interactive technology in a play-based learning environment. *Miller International Journal of STEM Education*, *5*(3). https://doi.org/10.1186/s40594-018-0135-2

Mullis, I. V. S., Martin, M. O., Foy, P., & Hooper, M. (2016). Trends in International Mathematics and Science Study (TIMSS) 2015 international results in mathematics. In *TIMSS & PIRLS International Study Center Lynch School of Education, Boston College*.

Muzakkir, Zulnaidi, H., & Rauf, R. . (2024). Mathematics module based on STEAM and quranic approach : A study for student ' s perception. *Journal on Mathematics Education*, *15*(2), 363–384. https://doi.org/10.22342/jme.v15i2.pp363-384

Nihayatun, L., & Rusnilawati. (2023). STEAM-Inquiry learning module assisted by liveworksheet for multiplication material in elementary school. *Profesi Pendidikan Dasar*, *10*(3), 32–46. https://doi.org/10.23917/ppd.v10i3.5478

Nurcahyo, M. A. (2020). The use of interactive multimedia to improve junior high school students' digital literacy in science subjects [in Bahasa]. *Jurnal Pendidikan Informatika Dan Sains*, *9*(2), 132–138. https://doi.org/10.31571/saintek.v9i2.2077

OECD. (2013). *PISA 2012 assessment and analytical framework: mathematics, reading, science, problem solving and financial literacy*. Paris: OECD Publishing.

OECD. (2019). *PISA 2018 Results: What students know and can do, PISA*. OECD Publishing.

Ojose, B. (2011). Mathematics literacy : are we able to put the mathematics we learn into everyday use? *Journal of Mathematics Education*, *4*(1), 89–100.

Ozkan, G., & Topsakal, U. (2021). Exploring the effectiveness of STEAM design processes on middle school students' creativity. *International Journal of Technology and Design Education*, *31*(4), 95–116. https://doi.org/10.1007/s10798-019-09547-z

Pambudi, D., Wulandari, A. N., & Sutopo. (2018). Efforts to improve elementary school teachers' skills in creating ICT-Based interactive learning media to improve students' mathematical literacy [in Bahasa]. *Jurnal Pendidikan Matematika Dan Matematika (JPMM) Solusi*, *2*(5), 371–376. https://doi.org/10.20961/jpmm solusi.v2i5.37923

Pantiwati, Y., Kusniarti, T., Permana, F. H., Nurrohman, E., & Sari, T. N. I. (2022). The effects of the blended project-based literacy that integrates school literacy movement strengthening character education learning model on metacognitive skills, critical thinking, and opinion expression. *European Journal of Educational Research*, *12*(1), 145–158. https://doi.org/10.12973/eu-jer.12.1.145

Park, J. . (2021). Cultivating STEAM Literacy : Emphasizing the implementation of the arts through reading practices supporting the asian diaspora. *ASIA-Pacific Science Education*, *7*, 586–614. https://doi.org/10.1163/23641177-bja10034

Puncreobutr, V. (2016). Education 4.0: new challenge of learning. *Journal of Humanities and Social Sciences*, *2*(2). https://doi.org/10.4236/ce.2012.32040

Pusmendik-Kemendikbud. (2023). *Minimum Competency Assessment* [in Bahasa].

Quigley, C. F., Herro, D., King, E., & Plank, H. (2020). Steam designed and enacted: understanding the process of design and implementation of steam curriculum in an elementary school. *J Sci Educ Technol*, *29*(4), 499–518. https://doi.org/10.1007/s10956-020-09832-w

Rahmawati, N. D., Komarudin, K., & Suherman, S. (2022). Development of HOTS-based mathematics assessment instruments for prospective elementary school teachers [in Bahasa]. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *11*(2), 860–871. https://doi.org/10.24127/ajpm.v11i2.4893

Retnawati, H. (2014). *Proving the validity of the instrument in the measurement*.

Salim, D. (2019). Mathematics skills in the 21st century [in Bahasa]. *Jurnal Cakrawala Pendas*, *5*(2), 133–140. https://doi.org/10.1109/ITHET. 2014.7155689

Schleicher, A. (2019). *PISA 2018: Insights and interpretations*. OECD Publishing.

Segers, E., Kleemans, T., & Verhoeven, L. (2015). Role of parent literacy and numeracy expectations and activities in predicting early numeracy skills. *Mathematical Thinking and Learning*, *17*(3), 219–236. http://dx.doi.org/10.1080/10986065.2015.1016819

Shafie, H., Majid, F. A., & Ismail, I. S. (2019). Technological pedagogical content knowledge (TPACK) in teaching 21st century skills in th21st century classroom. *Asian Journal University Education*, *15*(3), 24–33. https://doi.org/10.24191/ajue.v15i3.7818

Stacey, K. (2012). The international assessment of mathematical literacy: PISA 2012 framework and

items. *Journal 12th International Congress on Mathematical Education*, *12*(2), 1–17. https://doi.org/10.1007/978-3-319-17187-6_43

Steen, L. A. (2001). Mathematics and numeracy: Two literacies, one language. *Journal of Singapore Association of Mathematics Educators*, (6)1, 10-16. https://doi.org/10.12691/education-5-5-15

Susanta, A., Koto, I., & Susanto, E. (2022). Teachers' ability in writing mathematical literacy module based on local context. *Education Quarterly Reviews*, *5*(3), 173–179. https://doi.org/10.31014/aior.1993.05.03.536

Susanta, A., Rahimah, D., Koto, I., Susanto, E., Muchlis, E. E., & Azizah, M. (2023). Enhancing elementary literacy skills through a contextualized coastal course book : A developmental study in Bengkulu, Indonesia. *PPD: Profesi Pendidikan Dasar*, *10*(3), 1–16. https://doi.org/10.23917/ppd.v10i3.3169

Susanta, A., Sumardi, H., & Susanto, E. (2022). Students' mathematical literacy ability in solving problems on pattern material using the bengkulu local contexts. *Jurnal Didaktik Matematika*, *9*(2), 343–357. https://doi.org/10.24815/jdm.v9i2.26741

Susanta, A., Sumardi, H., Susanto, E., & Retnawati, H. (2023). Mathematics literacy task on number pattern using Bengkulu context for junior high school students. *Journal on Mathematics Education*, *14*(1), 85–102. https://doi.org/10.22342/jme.v14i1.pp85-102

Susanta, A., Sumardi, H., & Zulkardi, Z. (2022). Development of e-module using Bengkulu contexts to improve literacy skills of junior high school students. *Jurnal Pendidikan Matematika*, *16*(2), 171–186. https://doi.org/10.22342/jpm.16.2.17698.171-186

Susanta, A., Susanto, E., Stiadi, E., & Rusnilawati. (2023). Mathematical literacy skills for elementary school students: a comparative study between interactive stem learning and paper-and-pencil STEM learning. *European Journal of Educational Research*, *12*(4), 1569–1582. https://doi.org/doi: 10.12973/eu-jer.12.4.1569

Taljaard, J. (2016). *A review of multi - sensory technologies in a Science , Technology , Engineering , Arts and M athematics (STEAM) classroom defining learning styles Background on multi-sensory instruction*. *9*(2), 46–55. https://eric.ed.gov/?id=EJ1117662

Thiagarajan, S., Semmel, & Semmel. (1974). *Instructional Development for Training Teachers of Exceptional Children*.

Thingwiangthong, P., Termtachatipongsa, P., & Yuenyong, C. (2021). Status quo and needs of STEM Education curriculum to enhance creative problem solving competency. *Journal of Physics: Conference Series*, *1835*(1). https://doi.org/10.1088/1742-6596/1835/1/012089

Tran, N., Huang, C., Hsiao, K., Lin, K., & Hung, J. (2021). *Investigation on the In fl uences of STEAM-Based Curriculum on Scienti fi c Creativity of Elementary School Students*. *6*(October), 1–8. https://doi.org/10.3389/feduc.2021.694516

Wijaya, E., Sudjimat, D., & Nyoto, A. (2016). Transformation of 21st century education as a demand for human resource development in the global era [in Bahasa]. *Proceedings of the Seminar Nasional Pendidikan Matematika*, 263–278. https://repository.unikama.ac.id/840

Wu, C., Liu, C., & Huang, Y. (2022). The exploration of continuous learning intention in STEAM education through attitude, motivation, and cognitive load. *Int J STEM Educ*, *9*(1). https://doi.org/10.1186/s40594-022-00346-y

Wu, J., Guo, R., Wang, Z., & Zeng, R. (2021). Integrating spherical video-based virtual reality into

elementary school students' scientific inquiry instruction: effects on their problem-solving performance. *Interactive Learning Environments*, *29*(3), 496–509. https://doi.org/10.1080/10494820.2019.1587469

Yoon, M., & Baek, J. (2018). Development and application of the STEAM education program based on the soccer robot for elementary students. *Int J Mob Blended Learn*, *10*(3), 11–22. https://doi.org/10.4018/IJMBL.2018070102