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THE DEVELOPMENT OF A STEM-ORIENTED SCIENCE TEACHING AID PROTOTYPE THROUGH PROJECT-BASED LEARNING UTILIZING DIVERSE LOCAL RESOURCE MATERIALS

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ABSTRACT

This study aims to develop STEM-based science teaching aids prototypes through the Project-Based Learning (PjBL) model among elementary teacher education students. The research employed the ADDIE development model, encompassing analysis, design, development, implementation, and evaluation stages. Five prototypes were successfully developed using natural materials, recycled items, household objects, basic laboratory tools, and synthetic materials. Expert validation from media and content specialists indicated the products were highly feasible. Students' responses to both the learning process and media were highly positive, demonstrating active engagement, increased motivation, and deeper understanding of science concepts. Effectiveness testing showed a significant improvement in conceptual understanding, with a gain score of 0.56 (moderate–high category). This study confirms that integrating STEM approaches with PjBL effectively enhances pre-service teachers’ ability to develop innovative teaching aids tailored to the needs of elementary school learners.

Keywords: Project-based learning; teaching aids; STEM; elementary science; media development

INTRODUCTION

Science education at the elementary level plays a strategic role in laying the foundation for scientific thinking, science process skills, and scientific attitudes among students. It is regarded as a crucial means of developing students' knowledge, skills, and scientific attitudes, which include curiosity, openness to evidence, critical thinking abilities, and a sense of responsibility toward the environment within the learning process (Hardianti & Safitri, 2025). The process of inquiry utilizing local resource materials aims to develop scientific attitudes and apply scientific work in discovering scientific concepts (products). Scientific work in the discovery of scientific concepts is known as science process skills, which involve thinking, reasoning, and acting logically to investigate and construct scientific concepts that are useful in problem-solving processes (Nugraha *et al*., 2017).

Research consistently shows that teachers are the key factor influencing the development of 21st-century skills in students. Despite the rapid advancement of technology in the digital era, the role of teachers remains central and significantly impacts student achievement. Therefore, the role of teachers in the 21st century needs to shift from merely delivering knowledge to becoming facilitators, motivators, and inspirers for students (Sulistyaningrum *et al*., 2019). In line with this, prospective elementary school teachers need to be equipped with the ability to design and use contextual and innovative learning media from their time in higher education. This preparation should not only cover content mastery but also pedagogical skills in designing media that are relevant to students' characteristics and the development of educational technology. Unfortunately, many prospective teachers still face difficulties in developing science teaching aids that meet learning needs, especially those that integrate interdisciplinary approaches such as STEM (Science, Technology, Engineering, and Mathematics) and active learning methods like Project-Based Learning (PjBL).

Although many training sessions on instructional media development have been provided, most prospective teachers still lack authentic experience in developing teaching aids based on the STEM approach integrated into the PjBL model. This shortcoming affects the level of innovation and reduces students' readiness to design contextual media that meet the learning needs of science education in elementary schools. Project-Based Learning is a learning process that directly involves students in producing a project. Essentially, this learning model focuses on enhancing problem-solving skills through working on a project that results in a tangible product (Sari & Angreni, 2018). The PjBL learning model provides students with the opportunity to directly experience the process of scientific thinking through projects involving the development of teaching aids based on real-world problems.

According to (Kurniawati, 2024) the STEM approach in basic science education goes beyond theoretical knowledge by integrating relevant technology and scientific techniques, enabling students to understand scientific concepts more effectively through hands-on experiences. In this context, the STEM approach strengthens students' learning experiences by integrating various scientific aspects into a single structured activity. The integration of STEM education can be applied at all levels of education, including higher education. Through the STEM approach, students' creativity is developed so that they can solve everyday problems and reason critically, logically, and systematically. The STEM approach is used to connect and integrate STEM subjects by applying the knowledge learned to phenomena occurring in real life (Hidayati *et al*., 2021).

The rapid advancement of technology has shifted many tasks that were previously performed by humans to machines. Therefore, a learning approach is needed to prepare prospective elementary school teachers to become creative individuals, critical thinkers, and problem solvers with skills in technology and engineering, enabling them to survive in global competition (Rahmawati & Juandi, 2022). This learning approach is also in line with the policy direction of Merdeka Belajar and Kampus Merdeka, which encourages higher education institutions to equip students with autonomous, collaborative, and contextual learning experiences. Additionally, strengthening 21st-century skills for prospective elementary school teachers supports the achievement of the Pancasila Student Profile through transformative learning based on solving real-world problems.

The implementation of the PjBL model can be integrated with the STEM approach in classroom learning (Ramadhana *et al*., 2022). The combination of the PjBL model and the

STEM approach is believed to create more meaningful learning, as students not only understand concepts but also apply them in real-life contexts. This process encourages students to actively explore, design solutions, and produce tangible products directly related to the science learning material. Referring to constructivist theory, which is a theory that broadens students' thinking and requires them to practice the theories they have learned in their daily lives (Rahmat sinaga, 2018). Based on this theory, students will gain a deeper understanding when they are actively involved in the search for meaning through real experiences and reflection. PjBL and the STEM approach support this principle because they encourage students to construct scientific concepts on their own through direct involvement in projects and collaboration, rather than merely receiving knowledge passively.

Previous research has shown that students' involvement in developing project-based learning media can enhance 21st-century skills of prospective elementary school teachers, such as critical thinking, creativity, collaboration, and communication (Krueger & Kling, 2004). Similar findings were also reported by (Dewi *et al.*, 2023), which shows that project-based and STEM approaches are capable of enhancing problem-solving abilities and collaborative skills of prospective teacher students. However, research that specifically develops STEM-based science teaching aid prototypes through the PjBL model, involving students as both subjects and main developers, and utilizing various local environmental resources such as natural materials, recycled materials (3R), household materials, simple laboratory materials, and manufactured (fabricated) materials, is still rare.

This approach also aligns with the need to prepare prospective teachers who are adaptive, creative, and capable of utilizing local potential in teaching science at the elementary school level. It has great potential to support contextual, cost-effective learning and to bridge the gap between theory and practice in educational settings. Moreover, students' direct involvement in the design and creation of teaching aids will foster a sense of professional responsibility and enhance their readiness as future educators. Therefore, this study was conducted as an effort to provide a solution to the weakness of prospective teachers' skills in designing innovative learning media, while also presenting a project-based training model that is relevant, practical, and based on local potential.

Based on the background described, this study aims to:

1. Develop a prototype of Natural Science (IPA) teaching aids designed based on the STEM approach (Science, Technology, Engineering, and Mathematics) and integrated into the Project-Based Learning (PjBL) model, so that it can serve as a contextual, practical learning tool that fosters 21st-century skills in prospective teacher students.

2. Actively involve students of the Elementary School Teacher Education Study Program (PGSD) as co-developers in the process of designing, creating, and developing the teaching aids, utilizing various materials sourced from the surrounding environmental resources, such as

natural materials, recycled or reused materials (3R), household materials, simple laboratory materials, as well as manufactured or fabricated materials.

3. Assess the quality of the developed media through expert validation, and evaluate students' responses to the learning process and the final results, in terms of engagement, conceptual understanding, and its impact on critical thinking and collaborative skills.

The benefits of this research include providing authentic and meaningful learning experiences for PGSD students through direct involvement in the development of project-based learning media; producing innovative, contextual, and affordable science learning media; and supporting the achievement of the PGSD graduate profile, which includes competencies as creative, collaborative educators capable of innovating in designing and implementing science learning that meets the needs of elementary school students.

METHOD

This study is a Research and Development (R&D) study (Rahmadi, S.Ag., 2011) which employs a mixed methods approach (Yam, 2022), which aims to develop and test the feasibility and effectiveness of a STEM-based science teaching aid prototype through the Project Based Learning (PjBL) model. The development model used is the ADDIE model (Asmayanti et al., 2020), which consists of five main stages: Analysis, Design, Development, Implementation, and Evaluation.

Research Subjects

The subjects of this study are second-semester students of the Primary School Teacher Education (PGSD) Study Program at Universitas Pasifik Morotai who are enrolled in the Elementary Science Learning (Upper Grades) course. The students are involved both as participants in the project-based learning activities and as developers of the science teaching aids.

Development Procedure

The research procedure follows the stages of the ADDIE model, namely:

1. **Analysis**: Analyzing learning needs and the potential use of surrounding materials (natural, recycled, household, simple laboratory, fabricated materials).

2. **Design**: Designing STEM-based science teaching aids using the Project-Based Learning (PjBL) approach.

3. **Development**: Developing prototypes of teaching aids by students using various types of materials:

    - Natural materials (e.g., ecosystem miniatures)
    - Recycled materials (3R) (e.g., respiratory system model using used bottles)
    - Household materials (e.g., electric circuit using batteries and simple wires)
    - Simple laboratory materials (e.g., acid-base experiments)

   - Fabricated/manufactured materials (e.g., organ system models)

4. **Implementation**: Conducting a limited trial of the media with students during practice/microteaching sessions.

5. **Evaluation**: Assessing the quality of the media and student responses to both the learning process and the final product.

Data Collection Techniques

Data collection was carried out using several instruments as follows:

- Expert validation sheets for media and content (using a Likert scale of 1–5) to assess the feasibility aspects of the product.
- Student response questionnaires regarding the media and learning process (using Likert scale items and open-ended questions).
- Observation sheets to monitor student activities during the development process and microteaching sessions.
- Learning outcome tests (pre-test and post-test) to measure the improvement in students' understanding of science concepts.

Data Analysis Techniques

The data analysis in this study employed a mixed methods approach, combining descriptive quantitative and descriptive qualitative techniques, according to the types of data obtained.

1. **Quantitative Analysis (Descriptive)**

Quantitative analysis was used for numerical and scaled data, including:

- **Expert validation results**, analyzed by calculating the average score and the feasibility percentage of each aspect using the following formula:

$$\text{Percentage} = \left(\frac{\text{Score obtained}}{\text{Maximum score}}\right) \times 100\%$$

- **Student responses** to the media and learning process, analyzed by calculating the average score and percentage to determine levels of interest, ease of use, and media effectiveness.

The following formula is used to analyze student responses to the media and the learning process based on the Likert scale:

   - Average Student Response Score

$$\bar{X} = \frac{\sum X}{N}$$

Description:
$\bar{X}$ = average score

$\sum X$ = total score of all respondents

N = number of respondents

   - Percentage of Student Response Scores

$$\text{Percentage} = \left(\frac{\text{Score obtained}}{\text{Maximum score}}\right) \times 100\%$$

Description:

Obtained Score = the total actual score from all respondents for a particular item or indicator

Maximum Score = number of respondents × maximum score on the Likert scale

- Score Interpretation Categories

Table 1. Likert Scale Categories (1–5 Scale)

Average Score Range	Category
4.21 – 5.00	Very Good
3.41 – 4.20	Good
2.61 – 3.40	Fair
1.81 – 2.60	Poor
1.00 – 1.80	Very Poor

- **Student learning outcomes** (pretest and posttest), analyzed using gain scores to determine the improvement in students' understanding of science concepts. The gain score is calculated using the formula:

$$\text{Gain} = \left(\frac{\textit{Posttest- Pretest}}{\textit{100 - Pretest}}\right)$$

Interpretation of the gain score refers to Hake (1998), as follows:

- Gain > 0.70 = high
- 0.30 < Gain ≤ 0.70 = medium
- Gain ≤ 0.30 = low

2. **Qualitative Analysis (Descriptive)**

Qualitative analysis was used to process descriptive data from observations, open-ended responses, and expert feedback. This process included:

- **Expert (validator) feedback**, analyzed narratively to revise the prototype of the instructional media.
- **Observation results** of student activities, analyzed to assess engagement, creativity, collaboration, and scientific attitudes during the development and microteaching processes.
- **Open-ended student responses**, analyzed to explore perceptions, experiences, and the impact of project-based learning on understanding science concepts.

RESULT AND DISCUSSION

Results

1. Development Results of STEM-Based Science Teaching Aids Prototypes through the PjBL Model

Based on the implementation of the ADDIE model, five prototypes of STEM-based science teaching aids were successfully developed by PGSD students using a variety of materials sourced from the surrounding environment. These prototypes were designed based on science themes and concepts tailored to the learning needs at the elementary school level:

- **Ecosystem Miniature (natural materials):** illustrates the relationship between biotic and abiotic components within an ecosystem using soil, small plants, pebbles, and water.

Figure 1. Ecosystem Miniature Made from Natural Materials

- **Human respiratory system model (recycled/3R materials):** made from used plastic bottles, balloons, and straws to demonstrate the diaphragm's mechanism.

Figure 2. Human Respiratory System Model Made from Recycled/3R Materials

- **Simple electrical circuit (household materials):** uses batteries, reused wires, switches, and LED lights to show the concept of closed and open electrical circuits.

Figure 3. Simple Electrical Circuit Made from Household Materials

- **Acid-base solution experiment (simple laboratory materials):** uses natural indicators from purple cabbage extract to test various household liquids such as vinegar, soap, and lemon juice.

Figure 4. Acid-Base Solution Experiment Using Simple Laboratory Materials

- **Digestive system organ model (fabricated materials):** uses EVA foam, cardboard, and paint to create a 3D model of digestive organs and the food pathway.

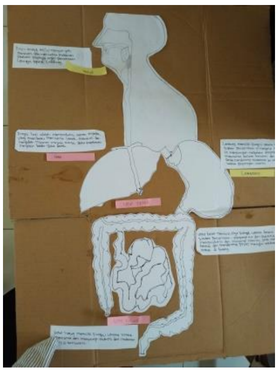

Figure 5. Digestive System Organ Model Made from Fabricated/Manufactured Materials

Each prototype was developed through a collaborative process among students, starting from planning, design, construction, to trial stages. This process integrates STEM principles and project-based learning stages, resulting in media that are not only innovative and contextual but also serve as tools for learning grounded in real-world problem-solving.

2. Product Feasibility Validation

The science teaching aid prototypes developed in this study were validated by two experts: a subject matter expert and a media expert, both with backgrounds in science education and instructional media development. The validation aimed to assess the feasibility of the products based on several aspects, including content appropriateness, visual design, integration of science concepts and STEM principles, and the suitability of the media with elementary school student characteristics.

The validation results showed that all prototypes fell into the "Highly Feasible" category, with the following summary:

Table 2. Recapitulation of Feasibility Validation Results of STEM-Based Science Teaching Aid Prototypes

Prototype Name	**Assessed Aspect**	**Media Expert Score (1–5)**	**Content Expert Score (1–5)**	**Feasibility Category**
Ecosystem Miniature (natural materials)	Content, visual design, STEM integration, suitability for elementary school	4.4	4.5	Highly Feasible
Respiratory System Model (recycled/3R materials)	Content, visual design, STEM integration, suitability for elementary school	4.5	4.6	Highly Feasible
Simple Electrical Circuit (household materials)	Content, visual design, STEM integration, suitability for elementary school	4.5	4.7	Highly Feasible
Acid-Base Experiment (simple lab materials)	Content, visual design, STEM integration, suitability for elementary school	4.6	4.5	Highly Feasible
Digestive System Model (manufactured materials)	Content, visual design, STEM integration, suitability for elementary school	4.6	4.8	Highly Feasible

Average Score	**4.5**	**4.6**	**Highly Feasible**

- Average score from media expert validation: 4.5 (categorized as very good)
- Average score from content expert validation: 4.6 (categorized as very good)

Feedback from the validators was generally minor, such as improvements to the aesthetics and labeling of the media components to make them more informative and visually appealing. All suggestions were incorporated through product revisions prior to implementation in the learning process. These findings indicate that the science teaching aid prototypes developed using the STEM approach and the Project-Based Learning (PjBL) model are of high quality and feasible for use as learning media in both university-level courses and elementary school practice.

This result shows that the media and materials have strong potential to support learning, especially because their visual and content aspects align with the principles of concrete and contextual science learning (Baroya, 2018).

3. Student Responses to Learning and Media Products

Student responses to the development process of the science teaching aid prototypes and their application in microteaching activities were collected through closed-ended questionnaires and open-ended questions. Based on questionnaire data analyzed from 30 respondents, the following results were obtained:

Table 3. Recapitulation of Student Responses to Learning and Media Products

Statements	Percentage of Positive Responses (%)	Category
The learning process was engaging and meaningful	82%	Very Good
The developed media was easy to use and suitable for science learning	87%	Very Good
Students were actively involved in the media development process	90%	Very Good

- A total of 82% of students stated that the learning process was very engaging and meaningful, as they were actively involved in the stages of designing, creating, and testing the media.

- As many as 87% of students felt that the developed media was easy to use and relevant for science learning at the elementary school level.
- A total of 90% of students reported active involvement in the media development process, including aspects of team collaboration and decision-making.

These findings are supported by open-ended responses indicating that students felt more confident and motivated. They stated that the opportunity to be creative and solve real-world problems helped them understand science concepts in a more concrete, enjoyable, and meaningful way.

Student responses align with previous studies which show that project-based approaches can enhance 21st-century skills, including critical thinking, collaboration, and responsibility (Musa'ad et al., 2024).

4. Improvement in Science Concept Understanding

To measure the effectiveness of project-based learning with a STEM approach, students' understanding of science concepts was assessed through a pretest and posttest. The analysis results showed a significant improvement:

Table 4. Average Pretest Score, Posttest Score, and Gain Score

Type of Test	**Average Score**	**Gain Category**
Pretest	62.3	—
Posttest	83.7	—
Gain Score	0.56	Medium–High

- Average pretest score: 62.3
- Average posttest score: 83.7
- Average gain score (using the normalized gain formula): 0.56, which falls into the medium-to-high category based on the classification by (Rivai & Yuliati, 2018).

These results indicate that the implemented learning model not only improved students' theoretical conceptual mastery but also enhanced their ability to apply science concepts in developing instructional media and during teaching practice.

The score increase demonstrates that using media made from recycled materials not only encouraged student engagement but also had a positive impact on their overall understanding of science concepts. Concrete media have proven effective in enhancing the process of knowledge construction and transfer of learning (Jahidin, 2019). Similarly, Lou et al. (2011) demonstrated that STEM-integrated project-based learning significantly improved students' motivation and academic achievement, which aligns with the gain score improvements observed in this study.

5. Student Engagement, Creativity, and Collaboration

Observations of student activities during the development process showed that they were actively involved in group discussions, decision-making, and selfdirected task distribution. Creativity was evident in the diverse designs of the media produced and in their ability to effectively utilize local materials. Collaboration was demonstrated through teamwork in completing projects on time and giving each other constructive feedback.

Learning using the PjBL model and the STEM approach encouraged students to think critically, solve problems, and continuously reflect on their learning process. These findings support previous research indicating that active involvement in project-based media development can enhance 21st-century skills.

Discussion

The results of this study indicate that the integration of the STEM approach and the Project-Based Learning (PjBL) model can be an effective solution to enhance the ability of prospective elementary school teachers in designing innovative, contextual, and relevant instructional media for science learning. This finding aligns with the study by Hidayati et al. (2024), which emphasized that integrating the STEM approach strengthens the understanding of scientific concepts through project-based practical activities. This finding is reinforced by Capraro *et al.* (2013), who emphasized that STEM project-based learning not only enhances academic achievement but also fosters integrated thinking across disciplines in real-world contexts.

In addition to producing feasible and functional media, the development process also provided an authentic learning experience that encouraged students' critical thinking, creativity, collaboration, and communication skills. This finding is supported by Dewi et al. (2023), who showed that student involvement in STEM-based learning significantly improves 4C competencies. These are core components of 21st-century skills, which according to Beers (2011), are essential to prepare students for a rapidly changing future that demands flexibility, innovation, and problem-solving capabilities.

Direct involvement of students as co-developers also had a positive impact on their readiness to become professional educators. They learned to overcome real-world challenges, work in teams, and design learning solutions based on local resources that are cost-effective and easily replicable in elementary schools. This is consistent with the findings of Fitriyani (2024), who stated that Project-Based Learning is highly effective in enhancing students' critical thinking and professional responsibility.

Moreover, the validity of the results is supported by Baroya (2018), who found that contextual concrete media strengthens science learning by facilitating concept understanding through direct experience. In this context, teaching aids based on surrounding resources not only save costs but also reinforce scientific and ecopedagogical approaches.

The gain score increase of 0.56 (moderate–high category) indicates the successful implementation of this strategy, which is consistent with the findings of Yuliati & Saputra (2020), who revealed that STEM-based learning significantly improves science concept mastery in high school students, and is even more beneficial when adapted for prospective elementary school teachers.

Thus, this study reinforces the importance of integrating interdisciplinary approaches and project-based learning in the teacher education curriculum. Besides addressing the challenges of 21st-century education, this approach also supports the

Merdeka Belajar policy and the achievement of the Pancasila Student Profile.

CONCLUSION

The research concludes that STEM-based science teaching media prototypes developed through the Project-Based Learning (PjBL) model are feasible and effective for contextual learning among prospective elementary school teachers. The development process using the ADDIE model resulted in validated, functional products. Active student involvement as co-developers enhanced 21st-century skills—critical thinking, collaboration, creativity, and professional responsibility—while their positive responses and improved understanding of science concepts reflect the success of the approach. Moreover, integrating STEM with PjBL effectively linked scientific theory to real-world contexts and promoted the use of local resources for creating innovative, low-cost teaching aids.

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