Preliminary Study: Development of Interactive Science Teaching Materials Based on STEAM-PjBL to Improve Students' Science Process Skills

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Abstract

This study aims to develop an interactive science teaching material based on the STEAM–Project Based Learning (STEAM-PjBL) approach to improve elementary school students' science process skills (SPS). The research method using the 4D model, focusing on the define stage, which included front-end analysis, learner analysis, concept analysis, task analysis, and the specifying instructional objectives. Data were collected through science process skills tests, classroom observations, interviews, and document analysis. The results of the initial SPS test showed that several indicators were still low, particularly communicating, observing, predicting, and inferring skills. Classroom observations revealed that science learning was still teacher-centered, with limited experimental and project-based activities, while teachers had not yet utilized interactive STEAM-PjBL-based teaching materials. The development of STEAM-PjBL-based interactive teaching materials is expected to facilitate active student involvement, support hands-on inquiry-based learning, and effectively enhance students' science process skills in elementary science education.

Keywords: Interactive Teaching Material, STEAM-PjBL, Science Process Skill (SPS)

Introduction

Science learning has been introduced as a subject in Indonesia starting from the elementary school level. Science learning covers topics that study various natural phenomena, including understanding oneself and the surrounding environment (Anggraini & Puspita, 2024). Science learning has an important role for students. Through science learning, students are trained to examine natural phenomena, enabling them to use this knowledge to solve problems in their daily lives. Science learning also encourages students to develop attitudes of care, responsibility, and environmental awareness. In addition, science learning can improve students' science process skills (SPS).

Science process skills (SPS) refer to students' abilities to use scientific methods. SPS consist of a series of activities such as collecting and organizing information, making predictions, explaining phenomena, solving problems, and learning science (Gizaw & Sota, 2023). SPS are also closely related to students' cognitive abilities in understanding natural phenomena in order to solve problems and improve learning outcomes (AlAli & Al-Barakat, 2024; Wazni & Fatmawati, 2022). Science process skills are divided into two levels: basic and integrated SPS (Turiman et al., 2012). Basic SPS indicators include observing, classifying, measuring, inferring, predicting, and communicating results, while integrated SPS indicators include interpreting data, defining operationally, controlling variables, formulating hypotheses, and conducting experiments (Derilo, 2019). Students need to be able mastering on basic science process skills as a fundamental foundation for developing integrated science process skills.

Science process skill is esential for students. SPS help students to develop cognitive, affective, psychomotor, and social skills (Br Sitepu et al, 2021). SPS also contribute to improving positive attitudes such as responsibility, curiosity, honesty, creativity, tolerance, and self-confidence (Kurniawati, 2021). In this regard, SPS are not only beneficial for science learning but also help students to enhance their critical thinking skills to solve everyday problems ((Zorluoğlu et al, (2022); Yildiz & Guler Yildiz (2021); Darmayanti & Setiawati (2022)

To develop students with good science process skills (SPS), learning needs to be conducted optimally and with high quality. In this context, students must be directly involved in the learning process so that they can gain meaningful learning experiences. This is in line with Datubaringan et al (2025), who state that learning becomes more effective when students actively participate. Learning is essentially a process of discovering knowledge through abstraction and reflection (Jampel et al., 2018). One of the learning approach that can enhance students' science process skills is the STEAM–Project Based Learning (STEAM-PjBL) approach. Through this approach, students

are guided to design projects that integrate multiple disciplines, including science, technology, engineering, art, and mathematics (STEAM). The combination of science learning and project-based learning provides opportunities for students to engage in interesting and meaningful learning experiences (Chistyakov et al., 2023). Integrated STEAM-PjBL learning strongly supports the development of critical thinking, collaboration, communication, problem-solving skills, and higher-order thinking skills (HOTS) among students (Paramita & Fitria (2025); Andup et al., (2025); Anugrahsari et al., 2025)

However, field analysis reveals that science learning is still predominantly teacher-centered. Students' involvement in the learning process remains very limited. The lack of student activity during learning is one of the main factors contributing to students low science process skills (SPS). Preliminary studies indicate that several SPS indicators are still low, particularly observing, communicating, and predicting, with achievement percentages below 50%. Interviews with teachers reveal that students are rarely involved in experimental activities or project-based tasks, resulting in underdeveloped skills in observing, predicting, and communicating results. Document analysis further shows that teachers do not yet have instructional materials that facilitate the development of students science process skills. The teaching materials currently used are limited to textbooks, which do not systematically and structurally incorporate experimental procedures or project-based activities.

By considering the use of teaching materials that contain systematic steps in project development integrated with the STEAM-PjBL approach, it is expected that students science process skills (SPS) can be improved. Previous studies have widely examined teaching materials and the STEAM-PjBL approach, including the development of IPAS teaching materials using an ethno-STEAM approach with the PjBL model to enhance critical thinking skills (Dewi & Muljani, 2024); the development of guided discovery-based teaching materials to improve science process skills (Imran et al., 2020); the development of teaching materials using the PjBL model to improve scientific literacy and numeracy (Izzania et al, 2025; Ismail & Fitria, 2021; Rahmani et al, 2021; Pratiwi et al, 2024; Siregar & Reinita, 2022); the development of STEAM-PjBL based teaching materials to improve scientific literacy skills (Izzania et al., 2021); as well as interactive science teaching materials developed by Sevilla et al, (2023), Nuraripin & Jaja (2021), and Novianti et al, (2022). However, these developments have not specifically focused on interactivity and the improvement of students science process skills. Therefore, this study offers novelty through the development of interactive science teaching materials based on the STEAM-PjBL approach to enhance science process skills of elementary school students.

Method

This study is a preliminary study that aimed to conducting an initial investigation, needs analysis, and situational analysis as the first stage in the development of interactive science learning materials based on STEAM-Project Based Learning (STEAM-PjBL) to enhance students science process skills at the elementary school level. The development of the interactive science learning materials is carried out using the Research and Development (R&D) method with the 4D model developed by Sivasailam Thiagarajan, Dorothy S. Semmel, and Melvyn I. Semmel. This model consists of four systematic stages, namely define, design, develop, and disseminate. This study focuses specifically on the define stage, which is the initial phase of the 4D model and aims to conduct an in-depth preliminary analysis prior to developing the interactive science learning materials. The research was conducted with fifth-grade students at a private elementary school in Cikupa District, Tangerang Regency.

The data collection methods used in this preliminary study included interviews, observations, and documentation. Interviews were conducted to obtain in-depth information regarding the science learning process, the challenges faced by teachers and students during instruction, and the need assessment for interactive science teaching materials to be developed. Observations were carried out to collect factual data related to the implementation of science learning and to identify problems encountered in classroom practice. Meanwhile, documentation was used to examine the availability, strengths, and limitations of the teaching materials currently used by teachers in facilitating project-based activities and in supporting the development of students science process skills.

The results of the initial analysis serve as a fundamental basis for the development of interactive science teaching materials in the subsequent stages. In this study, the design, development, and dissemination stages, which include product prototyping, expert validation, student trials, and product dissemination, are still in the planning phase. Therefore, the scope of this

research is limited to the preliminary study conducted prior to the development of interactive STEAM-PjBL based science teaching materials.

Results and Findings

In the 4D research and development model, the defining stage is the initial phase. At this stage, the activities focus on identifying and determining learning needs. In this phase, the researcher conducts the following analyses:

Front-End Analysis

The purpose of the front-end analysis is to identify the problems that occur in the science learning process in the classroom, as well as the instructional materials needed to address these problems. Based on the results of the science process skills test administered to 49 fifth-grade elementary school students, the following data were obtained:

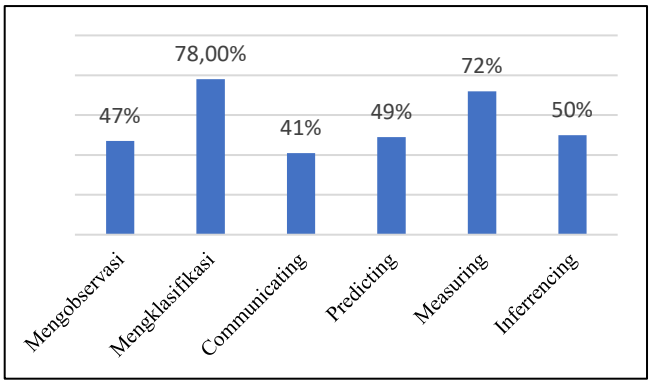

Figure 1. Science Process Skill's Test

Based on the results of the science process skills test above, it is showing that among the six indicators measured, several indicators of students' science process skills are still at a low level. The quantitative data show variations in achievement across the indicators. The communication indicator achieved a percentage of 41%, followed by observation at 47%, prediction at 49%, and inference at 50%. Meanwhile, the measurement indicator reached 72%, and the highest percentage was found in the classification indicator at 78%. These findings indicate that several science process skill indicators have not yet been optimally developed. Therefore, creative and innovative learning processes that actively involve students are needed to improve these science process skills..

The field observation's results indicate that the teaching methods used by teachers are still dominated by teacher-based instruction. Students' involvement in science activities remains limited. Based on interviews with teachers, experimental activities or project-based tasks are rarely conducted. This condition is one of the factors contributing to students' low science process skills. The low level of science process skills is also caused by the limited implementation of experimental activities, teachers' insufficient understanding of science process skills concepts, as well as limited resources and evaluation practices (Atikah & Haryanto, 2025). This finding is further supported by interviews with students, which reveal that activities related to predicting and communicating results in the form of diagrams, graphics, or presentations are rarely carried out.

In addition, the results of document analysis indicate that teachers do not yet have interactive teaching materials, particularly those based on STEAM-PjBL. The teaching materials currently used are still limited to textbooks, with experimental activities or project-based tasks that have not been optimally implemented. Therefore, it is necessary to develop interactive STEAM-PjBL based science teaching materials that can facilitate students in developing their science process skills. This need is reinforced by the results of the needs analysis, which show students and teachers expect interactive teaching materials that include a series of project-based activities in science learning. The results of the teachers' needs analysis also indicate a similar demand for interactive STEAM-PjBL based science teaching materials. The development of these materials is further supported by the school's facilities, which include a computer laboratory equipped with 30 devices. This condition provides an opportunity for researchers to develop interactive science teaching materials.

Learner Analysis

Learner analysis was conducted to identify students' characteristics, including learning styles, academic abilities, and prior knowledge. This analysis aimed to ensure that the development of interactive teaching materials would be aligned with the students' needs as users. Based on the results of the initial assessment conducted by the school counselor, it was found that fifth-grade students exhibited diverse learning styles, with the following percentages: visual (60,7%), auditory (17,8%), and kinesthetic (21%). The data indicate that students' learning styles are predominantly visual; therefore, the development of interactive teaching materials emphasizes visual elements such as images, videos, and hands-on activities that can be directly carried out by students.

In terms of academic ability, fifth-grade students show varying levels of achievement in science learning. Some students have demonstrated good academic performance, while others still require additional support to reach the expected level. Meanwhile, regarding computer operation skills, students tend to be proficient in using digital-based devices. These aspects constitute important findings that can be taken into consideration in the development of interactive science teaching materials.

Concept Analysis

Concept analysis was conducted to examine the subject matter concepts that would be developed in the interactive science teaching materials. In this research and development study, the material focuses on alternative energy sources, particularly water energy. This choice is based on the consideration that water energy is closely related to students' daily lives, enabling them to design and create simple projects that utilize water energy.

Task Analysis

Task analysis contains a series of key skills that must be mastered by students. Task analysis is conducted by breaking down the learning outcomes into measurable indicators. The task analysis for Science (IPA) Phase C on the topic of water as an alternative energy source is presented as follows:

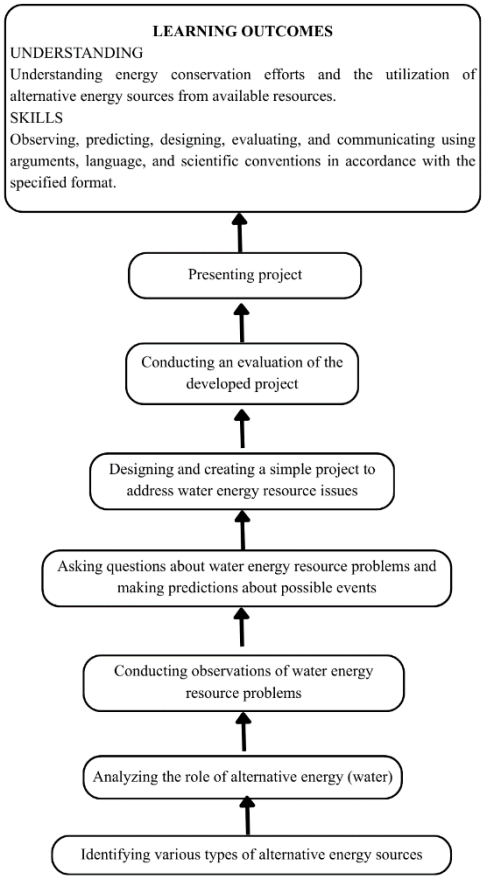

Figure 2. ***Task Analysis***

Specifying Instructional Objectives

The general objective of this study is to improve students' science process skills (SPS) through the use of interactive science teaching materials based on the STEAM-Project Based Learning (STEAM-PjBL) approach. To facilitate the measurement of learning outcomes, this general objective is further elaborated into the following specific objectives:

1. Through reading activities, students are able to identify various types of alternative energy sources accurately.
2. Through reading activities, students are able to analyze the role of alternative energy, particularly water energy, in everyday life accurately and logically.
3. After watching a video presented in the interactive learning material, students are able to observe water availability by involving multiple senses.
4. After watching the video, students are able to formulate questions using "why" and "what if" question words appropriately.
5. Through group discussions, students are able to design a simple water-based project accurately.
6. After completing the project, students are able to conduct evaluation and reflection logically.
7. After completing the project activities, students are able to prepare reports both orally and in written form.

Based on the learning objectives described above, the interactive science teaching materials to be developed need to facilitate students' active involvement in science learning so that their science process skills can be achieved. Clearly formulated learning objectives can assist researchers in developing products appropriately and in accordance with students' learning needs.

Conlusion

The define stage in the 4D model indicates that several indicators of students' science process skills are still low. This is evidenced by the percentages of the observing, predicting, and communicating indicators, which are all below 50%. Other problems identified in science learning include the dominant use of lecture-based teaching methods, limited student involvement in experimental activities or project development, and the absence of interactive STEAM-PjBL based teaching materials at the school where the study was conducted.

The results of the needs analysis and concept analysis show that both teachers and students require an instructional device in the form of interactive science teaching materials on the topic of water as an alternative energy source, integrated with the STEAM-PjBL approach. This development is expected to improve the science process skills of fifth-grade elementary school students. The concepts identified in the analysis stage were then translated into measurable specific learning objectives, enabling science learning to become more effective and optimal..

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