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Development of Problem-Based Teaching Materials on Energy Sources With an ESD Approach to Improve Science Process Skills of Fifth-Grade Elementary School Students

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ABSTRACT

Learning issue related to energy resources in the context of an emerging energy crisis along with energy conservation efforts, both individually and collectively, is still remain teacher-centered for Phase C elementary school students. Due to the lack of an ESD approach to sustainability related issues, these efforts resulting in limited opportunities for student to develop their SPS. This research aimed to develop a problem-based teaching materials integrated with ESD approach that is valid, practical, and effective in improving elementary students' SPS. The research employed a R&D method, adapting ADDIE model. The effectiveness test was conducted using a one-group pre-test and post-test design with N-gain analysis on 23 fifth-grade students. The results indicated that the instructional materials fit into the categories of "highly suitable" and "suitable." The content validation score was 82%, while the language and presentation design validation scores were 94% and 93%, respectively. The practicality assessment indicated scores of 95% from teachers and 93% from students. The mean pre-test score of 61.65 increased to 89.56 in the post-test. Furthermore, the N-gain score was 0.71, with an effectiveness rate of 71%, categorizing the developed teaching materials as quite effective.

1. Introduction

Science learning is important for training students to think scientifically and for their ability to apply scientific knowledge in daily life (Astuti et al., 2025). At the elementary school level, science learning still centers on basic concepts for understanding the surrounding nature (Megawati, 2021). IPAS education aims to equip students with knowledge and skills related to natural and social phenomena occurring in their immediate environment (Musfita et al., 2025). Furthermore, elementary school science learning focuses on emphasizing science, environment,

technology, and society to design and be able to create scientific concepts through application in learning with wise scientific competencies (Kurniawati et al., 2023). Science learning, which is currently integrated into social integration until it becomes IPAS, is a basic knowledge related to natural and social phenomena that aims to cultivate understanding, knowledge and skills in every era.

Science Process Skills (SPS) are skills in applying theories and other supporting elements aimed at developing existing concepts. Training SPS in students is equivalent to developing their abilities beyond science itself (Aldi & Ismail, 2023). SPS has a strong relationship with the development of students' cognitive abilities. Furthermore, SPS supports students in honing their thinking, reasoning, curiosity, creativity, and problem-solving skills (Khumraksa & Burachat, 2022). SPS are divided into two: basic SPS, which include observation, inference, prediction, measurement, experimentation, and classification; and integrated SPS, which are developed from basic SPS (Delen & Kesercioğlu, 2012). By developing SPS in learning, students become more responsible and understand the importance of applying scientific methods in science learning (Mustaqimah et al., 2025). However, this study only used three types of SPS adjusted to the learning objectives: observing, predicting and asking questions, and communicating results.

Learning processes sometimes do not provide students with opportunities for direct engagement, leading them to lose direction and have minimal learning process experience. Considering the importance of 21st-century skills that target students to be active in the learning process, innovative learning models such as Problem-Based Learning (PBL) are necessary (Sajidan et al., 2022). PBL is a pedagogical learning model that centers on students solving problems and reflecting on their learning (Blancet et al., 2012). In the learning process, the use of PBL is expected to enhance engagement, teamwork, communication, higher-order thinking skills, and student comprehension (Sari et al., 2025). The stages of PBL assist students in developing critical thinking skills and connecting concepts to real word problem presents in their daily lives (Faivantisa Wisda et al., 2026). Integrating this problem centered approach has been shown to improve students' SPS (Salsabilah & Sukarmin, 2025).

Problem-solving skills are essential for addressing sustainability challenges. Within the realm of education, this is recognized as Education for Sustainable Development (ESD). ESD was established as a prompt response to the educational necessities for tackling sustainability challenges. ESD utilizes innovative pedagogical approaches focused on fostering knowledge and awareness to initiate actions for creating a more sustainable society (UNESCO, 2020). ESD can yield learning outcomes that are cognitive, social-emotional, and behavioral changes specifically aimed at confronting challenges (UNESCO, 2017). ESD empowers its participants to develop the knowledge, skills, and sufficient capacity for human well-being by considering marginalized aspects, thereby ensuring they remain within the scope of addressing global challenges (Price & White, 2025). Education for sustainable development encourages society to become more productive in the future. To achieve this student must be engaged with in a democratic community

from an early age, enabling them to contribute to building a sustainable society in the years ahead (Putri & Rohaeti, 2025).

The 2022 Programme for International Student Assessment (PISA) survey results indicate a decline in the average performance of 15-year-old Indonesian students compared to 2018. In science, Indonesian students scored below the average of The Organization for Economic Co-operation and Development (OECD) countries, with a score of 382.9, ranking 66th out of 82 participating PISA countries. This is a significant contrast to Singapore, another Southeast Asian nation, which ranked first with a score of 561.4 (OECD, 2023). The decline in science learning achievement among Indonesian children is attributed to the lack of Science Process Skills (SPS) in science learning. This was also highlighted by Wiwit Suryanto, who concluded that a lack of experiments and direct practical application in life makes science abstract and difficult to understand, contributing to children's low interest in science learning (Nugroho, 2025). Science learning should integrate various aspects: concepts, skills, and values (Yasin, 2009). These three elements are an inseparable whole. However, in reality, these elements are not well-implemented in schools. Teachers often prioritize students' academic concepts, leading to less objective assessments. Students who are active receive high grades, while passive students receive moderate grades (Supahar et al., 2017).

Students SPS are still considered suboptimal, supported by several studies. Research findings show that the average SPS of students before intervention was 56%, which falls significantly below the student learning success standard of 75%, classifying it as very low (Enjoni & Febriyanto, 2020). Research by Hasmiah et al. (2025) indicated that students' SPS had a low percentage of 55.19%. Through the study by Pertiwi (2024), it was revealed that 90 students from three different types of schools in Makassar had an average SPS score of 41.56, categorized as low, with a Minimum Completeness Learning Standard (SKBM) of 75%. These results are influenced by numerous internal and external factors.

In the IPAS learning of energy sources, initial observations indicated a knowledge transfer approach (teacher-centered), with limited opportunities for students to engage with the importance of energy empowerment and conservation. Consequently, students' SPS were low. Additionally, students' limited problem-solving abilities indirectly restricted their capacity to analyze energy phenomena in daily life, and the existing teaching materials did not comprehensively link energy source materials with sustainability issues. The current challenge necessitates an innovative solution: the development of problem-based learning materials with an ESD approach to enhance the SPS of elementary school students. The objective of this research is to produce ESD-based teaching materials that are valid, practical, and effective in improving students' SPS in elementary schools.

2. Methodology

This research employs an R&D (Research and Development) approach using the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model,

based on Branch (2009) theory, which is suitable for developing learning products. In this study, ADDIE is used to develop teaching materials with an ESD approach through problem-based learning to enhance students' SPS in the subject of energy sources. The researcher chose the ADDIE model due to its clear, step-by-step progression from the initial to the final stages. The stages in this research are: (1) Analysis, which involves analyzing the needs of teachers and students; (2) Design, where the design of the teaching materials is formulated according to learning objectives and SPS indicators; (3) Development, where the developed teaching materials are validated by material experts, language experts, and presentation/display experts to ensure their feasibility; (4) Implementation, where the developed teaching materials are applied to students; and (5) Evaluation, which involves collecting learning outcome data during the treatment. The study will utilize quantitative data processed using SPSS. This data will be obtained from assessors, including lecturers, teachers, and students involved in the research.

The instruments used for validity and practicality are questionnaires containing statements structured on a 4-point Likert scale. The effectiveness of the developed teaching materials is assessed through a final evaluation in the form of a post-test, preceded by a pre-test. This research primarily focuses on improving students SPS through the development of problem-based learning materials with an ESD approach. The subjects of this study are 23 fifth-grade students from class 5A at SDN 002/VI Bangko, representing Phase C. The success of this research is measured based on.

- a. In this study, the device validation procedure is assessed by experts, namely dosen who are competent in their fields. The developed teaching materials will be considered valid if they achieve a minimum score of 80%, falling into the "good" category. The score determination is selected as an indicator of the feasibility of the product developed as feasible and meets quality standards before reaching the implementation stage in schools. The achievement of this score is a reference in determining the effectiveness of the product to be tested. Here is the table of score acquisition along with their categories:

Table 1. Teaching Material Validity Assessment Indicators

Score Range	Assessment Category
90-100	Excellent
80-89	Good
70-79	Fairly Good
60-69	Poor
<59	Not Good

- b. This study establishes practicality criteria to measure the extent to which teaching tools are easy to use. The practicality of the developed teaching materials is assessed by teachers and students after using the product. The practicality of the developed teaching materials is measured based on the trial results conducted by teachers, with a minimum score of 80% considered "practical" category. This value determination is used to ensure that the product

is not only valid but also easy to use and effective in improving students' SPS in the learning process. The following is a table of scores with their categories:

Table 2. Teaching Material Practicality Assessment Indicators

Score Range	Assessment Category
90-100	Highly Practical
80-89	Practical
70-79	Fairly Practical
60-69	Poorly Practical
<59	Not Practical

- c. The effectiveness aspect in this study was measured to find out the extent to which the developed teaching tools were able to increase students' SPS. The effectiveness of the developed teaching materials was determined if students' scores were above the minimum completeness threshold of 70, if there was an improvement after the treatment was administered, and if the N-Gain was at least in the moderate category, and the interpretation of the effectiveness of N-gain in the category is quite effective. This scoring criterion is a measuring tool to ensure that the implementation of teaching tools is able to increase the measurable SPS of students. With the achievement of the product criteria, it is declared effective in increasing student SPS. The following is a table of criteria for determining the effectiveness of the teaching tools developed:

Table 3. N-Gain Category Hake (1998)

Score Range	Assessment Category
N-Gain > 0,7	High
$0,3 \leq \text{N-Gain} \leq 0,7$	Medium
N-Gain < 0,3	Low

Table 4. Interpretation of the effectiveness of N-Gain (Supriadi, 2021)

Score Percent	Assessment Category
< 40	Ineffective
40-55	Less effective
56-75	Quite effective
> 76	effective

3. Results and Discussion

This research aimed to observe the improvement of Science Process Skills (SPS) in elementary school students using developed teaching materials based on a problem-based ESD approach. Following the research conducted through the ADDIE method, this study began with the design process of the teaching materials, followed by their validation, practical application, and finally, the assessment of their effectiveness in enhancing SPS. Given these conditions, the research focused on developing teaching materials that not only facilitate conceptual understanding but also improve students' SPS regarding sustainability issues. During the study, the researcher used problems around students related to energy through PBL by adjusting the syntax. Starting from the orientation of the problem to students to

evaluation, where every meeting must have SPS involved in it and the ESD domain in each meeting that has been prepared through the teaching materials that have been developed.

a. Teaching Material Design Process

In the initial stage, the analysis of teacher and student needs indicated a necessity for teaching materials that encouraged the improvement of students' Science Process Skills (SPS) through a problem-based ESD approach. Through a teacher needs analysis conducted via questionnaire, a score of 92% was obtained, which, when categorized, showed a strong need for these teaching materials. Additionally, the student needs analysis, taken from the sample research class, received a score of 94%, also falling into the category of needing these teaching materials. Specifically, these analysis results indicated that the learning process remained conventional, with the available teaching materials being limited, thus resulting in a lack of deeper exploration during the learning process. Students were more oriented towards the theoretical concepts of energy sources, leading to a lack of understanding regarding sustainability issues raised from real problems in their surrounding environment.

This teaching material was developed using Canva as the design platform, considering appropriate color schemes, elements aligned with content requirements, realistic illustrations, and distinct color coding for each topic. These features aim to boost students' learning enthusiasm and help them clearly recognize the form and characteristics of related objects and being able to remember previous learning by remembering colors in each discussion topic. The teaching materials also includes simple, straightforward instructions, ensuring its content is systematically arranged and easy to use. To support students in understanding the material systematically, from the use of learning instructions, using realistic images and color reduction of each discussion topic, the following appendix displays visualizations of the developed teaching materials:

Learning objectives within the ESD approach encompass three domains: the cognitive domain, related to knowledge, understanding, and issues concerning sustainability; the social-emotional domain, concerning social skills, societal values, and norms; and the behavioral domain, relating to individual attitudes and actions that demonstrate sustainable practices. These learning objectives are formulated in alignment with the Curriculum Standards (CP) for each learning area. The structured learning objectives should progress hierarchically, starting from foundational knowledge and culminating in sustainable actions that are implemented in daily life. ESD is important to implement for instilling sustainability knowledge in both students and teachers as a comprehensive effort to drive positive outcomes in ESD competencies, innovative pedagogy, curriculum development, new learning media, and inventive learning environments (Cebrián et al., 2020). As an ESD approach in this teaching tool, the following is an appendix of learning objectives that have been designed with the ESD domain, namely cognitive, socio-emotional, and behavioral:

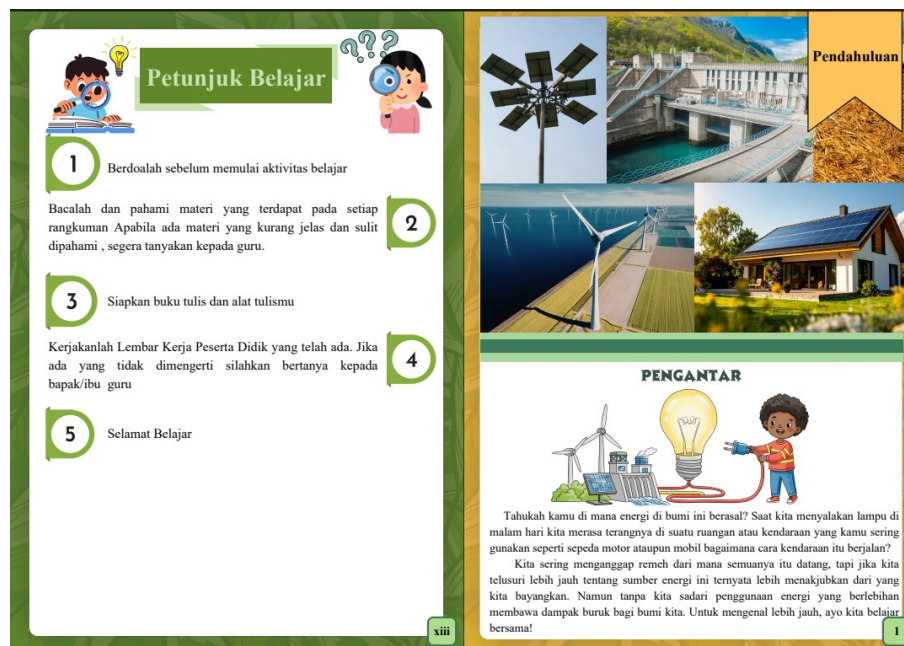


Figure 1. Learning instructions and use of realistic images



Figure 2. Different color divisions for each material

Furthermore, the learning design is also problem-based, following the syntax of the Problem-Based Learning (PBL) instructional flow. This begins with orienting students to the problem, organizing them for learning, guiding individual and group investigations, developing and presenting results, and finally, analyzing and evaluating the problem-solving process. These stages involve students as the center of learning in resolving issues encountered during the learning process.



Figure 3. Learning Objectives of the ESD Approach

Consequently, the design of the teaching materials is not solely focused on content and theory but is capable of developing structured learning through an ESD-based approach to enhance students' SPS and instill sustainable awareness. The development of these materials will assist learners with issues, particularly environmental ones, that are relevant to current local interests (Nguyen et al., 2024). To provide an overview of problem-based teaching materials with the ESD approach, this appendix shows the appropriate stages of PBL in ESD's goals in improving students' SPS, along with the appendices of the developed teaching material:

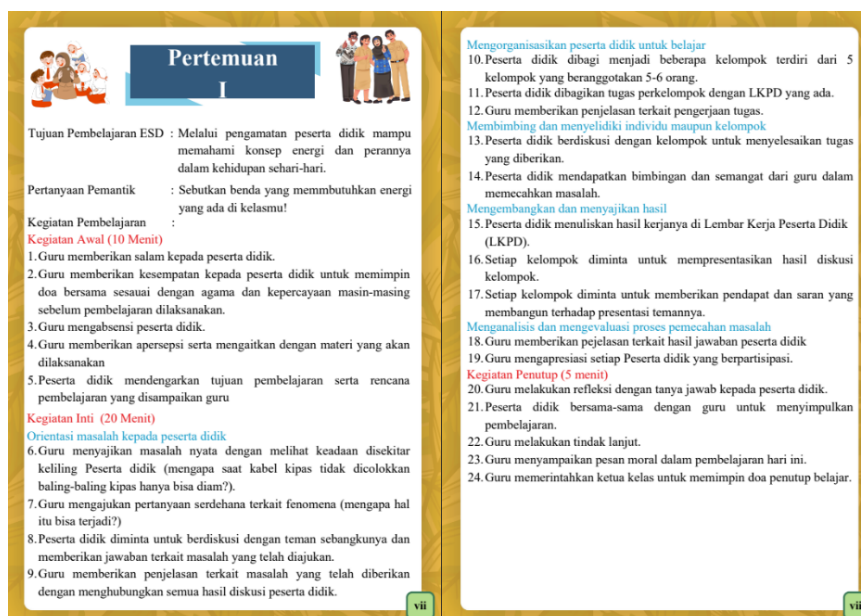


Figure 4. Learning Stages Corresponding to the PBL Syntax

b. Teaching Material Validation

The teaching materials developed went through a validation stage before proceeding to the next. This stage includes the development stage consisting of validation conducted covered content, language, and presentation display. The assessment indicators served as a reference to determine the validity of the developed product. The assessment at this stage is carried out by lecturers who are experts in their fields, this stage will also determine the feasibility of the product for the next stage, namely implementation. If a product received a score of < 80 , categorized as "fairly good" it would require revision and re-validation until it achieved a score of > 80 , categorized as "good."

- 1) Content: Through the content validation performed on the developed teaching materials, a score of 82% was obtained, falling into the "good" category. The developed materials adhere to the PBL syntax and are aligned with the SPS elements being developed. The content is developed in line with the learning outcomes of the current curriculum. Additionally, ESD domains are integrated systematically and clearly, connecting topics to real problems in students' daily environment. This approach makes the material more contextual and helps students understand the concepts more easily.
- 2) Language through the language validation performed on the developed teaching materials, a score of 94% was obtained, falling into the "excellent" category. These teaching materials use language appropriate to the developmental stage of the learners, employing easily understandable sentences. Additionally, each image within the teaching materials is accompanied by a brief and clear explanation. The language used adheres to proper linguistic standards and supports effective interaction during the learning process. Furthermore, simple scientific terms are accompanied by a straightforward glossary, intended to expand students' scientific vocabulary.
- 3) Appearance and Presentation: The validation conducted on the developed teaching materials yielded a score of 93%, falling into the "excellent" category. This is because the teaching materials appear unique and incorporate numerous visible elements, thereby making the learning process more contextual. Students are in the concrete operational stage, requiring appropriate media to visualize abstract concepts that cannot be directly observed through the senses (Rahmi Yudita et al., 2026). This teaching material includes clear instruction follows a logical content sequence and uses distinct color coding for different section helping students easily recall their last learning progress. The content is also organized in a structured manner, ensuring systematic presentation and ease of use.

c. Teaching Material Practicality

The teaching materials to be developed will be tested to assess their practicality in use, as evaluated by teachers and students. In terms of practicality assessed by teachers, the developed teaching materials obtained a score 95% falling in to the

very good or highly practical category. This result confirms that the materials are well-designed, address problems relevant to students' daily environment, and provide new insights into sustainability ultimately enhancing students' SPS. Additionally, the integration of ESD represents a novel feature of this material, introduction new knowledge and perspective on sustainable development for the future.

The practicality of the developed teaching materials was also assessed by the students regarding the extent to which these materials enhance SPS. An important aspect related to this practicality is the extent of students' understanding of the teaching materials developed, in addition to the appearance and language used. The obtained score was 93%, placing it in the "excellent" or "highly practical" category. The practicality results indicate that students understood the learning process using these developed teaching materials. Consequently, they were able to gain new understanding related to sustainability issues through real-world problems present in their surroundings, thereby improving their SPS.

These teaching materials were assessed as practical because they align with problem conditions that are very close to the students, making it easier for teachers to find issues that students can directly observe and experience. This score also indicates an interest in sustainability issues during the learning process, leading many students to gain new knowledge and increase their awareness of their surroundings concerning sustainability. This highlights the importance of the ESD approach in enhancing knowledge and attention towards sustainable development (Ferguson et al., 2022).

d. Teaching Material Effectiveness

This study uses the PBL syntax as a basis in the learning process starting from orientation to evaluation in each meeting with the ESD approach which is outlined in the form of learning objectives that include cognitive, socio-emotional, and behavioral domains in improving students' SPS. The teaching materials used are used by all students of class V A who have passed the validation stage to adjust the needs of students in the learning process. During the research, students were confused about ESD, but along the learning process, they learned that ESD is an important thing that must be known as a generation of changes for the sustainability of the universe in the future. The elementary school level begins with a simple phenomenon that is raised in problems that are often encountered from the environment of students related to energy, with SPS students can be more complex to learn and better understand related to energy source materials.

The developed teaching materials were considered effective if students' scores were above the minimum completeness threshold of 70. Out of 23 participants, it can be stated that they met the minimum completeness score of 70, with the lowest score being 78 and the highest score being 100. Before the treatment, 17 participants had scores below the minimum completeness, with the lowest score being 27 and the highest being 85. The average pre-test score was 61,65, while the average post-test score was 89,56. There was an improvement after the treatment, and the N-Gain

was high. The data above demonstrates the effectiveness of the teaching materials through the improvement in pre-test and post-test results, as well as the N-Gain. The average pre-test score before the treatment was 61.65 with a standard deviation of 12.84. After the treatment, the average post-test score obtained was 89.56 with a standard deviation of 6.17.

The N-Gain observed between the pre-test and post-test stages was 0.71. When categorized, this falls into the "high" category, as it is between the N-Gain > 0.7 threshold. This result is considered positive if it falls within the moderate or high category. Considering the effectiveness of the developed teaching materials, the obtained percentage of 71% falls into the "quite effective" category. The results established that the teaching materials with a problem-based ESD approach on energy sources are categorized as positive, meaning they have a high N-Gain and are highly effective in improving students' SPS. To provide an overview of the changes in pre-test and post-test after receiving treatment, the following are the results of descriptive statistical analysis processed using the SPSS application:

Table 5. N-Gain *Pre-test dan Pos-test*

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Pretest	23	27,00	85,00	61,6522	12,84031
Posttest	23	78,00	100,00	89,5652	6,17050
Ngain	23	0,36	1,00	0,7187	0,16854
Valid N (listwise)	23				

Analysis of each Science Process Skill (SPS) element shows significant improvements: observation skills increased by 66%, prediction and questioning skills each rose by 44%, and communication of results improved by 57%. During the pre-test and post-test, students were given six questions. Every two question contained different SPS elements with the same difficulty of pre-test and post-test questions. During the pre-test and post-test, the SPS element, namely observation, students only made observations, without involving all five senses and only focused on using sight without involving the other five senses. During the post-test, students involved all five sense to see, hear and touch and students were able to.

The SPS element of predicting and asking questions at the pre-test stage, students only used intuitive guesses, just guessing without involving their knowledge of sustainability in the future, during the post-test, students were more able to involve their knowledge by providing logical explanations. The SPS element of communicating results at the pre-test stage, students were not yet able to provide conclusions or decisions with appropriate arguments. During the post-test, students began to show constructive arguments and were in line with sustainable development in the future. Referring to the discussion above, the following is attached a detailed table of SPS elements used in this study from before receiving treatment and after receiving treatment:

Table 6. SPS capability

Element SPS	Pre-Test	Post-Test
Observe	30%	96%
Predicting and asking question	39%	83%
Communicate results	43%	100%

These gains occur because students can solve real-world problems using the ESD approach embedded in the SPS framework within the developed teaching materials. Several factors underlie these positive outcomes. The materials present clear procedures for Problem-Based Learning (PBL) integrated with ESD domains, enabling students not only to understand energy concepts but also to engage in sustainable actions through locally relevant issues. The learning process is student-centered, meaning students solve identified problems with teacher guidance. Additionally, a conducive school environment supports effective learning; conversely, distractions can disrupt focus and hinder learning progress.

4. Conclusion

Based on the results of the research that has been conducted, it can be concluded that the development of teaching materials with a problem-based ESD approach in learning IPAS of energy source materials in class V using the ADDIE syntax has met the criteria of valid, practical and effective in improving students' SPS. Through a series of stages of development of teaching materials, a systematic, structured, and attractive teaching tool is created so that it is very relevant to the needs of elementary school students in understanding energy source materials in a complex way. Through a series of validations, the teaching tool uses the right PBL syntax, has an ESD domain, involves SPS, language that is appropriate for the elementary school level, attractive appearance and reality so that functionally it greatly supports the learning process. The practicality of teaching materials can be used by teachers and students more easily to understand energy source materials by using this teaching tool. This teaching tool is able to increase students' SPS starting with problems around the student environment starting from observing, students are able to involve at least three senses, predict and ask questions, students are more able to involve all knowledge with logical explanations without using intuitive guessing, and communicate results, students are better able to provide constructive arguments with the knowledge gained in accordance with sustainable development. The ESD approach has been proven to shift the perspective of students, who were originally only recipients of information, now have a main role that has a high concern for sustainability awareness. Thus, the teaching materials developed can be one way to improve SPS and understanding of sustainability issues by raising problems around the student environment.

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