



Development of STEAM (Science, Technology, Engineering, Art, and Mathematics) to Enhance Elementary School Students' Science Literacy

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Abstract: This study aims to develop an integrated STEAM model of experiential learning and constructivism in improving elementary school students' scientific literacy. The sampling technique uses purposive sampling. Data collection techniques include interviews, questionnaires, and tests. Data processing is carried out using descriptive statistics. The development method used is design-based research (DBR), which has four stages; Stage 1, The preliminary study found challenges and problems regarding the implementation of the STEAM learning model in elementary schools. Stage 2, design and product development. Stage 3, involves a validation test involving five experts: technology, materials, language and two of education practitioners. The fourth stage is product improvement. The study results showed that the STEAM model met the criteria for being feasible and practical. The results of statistical testing using the T Test (Independent Sample T test) obtained a significance value of 0.001 < 0.05. The effectiveness criteria were met with an average score of Ngain in the experimental class of 0.62 in the moderate category. The N Gain Percent test scored 62% with a reasonably moderate category. The STEAM model, integrated with constructivism and experiential learning, has proven effective in improving elementary school students' scientific literacy.

Keywords: Constructivism; Experiential learning; Science literacy; STEAM

Introduction

Science literacy is part of the School Literacy Movement (GLS) initiated by the Minister of Culture and Education since 2015 (Turrayan, 2021). Science literacy is applying knowledge to identify questions, construct new knowledge, provide scientific explanations, and develop reflective thinking patterns to solve science-related problems (OECD, 2024). Science literacy is a skill that elementary school students must have. It aims to ensure that they understand scientific concepts and can apply them in everyday life.

According to the author's experience, students with low science literacy skills are characterized by several issues, including difficulty understanding problems,

finding solutions, thinking critically, and collaborating. These skills are essential components of science competence. On several occasions, students have difficulty solving problems given by teachers, especially in assignments such as observation, project creation, and problem-solving-based activities. The low ability to understand informational texts can impact students' problem-solving abilities. If students are less able to understand information from the text, they will have difficulty analyzing problems, compiling data-based solutions, and making the right decisions. Understanding informational texts is closely related to students' overall literacy abilities.

The results of observations of student literacy in several schools in the Buwun Mas area indicate that

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most students' literacy skills are in the moderate category. More broadly, West Lombok Regency literacy data in 2023 shows that 40.00% to 70.00% of students achieve minimum literacy competencies, which are still categorized as moderate (Ministry of Education and Culture, 2024). This condition confirms that students' literacy skills must be improved. This aligns with research results showing that Indonesian students' overall science literacy skills are still relatively low (Turrayan, 2021; Utami et al., 2022).

Based on the international science literacy scores released by the OECD in the last three cycles, Indonesian students scored 403 (2016), 396 (2019), and 383 (2024), respectively, all of which are below the international average. In line with the OECD data, Sari et al. (2021) research found that only 30% of elementary school students achieved the minimum standard of science literacy (Rahayu & Anggraeni, 2017). Stated that the science literacy of students in Indonesia is relatively low. In line with this, Kelly et al. (2013) reinforced that Indonesian students have low levels of science literacy. In Mataram, the science literacy competency of most students is in the low category (Astria et al., 2022).

This challenge arises because the learning process has not facilitated students to apply scientific literacy in everyday life. Cultivating literacy can encourage students to develop literacy (Musaddat et al., 2021). A preliminary study found that students' scientific literacy is low, so a practical learning approach is needed to improve this ability. The solution that can be used to overcome the problem of low scientific literacy skills of students is the use of STEAM in learning. STEAM can be applied in learning to improve scientific literacy in students (Adriyawati et al. 2020). STEAM is recognized as a learning approach that can encourage the development of creativity and critical thinking skills in students (Imamah, 2020). STEAM is one of the effective learning models to motivate students to be active in learning activities (Hamid, 2024). Adriyawati et al. (2020) found that the application of STEAM in elementary school science learning can develop students' scientific literacy. This increase occurs because when learning STEAM, students can see the relevance of scientific knowledge in explaining phenomena encountered in everyday life. Scientific literacy can provide students with the ability to understand scientific concepts, phenomena, and processes necessary to participate in society in the 21st century (Karampelas, 2021; Pertiwi et al., 2018).

STEAM has also been proven to be an effective learning model to improve students' understanding of scientific concepts. STEAM learning activities can improve students' scientific literacy on climate change material (Sriyati et al. 2023). Astria et al. (2022) research shows that STEAM-based learning can help students

develop critical and creative thinking skills in solving science problems. Baran et al. (2021), Suryandari et al. (2018), Tati et al. (2017), and Triana et al. (2020) revealed that the application of STEAM was declared effective in improving students' critical thinking skills and scientific literacy. STEAM-based learning (science, technology, engineering, art, and mathematics) is more easily accepted and used by students. The success of STEAM occurs because STEAM learning is contextual learning.

The studies above have proven that STEAM has been proven to be an effective learning model to improve students' understanding of scientific concepts. But the studies also show the STEAM also has several disadvantages, one of which is time constraints (Sugita et al., 2025; Barkah et al., 2024; Nuragnia et al., 2021). To solve the problem, the research is modified the syntax of STEAM to make it more efficient. It became the novelty of this research. In addition, theoretically, the STEAM syntax offer is based on the engineering design process, namely integrating experiential learning and constructivism into the STEAM model, which is rarely found in previous studies. The development of the STEAM model refers to Gagne's reverse theory and Reigeluth and Merrill's three learning components which not only focus on developing cognitive aspects but also involve elements of creativity through a combination of science, technology, engineering, art, and mathematics in improving students' scientific literacy in terms of content, process, and context. With this approach, it is expected that students will not only understand scientific concepts but also be able to apply them practically in their creative projects. This research will make a new contribution to the field of education by providing learning experiences using STEAM that can be widely applied in elementary schools.

This study was carried out with a problem formulation: (1) How is the map of problems and fulfillment of STEAM learning aspects in elementary schools today? (2) How does the design and product of the STEAM model improve elementary school students' scientific literacy? (3) How is the effectiveness of using the STEAM model in improving elementary school students' scientific literacy? (4) How does the final STEAM model improve elementary school students' scientific literacy?

Method

The research was conducted using the research and development (R&D) method with a design-based research (DBR) model consisting of four stages: problem analysis, design preparation, interactive testing, and test reflection (Reeves, 2016). The experimental and control class experimental designs are presented in Table 1.

Table 1. Experimental and Control Class Scheme

Group	Pretest	Treatment	Posttest
Experiment	O ₁	STEAM	O ₃
Control	O ₂	Conventional	O ₄

The subject allocated to experimental and control group selected by purposive sampling (Table 1). The object of this study was learning using the STEAM model in SD Negeri 1 Buwun Mas (Experimental classes) and Conventional model in SD Negeri 4 Buwun Mas (Control classes). The data were collected by questionnaires, interviews, and tests. The questionnaires and interviews were used to analyze STEAM learning issues in schools and were aimed at teachers. The indicators were the suitability of STEAM components to the learning reality. Additionally, questionnaires were used for validation expert of language, technology, materials, and practitioners, with product feasibility parameters. Knowledge tests were aimed at students and were used to measure improvements in students' scientific literacy. The questionnaire was formulated based on a Likert scale. The questionnaire instrument item is presented in two aspects, namely the "reality" and "expectations" of the respondents, and both are compared to conclude the picture of reality and teacher's expectation. Data were analyzed descriptively and quantitatively, and experimental test results were analyzed descriptively, statistically, comparatively, and in terms of N-Gain. The test results were used as the basis for revising the STEAM model. Comparative tests were analyzed using the t-test. The provisions for hypothesis testing in this study are that if the probability significance value is < 0.05 at a significance level of 5%, Ho is rejected. However, if the probability significance value is > 0.05 at a significance level of 5%, then Ho is accepted. Before this test, a normality test was carried out using the Kolmogorov-Smirnov test, and the data were declared normally distributed. Furthermore, the homogeneity test used Levene's test with homogeneous data results.

Result and Discussion

Preliminary Study

The survey results on science learning in schools showed the following findings: First, the content aspect found that learning has not been directed at learning that

forms science literacy and students' thinking skills, but only focuses on reading books in schools. The learning that is implemented is not yet STEAM-based. Second, from the aspect of the learning process, it tends to be carried out with ordinary lectures and questions and answers, more students are instructed to read textbooks and answer exercises, minimal discussion activities, and direct learning. Third, learning focuses on aspects outside the context because it only uses textbooks. Fourth, support for resources and the environment is still lacking. Most teachers have directed learning towards problem-solving and the use of technology. However, several obstacles, such as limited facilities, time, and the ability to design learning activities, truly describe the process of scientific thinking and work.

This gap between expectations and reality indicates the need for increased teacher capacity, adequate resource support, and ongoing coaching so that science learning can truly reflect STEAM's characteristics and positively impact student competencies, especially science literacy skills. Teachers are the key to implementing learning (Shernoff, 2024). Rahayu et al. (2022) stated that implementing the curriculum must be accompanied by empowering human resources through training and coaching. More clearly, Lembong et al. (2024) stated that the purpose of teacher training and coaching is to improve pedagogical competence and skills to provide innovative, creative, and relevant learning to meet students' needs.

Design and Product Development

The development of the model is based on the reverse design of Gagne et al. (1992), in the form of formulating learning outcomes. Referring to the results of the preliminary study, the primary focus of this study is that students have scientific literacy. The formulation of learning outcomes is the basis for developing a design consisting of three components: objectives, procedures, and learning assessments. The main components of this model are modified from learning variables according to Reigeluth and Merrill in the form of conditions, methods, and learning outcomes (Sukardi et al., 2016). Specifically, the learning procedure is adopted from the opinion of Reigeluth and Merrill, consisting of three components, namely organizing material, delivering material, and managing learning. The STEAM model design is presented in Table 2.

Table 2. STEAM Design Model

Model Components	Explanation
Learning objectives	It contains learning objectives and learning achievement indicators. The objectives emphasize improving students' scientific literacy skills through the construction of STEAM-based learning device products.
Learning Procedures	

Model Components	Explanation
a. Organizing Material	Includes material arrangement, presentation of learning outcomes and indicators, text and image design, summary, student LKPD, and glossary. The ordering of materials is based on the sequence of student understanding.
b. Delivery of Material	The material is delivered using a social reconstruction approach of cooperation, interaction, communication, and direct experience. Its implementation is in the form of: (a) group learning; (b) face-to-face; (c) structured assignments in class through practice.
c. Learning Management	The learning stages follow the syntax of social reconstruction, namely: (a) activation of initial knowledge; (b) presentation of new knowledge; (c) understanding exercises; (d) practice in class; and (e) reflection on the process and results of the exercise.
Evaluation	The assessment is directed at the use of project-based assessment. Includes: (a) group assignment guidelines (LKPD); (b) assessment criteria for each aspect (planning, implementation, results/products, and reporting); (c) instruments; and (d) assessment rubrics.

Interactive Testing Cycle

The first test used expert validity testing to test the content and construction. Gultom (2017) stated that validation testing is needed to produce products that have standards and are suitable for use and identify product weaknesses (Dewanti, 2018). This testing involves three experts. Expert testing is carried out by involving technology experts, language experts, and material experts. The results of this testing are obtained in Table 3.

Table 3. Summary of the Results of the Technology, Language, and Content Expert Tests

Testing Aspects	Score	Assessment Category
Technology Expert	4.14	Very good
Linguist	4	Very good
Content Expert	4.6	Very good

The expert test interpretation criteria refer to Sukardi (2016), namely: very good, if the average assessment or response (pt) > 4; good, if 3 < pt <4; sufficient, if 2 < pt <3; less, if 1 < pt. Based on Table 2 above, it can be seen that the results of the expert test scores are, respectively, 4.14, 4, and 4.6. All of these results are included in the excellent category. So that the product is suitable for use in elementary schools. Thus, based on the test results, it is concluded that STEAM-based learning devices are suitable for use in elementary schools.

Instrument Validity Test

Instrument testing was carried out through validity and reliability tests. Validity test data showed that the Pearson correlation of each question was > 0.05, so all questions in the science literacy instrument were said to be valid for use to measure students' science literacy. Furthermore, a reliability test was carried out, with the

Cronbach's Alpha value of 0.853. This value is included in the very high category with a score range of 0.81-1, so the questions in the science literacy instrument are said to be reliable for use to measure students' science literacy. Questions declared valid and reliable were then tested to differentiate each question item. The results were obtained, namely, 10 out of 15 questions showed good validity with a correlation value greater than 0.50. At the same time, 5 out of 15 questions were in the sufficient category with a correlation value <0.05, with an average of 0.291-0.355. So, it can be concluded that overall, the tested question instrument showed adequate quality to measure the level of students' science literacy abilities. Analysis of the questions' difficulty level was also carried out, with the results of all items being in the easy and medium range, with a mean value category between 0.33 until 0.80, which indicates that the questions given are quite proportional in terms of difficulty. The data found that 3 out of 15 questions were included in the easy category, because the mean > 0.69, while 12 out of 15 questions were included in the medium category with a mean of 0.33-0.60. This means that the distribution of questions is good and even in measuring students' abilities.

Effectiveness Test

This test was conducted to determine the model's effectiveness in developing students' scientific literacy. This test was conducted using the t-test. Two requirements must be met before this test is conducted: normality and homogeneity. The data is normally distributed because the significance value is more than 0.05, which is 0.200. The data is also distributed homogeneously with a significance of 0.675 > 0.05. With the fulfillment of these two requirements, testing using the Independent Sample T Test parametric statistics was carried out. The test results are as follows.

Table 4. Summary of Hypothesis Testing

Variables	Class	N	Mean	Std.	t value	Df	Sig
Student Science Literacy	Experiment	32	84.66	11.355	-6.686	61	0.001
	Control	31	62.94	14.306			

Table 3 shows that there is a significant difference between the posttest results of the experimental and control groups because the sig value is $0.001 < 0.05$. The average posttest results of the experimental group are statistically higher than those of the control group. To determine the level of effectiveness, the N Gain test was conducted, with the following results.

Table 5. N Gain Test Results

Group	N-Gain	N-Gain (%)	Interpretation
Control	0.18	18%	Low
Experiment	0.62	62%	Moderate

The data above shows that using STEAM-based learning devices effectively improves students' scientific literacy, with a percentage of 62% in the moderate category. The experimental group showed a much higher increase in learning outcomes than the control group. This shows that the treatment given to the experimental group effectively improves elementary school students' scientific literacy. These results are based on a study by Atiaturrahmaniah et al. (2022), which improved students' scientific literacy by applying the STEAM model. STEAM aims to direct students to gain direct learning experiences and be involved in the learning process, encouraging them to have optimal learning competencies (Amelia & Marini, 2022). Both opinions align with Kolb's Experiential Learning theory (Sukardi et al., 2023), which states that this model is a learning model that facilitates students to construct their knowledge. In line with Kolb's theory, Vygotsky, with constructivism theory, also states that ideal learning facilitates students to combine knowledge and experience through interaction with the environment and their personal experiences (Salsabila & Muqowim, 2024). Learning based on experiential learning and constructivism is effective in providing optimal learning experiences for students in achieving learning goals (Sukardi et al., 2023), and learning based on constructivism theory makes a positive contribution to

conceptual understanding, student involvement, and learning motivation (Casfian et al., 2024).

STEAM combines both theories so that it can improve students' scientific literacy. This can be seen in the eight steps of STEAM according to Jolly (2017), where learning refers to the Engineering Design Process (EDP), which starts from defining the problem, conducting research, imagining solutions, making plans, constructing ideas, evaluating, redesigning, and communicating results. All of these syntaxes support experiential learning and constructivism theory in the learning process because students are actively involved in constructing their knowledge, accompanied by learning experiences obtained through learning activities, while teachers act as facilitators. These findings are in line with Shernoff's opinion (2024) that one of the advantages of STEAM is emphasizing a collaborative approach in providing learning experiences that are not only centered on teachers but also through collaboration from students.

The effectiveness of STEAM-based learning is also in line with Musaddat et al. (2021), who argue that the right learning strategy can accelerate the cultivation of literacy. This cultivation can be realized through experience-based learning or experiential learning because experience-based learning has been proven effective in providing meaningful learning (Sukardi et al., 2023). STEAM can provide students powerful, engaging, and real learning opportunities (Shernoff, 2024). STEAM also increases student motivation and engagement in learning.

Final Model Revision

The final result of the entire testing process is the compilation of the final model of the STEAM model integrated into the learning device. Various inputs and improvements were obtained in the testing process to produce the final model. Model improvements are more technical than substantive improvements. The description of the final model is shown in the table 6.

Table 6. Final STEAM Model Description

Model Components	Explanation
Learning objectives	The components of this model have not changed. The structure still follows the Education or Subject policy based on learning outcomes, which are derived into learning objectives and learning objective flows. Learning Outcomes This achievement is determined based on the applicable Education policy. The Ministry of Primary and Secondary Education has determined this learning achievement, which is adapted from SK BSKAP nomor 32 tahun 2024 tentang Capaian Pembelajaran (CP). Learning objectives The objectives emphasize students' scientific literacy as the primary focus. This objective refers to three topics of science learning in one topic. Learning Objectives Flow The flow of learning objectives is directly related to students' ability to observe, create, and analyze. These objectives are systematically arranged to achieve learning objectives and learning outcomes.

Model Components	Explanation
Learning Procedures	
a. Organizing Material	<p>The organization of this material is based on the arrangement of the material and the principle of social reconstruction. The organization of the material remains focused on the arrangement of the material, presentation of learning objectives, flow of learning objectives, text and image design, summary, evaluation, and Exercises.</p> <p>The sequencing of materials is based on the flow of learning objectives arranged systematically to achieve learning objectives and outcomes as a whole.</p> <p>Each material is presented communicatively, complete with colored illustrations. The text is arranged with appropriate margin rules, the right choice of fonts, and meaningful image designs to strengthen the message and make it enjoyable.</p>
b. Delivery of Material	<p>This component does not fundamentally differ from the initial design. The delivery of the material is based on the principles of social reconstruction and constructivism, such as learning as a joint activity, interaction, and cooperation, combined with direct practice activities.</p> <p>Learning in study groups, where each study group has a clear structure and clear division of tasks, during learning and practice outside the class.</p> <p>Face-to-face meetings are held in class to discuss the learning of each chapter/main material.</p>
c. Learning Management	<p>The design of this component has not changed.</p> <p>Learning begins by activating knowledge through trigger questions.</p> <p>The learning stages follow the syntax of the STEAM model, namely: Define the problem, research, plan, create, test and evaluate, redesign, and communicate</p> <p>Learning is done inside and outside the classroom. Learning outside the classroom is done during the first meeting for approximately 5 minutes.</p> <p>Knowledge reflection is carried out by displaying PPT and videos to strengthen students' understanding of the material.</p> <p>The comprehension exercise is carried out by answering cognitive reflections with a time allocation of 30 minutes.</p>
Evaluation	<p>The assessment is conducted using a project-based approach. This component is also no different from the initial design, including:</p> <p>Group assignment guidelines (LKPD) starting from planning, implementation, results, and reporting</p> <p>assessment criteria for each aspect (planning, implementation, results/products, and reporting),</p> <p>The instrument contains written tools to measure students' scientific literacy based on indicators and assessment criteria.</p> <p>The assessment rubric is compiled using a Likert scale that has four options, namely: score 4 (Proficient), score 3 (Proficient), Score 2 (Enough), Score 1 (Needs guidance)</p>

Results should be clear and concise. The discussion should explore the significance of the results of the work, not repeat them. A combined Results and Discussion section is often appropriate. Avoid extensive citations and discussion of published literature.

Conclusion

Based on the explanation above, it can be concluded that the STEAM effectively improved students' scientific literacy. This is evidenced by the achievement of the N-Gain percent of 62% with moderate category. This means that STEAM-based learning integrated with constructivism and experiential learning can be used in elementary schools because it can encourage student science literacy.

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Conceptualization, methodology, validation, investigation, analysis, and resources, I.J.; data curation, writing original draft preparation, writing review and editing, visualization, S., S.M.; All authors have agreed to published the version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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