Steam-Based Science Module to Optimize Critical Thinking Skills of Grade V Elementary School Students

Eko Sujaryanto, Sarwanto, Septi Yulisetiani

Universitas Sebelas Maret
eko_sujaryanto@yahoo.com

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Abstract
Developing critical skills of fifth-grade elementary school students in Natural and Social Sciences (IPAS) is crucial for 21st-century education, and STEAM offers a contextual approach to address the lack of higher-order skills in current practice. This study aims to: (1) identify the need to develop a STEAM-based IPAS teaching module, (2) design a STEAM-based IPAS teaching module that suits the characteristics of elementary school students, and (3) produce an initial product of the teaching module that is validated by experts. This study uses the R&D (Research and Development) model from Borg and Gall which is simplified into three stages by Sukmadinata, namely preliminary study, model development, and model testing. This article focuses on the preliminary study and initial product development of the module. Data were obtained through literature studies, interviews, observations and document analysis. The development results produced a STEAM-based IPAS module design which was then validated by material experts, media experts, and linguists. The validation results indicate that the module meets the feasibility for use in fifth-grade elementary school IPAS learning. The developed module is ready for use in a limited trial phase in further research.
Keywords: *Module, STEAM, Science, Development Design, Elementary School*

Abstrak
Mengembangkan keterampilan kritis peserta didik kelas V sekolah dasar dalam Ilmu Pengetahuan Alam dan Sosial (IPAS) sangat penting untuk pendidikan abad ke-21, dan STEAM menawarkan pendekatan kontekstual untuk mengatasi kurangnya keterampilan tingkat tinggi dalam praktik saat ini. Penelitian ini bertujuan untuk: (1) mengidentifikasi kebutuhan untuk mengembangkan modul pengajaran IPAS berbasis STEAM, (2) merancang modul pengajaran IPAS berbasis STEAM yang sesuai dengan karakteristik peserta didik sekolah dasar, dan (3) menghasilkan produk awal modul pengajaran yang divalidasi oleh para ahli. Penelitian ini menggunakan model R&D (Research and Development) dari Borg dan Gall yang disederhanakan menjadi tiga tahap oleh Sukmadinata, yaitu studi pendahuluan, pengembangan model, dan pengujian model. Artikel ini berfokus pada studi pendahuluan dan pengembangan produk awal modul. Data diperoleh melalui studi literatur, wawancara, observasi dan analisis dokumen. Hasil pengembangan menghasilkan desain modul IPAS berbasis STEAM yang kemudian divalidasi oleh ahli materi, ahli media, dan ahli bahasa. Hasil validasi menunjukkan bahwa modul memenuhi kelayakan untuk digunakan dalam pembelajaran IPAS kelas V sekolah dasar. Modul yang dikembangkan siap digunakan dalam fase uji coba terbatas dalam penelitian lebih lanjut.
Kata kunci: *Modul, STEAM, IPAS, Desain Pengembangan, Sekolah Dasar*

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INTRODUCTION

The 21st century is an era that demands fundamental changes in the education system, not only in terms of learning content, but also in the approaches, methods, and competencies developed in students. One essential competency that students must possess is critical thinking skills. This ability is not only important for solving everyday problems but also for participating actively and wisely in an increasingly complex social and global life. Critical thinking encompasses the ability to analyze, evaluate, and draw logical conclusions from information and make decisions based on data and facts (Facione, 2011). Therefore, critical thinking skills need to be developed from elementary school so that they are systematically and sustainably embedded.

In the context of elementary education in Indonesia, one subject with significant potential for developing critical thinking skills is Natural and Social Sciences (IPAS). This subject integrates science and social studies and is designed to help students understand natural and social phenomena holistically and contextually. However, the reality on the ground shows that IPAS learning is still dominated by a traditional, teacher-centered approach, with lecture and memorization methods that do not engage students in higher-order thinking processes. Research by Hidayati and Yamin (2020) shows that the majority of elementary school teachers still use conventional approaches that do not challenge students to think critically, creatively, or solve problems.

This situation is exacerbated by the limited availability of media and teaching tools specifically designed to foster critical thinking skills in science learning. The teaching modules used tend to emphasize conceptual and procedural understanding, without providing space for students to explore knowledge through inquiry activities, experiments, or projects. As a result, science learning loses its appeal and relevance for students and fails to develop the skills needed in the modern era. Research by Putri et al. (2021) shows that only 25% of teachers explicitly stated that the teaching tools used encouraged students to think critically in solving science problems.

To address these challenges, a learning approach is needed that integrates various disciplines in a contextual and applicable manner. One innovative approach that has developed in the last decade is the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach. This approach integrates elements of science, technology, engineering, arts, and mathematics into a unified learning process based on projects and problem-solving. According to Yakman and Lee (2012), STEAM is not simply the sum of five disciplines, but rather a transdisciplinary approach that encourages students to think systematically, creatively, and reflectively about the various real-world problems facing humanity.

The integration of the STEAM approach into science and science learning is highly relevant to the demands of the Independent Curriculum, which emphasizes differentiated, contextual, and student-centered learning. The Independent Curriculum provides teachers with the flexibility to develop teaching materials tailored to student needs and characteristics and encourages the use of project-based and exploratory approaches. The Ministry of Education, Culture, Research, and Technology (2022) states that the STEAM approach aligns with the principles of liberating learning, where students are given space to ask questions, explore, discover, and create in their learning process.(Nikmah, Z., Artharina, F. P., & Nuvitalia, D. 2023).

However, the integration of STEAM into science learning in elementary schools still faces various challenges. One of these is the lack of teaching modules specifically designed to accommodate STEAM principles in the science context. Existing modules are generally disciplinary, non-contextual, and do not stimulate student creativity and engagement in intellectually and emotionally challenging activities. Furthermore, some teachers admit to not fully understanding how to design and implement STEAM-based learning appropriate for elementary school levels (Hermawan & Sulastri, 2020).

This phenomenon demonstrates the urgent need to develop a STEAM-based science teaching module that can serve as a practical guide for teachers and an engaging and meaningful learning medium for students. This module is expected to not only present integrated science material but also include learning activities that encourage students to observe, ask questions, research, create, and reflect on their learning process.

Based on the above description, it is urgent to conduct developmental research focusing on the design of a STEAM-based Natural and Social Sciences (IPAS) teaching module that aligns with the characteristics of elementary school students. This is important because IPAS learning has not yet optimally fostered critical, creative, collaborative, and communicative skills, which are essential 21st-century competencies. The presence of a STEAM-based teaching module will serve not only as a concrete innovation in IPAS learning but also as a strategic effort to integrate 21st-century skills into elementary education in a measurable and sustainable manner.

Several previous studies also highlight the urgency of integrating STEAM into IPAS learning. For instance, Nikmah, Artharina, and Nuvitalia (2023) found that the implementation of STEAM-based IPAS learning within the Independent Curriculum increased student engagement and fostered higher-order thinking skills. These findings affirm that the STEAM approach is not only theoretically relevant but also practically effective in improving the quality of IPAS learning in elementary schools.

This research was designed to answer several problem formulations as follows: (1) What are the needs of students and teachers for STEAM-based science and natural science teaching modules in elementary schools? (2) How is the design of a STEAM-based science and natural science teaching module that is appropriate to the characteristics of elementary school students? (3) How is the feasibility of the initial product of the STEAM-based science and natural science teaching module based on the results of expert validation? These questions are the basis for developing teaching modules that are relevant and appropriate to the needs of science and natural science learning at the elementary school level.

In line with the formulation of the problem, this study aims to: (1) Identify the need for developing STEAM-based science and natural science teaching modules in elementary schools; (2) Design a STEAM-based science and natural science teaching module that suits the characteristics and needs of students; and (3) Produce an initial product of a STEAM-based science and natural science teaching module that has been validated in terms of content, media, and language. This objective is expected to produce quality learning products and support the improvement of students' critical thinking skills.

METHOD

This research is a type of research and development (R&D) according to the model of Borg and Gall (2003), simplified by Sukmadinata (2008), namely: (1) preliminary study, (2) model development, and (3) model testing. The research method uses a qualitative approach with descriptive methods aimed at gaining an in-depth understanding of the conditions of science learning in fifth-grade elementary schools. Data collection was conducted through literature studies to strengthen the theoretical basis for module development and field surveys using observation techniques, structured interviews with teachers, and distribution of questionnaires to students. Data sources for this research include fifth-grade teachers, fifth-grade students, learning documents, and learning events in three elementary schools in Musuk District, Boyolali Regency. Data validity was tested using technical triangulation, namely comparing the results of observations, interviews, questionnaires, and documentation. Data analysis used the interactive model of Miles and Huberman (1994), which includes the stages of data collection, data reduction, data presentation, and drawing and verifying conclusions.

The initial product was compiled based on the conclusions, then validated by experts and analyzed using descriptive statistics by calculating the average score based on a Likert scale, which was classified into several categories. The category results were used to assess the level of appropriateness of the content, display, language, and suitability of the Science and Natural Sciences module. The research was conducted in the first semester of the 2024/2025 academic year with the output in the form of an initial design of a STEAM-based Science and Natural Sciences module on the material Let's Get to Know Our Earth, compiled based on the results of the analysis of teacher and student needs to improve critical thinking skills.

RESULTS AND DISCUSSION

The results of each research stage include preliminary studies and expert validation. The results obtained are analyzed descriptively and linked to previous theories and research.

1. Preliminary Study

   The preliminary study's findings were obtained through literature review, observation, interviews, and questionnaires distributed to fifth-grade elementary school teachers and students. Through the literature review, the researchers found that STEAM-based science and education has significant potential for developing students' critical thinking skills. The literature review also demonstrated the importance of contextual, varied teaching materials that encourage exploratory activities for more meaningful learning.

   a. Results of the Teacher and Student Questionnaire

      A questionnaire distributed to ten teachers showed that most students were quite interested in science lessons, especially when teachers presented practical activities or simple experiments. However, students still struggled with comprehension when the material was presented only theoretically. Teachers also assessed that existing teaching materials were less engaging and did not fully encourage critical thinking skills. The questionnaire also revealed that teachers desired more varied and interactive teaching materials.

      A questionnaire of 48 students showed that 73% found the science material difficult to understand, although the majority (70%) remained enthusiastic about listening to the teacher's explanations. Students considered learning more enjoyable when it was related to everyday life or involved hands-on practice. They disliked the dominance of textbooks and preferred engaging learning materials based on technology, art, or project activities. These results also indicate that students exhibit a strong interest in learning that demands critical thinking skills and in-depth reasoning.

   b. Observation Results and Documentation

      The results of classroom observations corroborated the findings of interviews and questionnaires, namely that teachers tended to use lecture methods, leaving students more passive listeners. Project-based learning activities and experiments were rarely implemented. Students appeared more enthusiastic when teachers presented simple demonstrations or used visual media.

   c. Interview Results

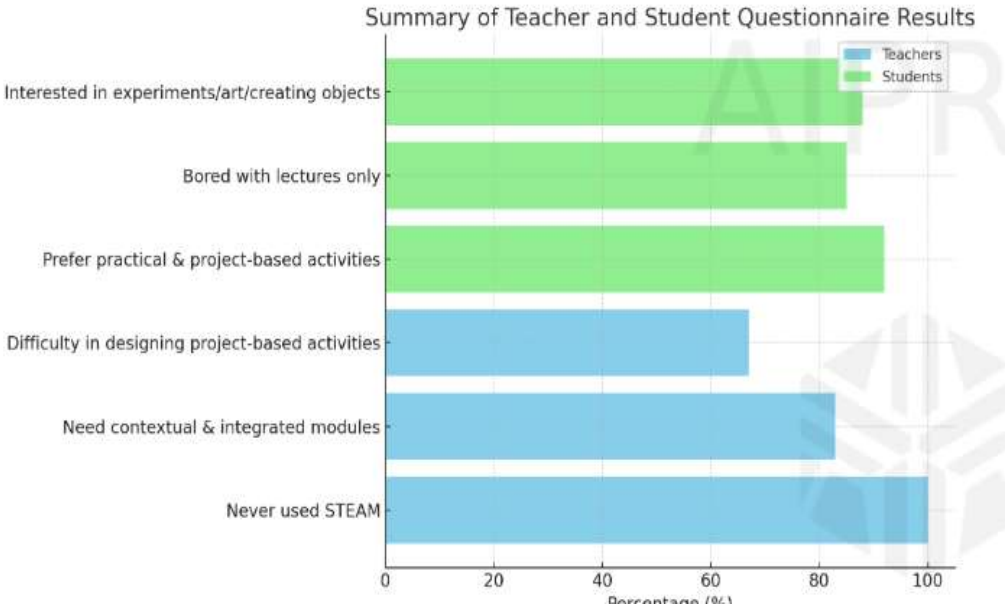
      In-depth interviews corroborated the findings from the questionnaire. Teachers expressed their hope for a modular guide that could help them implement a simple interdisciplinary approach. Meanwhile, students stated that they enjoyed learning more through activities that involved creativity and group work. In-depth interviews corroborated the findings from the questionnaire. Teachers expressed their hope for a modular guide that could help them implement a simple interdisciplinary approach. Meanwhile, students stated that they enjoyed learning more through activities that involved creativity and group work.

d. Data validity
Data validity was checked through technical triangulation by comparing the results of observations, interviews, and documentation. Data from all three sources showed consistency, both regarding the limited use of learning media, increased student interest during practice, and teacher challenges due to limited school facilities.

Interpretation: The results of the preliminary study identified several important needs: (1) more contextual and relevant science teaching materials for everyday life, (2) interactive media or modules that can increase student motivation and engagement, (3) development of critical thinking skills through challenging and meaningful activities, and (4) solutions to the limitations of learning resources and variations in learning methods in schools. These findings form the basis for designing a STEAM-based science module on the Let's Get to Know Our Earth material which is expected to improve the quality of learning and critical thinking skills of fifth grade elementary school students.

Summary of Questionnaire Findings

Respondents	Indicator	Percentage	Interpretation
Teachers (n=10)	Never applied STEAM explicitly	100%	Teachers lack STEAM-based practices
Teachers (n=10)	Need contextual and integrated modules	85%	High demand for innovative modules
Teachers (n=10)	Difficulty designing project-based activities	65%	Limited resources hinder innovation
Students (n=48)	Prefer project/practical activities	92%	Students want active learning
Students (n=48)	Feel bored with lecture-only lessons	85%	Conventional methods demotivate students
Students (n=48)	Interested in experiments/art/object-making	88%	Strong preference for creative and hands-on learning



The graph illustrates the needs of teachers and students regarding STEAM-based learning modules. All teachers (100%) reported that they had never explicitly implemented the STEAM approach. Furthermore, 83% of teachers indicated the need for contextual and integrated modules, while 67% admitted difficulties in designing project-based activities due to limited resources. On the other hand, 92% of students expressed a preference for learning activities involving practice and projects, 85% stated they felt bored when learning was limited to teacher explanations, and 88% showed interest in activities such as experiments, art, or creating objects. These findings confirm the urgent need for innovative teaching modules that incorporate STEAM principles to make learning more engaging and meaningful.

2. Development of STEAM-Based Science Module Design

The Science and Science module was developed based on the results of a preliminary study and the learning outcomes structure of the Independent Curriculum for fifth grade elementary school. The chosen material is "Let's Get to Know Our Earth," which allows for the integration of the five elements of the STEAM approach in a contextual and engaging manner for students. The module structure consists of several main components, namely the module identity and learning outcomes, learning objectives, and activity descriptions based on the STEAM stages. Learning activities are structured based on the STEAM approach, including: science aspects with discussion activities on the natural appearance of our earth, the earth's changing surface, and the earth's layers; technology to explore the earth's plates through digital simulations; engineering by designing a water cycle diorama; arts by creating a pop-up of the earth's atmospheric layers; and mathematics by creating a graph of the relationship between temperature and the depth of the earth's layers. The module is also equipped with reflection and evaluation activities that encourage critical thinking skills. Overall, this module is designed to build a holistic understanding of the earth and train students in integrating the concepts of science, technology, art, and mathematics in meaningful learning.

The project-based approach is implemented with the following syntax: problem orientation – exploration – solution design – implementation – reflection. This approach encourages students to conduct inquiry, work collaboratively, and produce tangible products. The modules are structured with integration, creativity, and meaningfulness in mind. Each activity is designed to facilitate critical thinking, reflection, and collaboration, tailored to the characteristics of elementary school students.

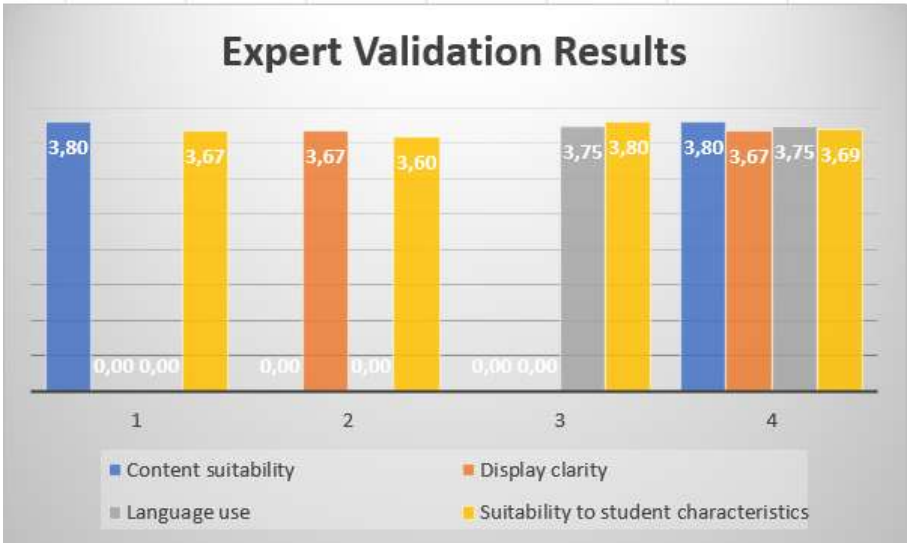
3. IPAS Module Validation Results

The developed module was validated by three experts (materials, media, and language). The validation results are presented in the following table:

Table 1. Expert Validation Results of STEAM-Based Science Teaching Modules

Rated aspect	Subject Matter Expert	Media Expert	Linguist	Average
Content suitability	3.80	–	–	3.80
Display clarity	–	3.67	–	3.67
Language use	–	–	3.75	3.75
Suitability to student characteristics	3.67	3.60	3.80	3.69

The score is categorized as "Very Good", which means the module is suitable for use at the trial stage.



Picture 1. Results of Science Process Skills Observations

Expert comments also showed appreciation for the integration of STEAM in the module, but provided suggestions for improvements to the task instructions section to make it more concise and easier for elementary school students to understand.

4. Readability Test Results

A limited trial of the STEAM-based science module was conducted in a fifth-grade class at SDN 2 Musuk, Boyolali, in March 2025, involving 16 students and a teacher. Observations showed that students were enthusiastic, actively engaged in discussions, and easily followed the practicum. The teacher found the clear learning flow helpful. However, several obstacles were encountered, such as excessively long text, small font size, and difficult-to-understand scientific terms, requiring additional explanation.

The following is a summary of the results of teacher and student interviews in the readability test as seen in the following table.

Aspect Assessed	Teacher's Comment	Student's Comment	Researcher's Notes/ Recommendation
Readability	The font size in certain parts is too small.	The writing is sometimes too long, making it tiring to read.	Adjust the font size and condense the text to make it more comfortable for students to read.
Content Presentation	The material is well-structured, and the learning flow is clear.	The material is easy to understand, but some difficult words need to be explained by the teacher.	Simplification of terms.
Learning Activities	The practical activities are relevant and easy to carry out.	I like the experimental part because it's fun and easy to do.	Maintain simple hands-on/material-based practical activities.

Ease of Use	The module makes it easy for teachers to teach because the steps are clear.	The instructions are sometimes long, so it takes time to understand them.	Simplification
Student Engagement	Students are more active and involved in the learning process.	They feel more motivated to learn because they can have hands-on practice.	Maintain active learning methods based on STEAM.

Data analysis in this readability test produced five main findings: (1) readability still needs to be improved through text summarization and font size adjustments, (2) the presentation of the material was assessed as neat and clear but some terms needed simplification, (3) the practical learning activities were relevant, easy to do, and liked by students, (4) the module made it easier for teachers to teach even though the instructions in some parts were too long, and (5) student involvement increased significantly with the practical activities.

Overall, teacher and student responses were positive, indicating the module is suitable for extensive testing. Some recommendations for improvement include increasing the font size, summarizing instructions, adding a glossary, and clarifying illustrations to make them more engaging.

The results of this study support previous findings that the STEAM approach is effective in improving 21st-century skills, including critical thinking (Quigley & Herro, 2016; Freeman et al., 2017). The developed science and natural sciences module integrates various disciplines in a contextual manner and is appropriate for the abilities of elementary school students.

Furthermore, validation results indicate that the module development with the appropriate approach is well-received by both experts and students. This reinforces Hopkins' (2008) argument that the quality of teaching materials developed through the research cycle has the potential to significantly improve learning quality.

These research findings align with previous findings that confirm that STEAM integration in learning is effective in developing 21st-century skills, particularly critical thinking skills. International research shows that the implementation of STEAM has a significant impact on improving elementary school students' critical thinking skills in science and social studies because this approach provides contextual and meaningful learning experiences (Papanda Journal of Research in Primary Education, 2024). In addition, project-based learning with STEAM integration has been proven to improve creative and collaborative thinking skills, as well as complex problem-solving, thus preparing students to face real challenges in the future (Arxiv, 2023).

CONCLUSION

This research aims to develop a STEAM-based science and natural science module tailored to the characteristics of elementary school students to foster critical thinking skills. Based on the results of the needs analysis, design, and expert validation, the following conclusions were reached:

First, the preliminary study indicates that both teachers and students require science and natural science teaching materials that are more contextual, interactive, and promote critical thinking skills. Questionnaires, interviews, and observations revealed that students still have difficulty understanding science material when presented solely theoretically, while teachers assessed that existing teaching materials were not

sufficiently varied and engaging. Thus, there is a clear need for a STEAM-based science and natural science module that aligns with the characteristics of elementary school students.

Second, the module design, developed based on the results of the preliminary study and the learning outcomes of the Independent Curriculum, successfully integrates the five elements of STEAM into the "Let's Get to Know Our Earth" material. This module not only presents scientific concepts scientifically but also integrates technology, engineering, art, and mathematics through project-based activities that encourage inquiry, collaboration, creativity, and reflection. This design consistently supports meaningful learning and aligns with the cognitive development of elementary school students.

Third, expert validation results indicate that the STEAM-based science and natural sciences module was rated very good in terms of material, media, and language, with an average score above 3.6. This finding confirms that the developed module is suitable for implementation in learning, although it still requires minor improvements in the clarity of instructions and simplification of terms to better align with students' level of understanding.

Fourth, the results of the readability test in fifth-grade students at SDN 2 Musuk reinforce previous findings, where students demonstrated enthusiasm, active engagement, and increased enthusiasm for learning when using the module. Teachers found the module helpful because it provided a clear and practical learning flow. However, there were several improvements, such as increasing the font size, summarizing instructional text, and adding a glossary. These improvements provide important input for refining the module before its widespread testing.

Thus, it can be concluded that the STEAM-based science and natural sciences module developed in this study is relevant to the needs of students and teachers, has a design that aligns with the characteristics of elementary school learning, and is suitable for use based on the results of expert validation and the readability test. This module has the potential to make a significant contribution to improving the quality of science and science learning while simultaneously developing critical thinking skills in elementary school students.

The implication of this research is that the use of the STEAM approach in science and science learning has significant potential to enhance meaningful and contextual learning. This module can be used not only by teachers as a teaching tool but also as a reference for developing interdisciplinary learning at other elementary education levels.

Recommendations for further research include implementing and evaluating the module's effectiveness in the classroom through limited trials and broader field testing. The researchers also recommend developing similar modules for other science and science topics, as well as for grades IV and VI, to support the continuity of STEAM-based learning in elementary schools.

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