JPPIPA 10(7) (2026)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

# Implementation of an EDP-Based STEM Project to Develop Students' Problem-Solving Skills in Light and Heat Energy Concepts

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Received: December 13, 2025
Revised: June 03, 2026
Accepted: July 25, 2026
Published: July 31, 2026

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DOI: 10.29303/jppipa.v12i7.13870



**Abstract:** Elementary science learning requires contextual activities that enable students to apply scientific concepts when addressing real-life problems. However, in-depth qualitative evidence explaining how each Engineering Design Process-based STEM (EDP-STEM) stage supports elementary students' problem-solving skills remains limited, particularly in light and heat energy learning. This study aimed to describe EDP-STEM implementation through a solar oven project and analyze how its stages supported fifth-grade students' problem-solving processes. Its novelty lies in mapping five EDP-STEM stages to four problem-solving indicators using multiple qualitative data sources. A qualitative case study was conducted with 26 students in four groups during eight learning sessions. Data were collected through observations, interviews, student worksheets, reflective journals, field notes, rubrics, photographs, and videos. The data were organized, coded, categorized, compared, and interpreted, while credibility was supported through source and method triangulation. Students identified insufficient heat, unstable reflectors, thick plastic covers, and uneven sunlight distribution, then proposed corresponding design modifications. Project scores ranged from 88 to 96; three groups received an A grade and one received a B grade. The clearest evidence concerned problem identification and consideration of possible solutions. Overall, the four indicators emerged through interconnected cycles of designing, testing, evaluating, reflecting, and revising.

**Keywords:** EDP-STEM; Engineering design process; Light and heat energy; Problem-solving skills; Solar oven

## Introduction

The 21st century has transformed the global education landscape, increasing the demand for critical thinking, creativity, collaboration, digital literacy, and problem-solving as essential student competencies. In education, interactive digital media and case-based learning activities can provide opportunities to train students' problem-solving skills (Daryanes et al., 2023). In Indonesia, the Kurikulum Merdeka encourages learning activities that integrate technology and 21st-century skills, including critical thinking, problem-solving, communication, collaboration, and creativity (Suciptaningsih et al., 2023).

Problem-solving is widely recognized as one of the most essential skills for navigating daily life challenges. However, the PISA 2022 results showed that Indonesian students performed below the OECD average in mathematics, reading, and science, indicating continuing challenges in applying knowledge and skills to contextual problems (OECD, 2023). Several studies also report that students often experience difficulties in solving non-routine problems, reflecting their limited ability to apply knowledge and strategies when addressing unfamiliar situations (Bhakti et al., 2020; Setiawan, 2020; Siswanto & Meiliasari, 2024).

One contributing factor is that science learning can still emphasize routine and procedural problem-solving.

**How to Cite:**
Amir, R. H., Sekaringtyas, T., & Yunus, M. (2026). Implementation of an EDP-Based STEM Project to Develop Students' Problem-Solving Skills in Light and Heat Energy Concepts. *Jurnal Penelitian Pendidikan IPA*, *12*(7), 21–32. https://doi.org/10.29303/jppipa.v12i7.13870

Practical science learning may also be constrained by limited resources, time, teacher expertise, and overly procedural activities that provide insufficient opportunities for meaningful inquiry (Babalola et al., 2020). These limitations reduce opportunities for students to analyze problems, design solutions, and think critically. Hence, innovative approaches that integrate experiential and conceptual learning are needed to address these challenges. Learning activities that engage students in analyzing contextual problems and developing possible responses can provide opportunities to stimulate critical thinking from the elementary school level (Ardwiyanti et al., 2021; Sekaringtyas et al., 2025).

The Engineering Design Process (EDP) within the STEM framework offers a promising solution. EDP is a systematic, iterative problem-solving process that engages students in defining problems, generating ideas, designing and constructing prototypes, testing, and redesigning (English & King, 2015; Kelley & Knowles, 2016). When applied in science education, EDP-STEM not only strengthens conceptual understanding but also nurtures creativity, collaboration, and confidence in problem-solving (Barroso et al., 2016). Moreover, the integration of the Engineering Design Process into STEM project-based learning provides a structured context for learners to clarify problems, generate ideas, model designs, and evaluate their feasibility (Lin et al., 2021). Project-based learning also provides authentic contexts in which students can apply science concepts through meaningful activities (Apriany et al., 2020; Chairunnisya et al., 2023; Hayat et al., 2023; Nasution et al., 2025; Sutisnawati et al., 2025).

Project-based learning has also been reported to improve fifth-grade elementary students' cognitive learning outcomes in science (Apriany et al., 2020). At the elementary school level, STEAM learning has also been associated with active student participation, positive responses, and improved learning outcomes (Nasrah et al., 2021). Studies on STEM education in Indonesia have been dominated by learning strategy research, particularly the integration of STEM with project-based learning, indicating the need for broader investigations of STEM implementation in different learning contexts and outcomes.

Among elementary school science topics, light and heat energy represent fundamental concepts that are both scientifically important and closely related to daily life. However, research has shown that students still struggle with misconceptions, such as differentiating heat from temperature or understanding energy transfer (Salame et al., 2025). To overcome these difficulties, practical and contextual projects are essential. One relevant example is building a solar oven, which allows students to directly experience how light energy can be transformed into heat energy, linking theory with practice while simultaneously raising awareness of renewable energy (Owusu & Asumadu-Sarkodie, 2016).

Previous studies have implemented the Engineering Design Process in various STEM projects, including aerospace design projects (English & King, 2015), bridge-building activities (Barroso et al., 2016), and robotics-based learning activities (Ziaeefard et al., 2017). EDP tools have also been used to support students' scientific communication by engaging them in explaining ideas and communicating evidence obtained during the design process (Putra et al., 2025). Together, these studies demonstrate that engineering design activities can support a range of learning processes, including idea development, design evaluation, communication, collaboration, and problem-solving. However, studies examining the implementation of EDP-STEM in elementary schools remain relatively limited, indicating the need for further exploration in contextual science learning (Sutisnawati et al., 2025).

This study addresses this gap by implementing EDP-STEM through a solar oven project that integrates light and heat energy concepts. The project provides students with opportunities to identify design problems, propose alternative solutions, construct and test a product, evaluate its weaknesses, and improve the design based on evidence obtained during the learning process.

The novelty of this study lies in its in-depth qualitative examination of how each stage of the Engineering Design Process contributes to elementary students' problem-solving skills through a solar oven project. The analysis draws on multiple sources of evidence, including classroom observations, interviews, student worksheets, reflective journals, researcher field notes, and project documentation. Therefore, this study aims to: (1) describe the implementation of EDP-STEM in elementary science learning through a solar oven project, and (2) analyze how the EDP-STEM stages support fifth-grade students' problem-solving skills in the context of light and heat energy concepts.

## Method

This study employed a qualitative case study approach to obtain an in-depth understanding of the implementation of the Engineering Design Process (EDP)-STEM and its contribution to elementary students' problem-solving skills (Creswell, 2012). This approach enabled the researchers to examine students' actions, interactions, ideas, and responses throughout the learning process in their natural classroom context (Cohen et al., 2017). During the implementation, the researcher collaborated with the classroom teacher in facilitating the EDP-STEM learning activities, while two peer observers documented significant events throughout the learning process.

*Research Subject*

The study was conducted from 2025 to 2026 at SD Negeri Bawakaraeng 1, Makassar, Indonesia. Preliminary activities in 2025 included gathering initial information and purposively selecting the research site. The participants were 26 fifth-grade students, comprising 12 boys and 14 girls. The EDP-STEM learning activities and primary data collection were conducted in eight sessions from May to June 2026 through a solar oven project on light and heat energy.

*Research Procedure*

The research procedure consisted of three main stages: preliminary preparation, EDP-STEM implementation, and final analysis. During the preliminary stage, the researchers prepared the lesson plans, student worksheets, observation sheets, interview guidelines, reflective journals, problem-solving rubrics, and materials required for the solar oven project. During the implementation stage, the EDP-STEM learning activities were conducted in eight sessions. In the final stage, the collected data were organized, analyzed, and interpreted to identify students' problem-solving skills. The overall flow of the research procedure is presented in Figure 1.

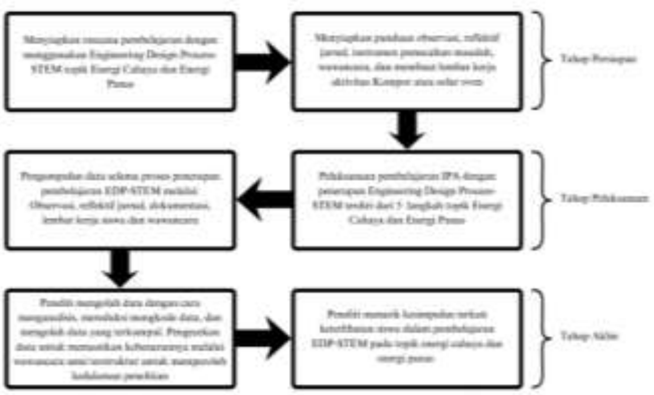

**Figure 1.** Flow of the research procedure

The EDP-STEM learning activities followed the framework proposed by English et al. (2017), which consists of five stages: Problem Scoping, Idea Creation, Designing and Constructing, Assessing Design, and Redesigning and Reconstructing. Each stage encouraged students to identify contextual problems, generate ideas, develop and test designs, evaluate weaknesses, and improve their solar oven products. The stages of EDP-STEM are illustrated in Figure 2.

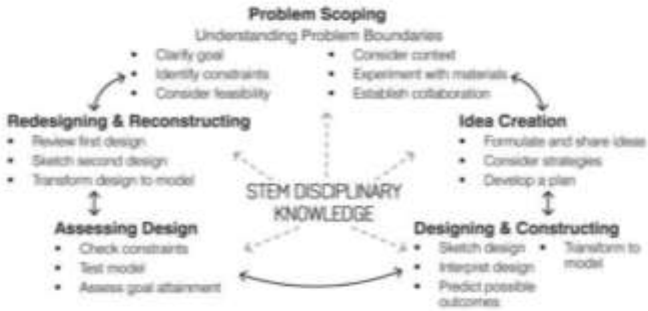


**Figure 2.** EDP-STEM stages adapted from (English et al., 2017)

*Data Collection*

Data were collected through semi-structured interviews, classroom observations, student reflective journals, student worksheets, researcher field notes, problem-solving rubrics, and project documentation in the form of photographs and videos. The use of multiple data sources enabled the researchers to obtain a comprehensive understanding of students' activities and problem-solving processes throughout the EDP-STEM learning stages.

*Semi-Structured Interviews*

Semi-structured interviews were conducted with students outside class hours to obtain in-depth information about their experiences, understanding, and difficulties during the EDP-STEM learning activities. This type of interview uses guiding questions while allowing the researcher to ask follow-up questions to clarify and further explore participants' responses (Cohen et al., 2017). The interviews focused on students' experiences in participating in EDP-STEM learning on light and heat energy concepts. Examples of the interview questions included:

- What was your experience participating in EDP-STEM learning on the topic of light and heat energy?
- Do you think the EDP-STEM approach made it easier for you to understand the material?

*Classroom Observation*

Classroom observations were conducted by two peer observers during the implementation of the EDP-STEM learning activities. Qualitative observation enables researchers to record participants' actions, interactions, and activities directly within the natural setting in which they occur (Creswell, 2012). The observations focused on students' participation, group interactions, problem identification, Idea Creation, design and construction activities, testing processes, and design improvements. The observers recorded significant classroom events using observation sheets and field notes. Photographs and videos were also used to support the observation data and to review classroom events when further clarification was required.

*Reflective Journals*

At the end of each lesson, students completed reflective journals describing their learning experiences during the EDP-STEM activities. In qualitative research, personal journals can provide information in participants' own words and help researchers understand their perspectives and experiences (Creswell, 2012). The journals contained students' understanding of the material, their suggestions and ideas, and the difficulties they encountered during the learning process. An example of a reflective journal question was:

- What are your thoughts about the learning activities you participated in today?

*Student Worksheets*

Student worksheets were used to guide students through the EDP-STEM stages and to document their written problem-solving processes. The worksheets contained contextual questions that encouraged students to identify problems, consider possible solutions, record observations, evaluate the solar oven design, and formulate conclusions. The students' worksheet responses were examined with reference to the problem-solving assessment framework proposed by Greenstein (2012). One example of a contextual question was:

- Sunlight is very important for a solar oven to function optimally. Clear weather is required for the oven to work properly. However, while using the solar oven, the weather suddenly turns cloudy. Can the solar oven still be used effectively under cloudy conditions? Provide a solution to this problem!

*Data Analysis*

The qualitative data were organized, coded, categorized, and interpreted according to the five EDP-STEM stages and the four problem-solving indicators adapted from Greenstein (2012): problem identification, question formulation, consideration of possible solutions, and conclusion drawing. Evidence from interviews, classroom observations, student worksheets, reflective journals, researcher field notes, problem-solving rubrics, photographs, and videos was compared to identify recurring patterns and relationships between the EDP-STEM activities and students' problem-solving processes. Data credibility was supported through source and method triangulation by comparing evidence across these different data sources and the observation records of the two peer observers.

## Result and Discussion

*Result*

This study focuses on developing students' problem-solving skills through the implementation of the Engineering Design Process (EDP)-STEM approach integrated with the topic of light and heat energy. The learning process was designed to connect students' theoretical knowledge of energy with hands-on experiences through the construction of a solar oven. This section presents the findings from each stage of the EDP-STEM approach, focusing on how students understood the concepts of light and heat energy and applied them in designing, constructing, testing, evaluating, and improving a solar oven. The learning activities followed the five EDP-STEM stages proposed by English et al. (2017): Problem Scoping, Idea Creation, Designing and Constructing, Assessing Design, and Redesigning and Reconstructing. The implementation of each stage is presented below.

*Problem Scoping*

In the Problem Scoping stage, the researcher and the classroom teacher prepared learning media and materials related to light and heat energy concepts. Although the classroom teacher was already familiar with STEM learning, the researcher explained the EDP-STEM stages that would be implemented during the eight learning sessions. The main project assigned to the students was the construction of a simple solar oven as an application of light and heat energy concepts.

To support students' understanding, the classroom teacher used audiovisual media and a projector to present the properties of light, including straight-line propagation, reflection, refraction, absorption, and shadow formation, as well as the concepts of heat and temperature. Stimulating questions were posed to encourage students to connect these concepts with their everyday experiences.

Students were organized into four groups, each consisting of seven to eight members, to identify problems, gather relevant information, and plan the solar oven project. The classroom teacher allowed students to choose their group members to facilitate coordination. At this stage, students were guided to record key information related to light energy, heat energy, and the design requirements of a simple solar oven. These activities helped students define the boundaries of the problem and encouraged their curiosity about possible solutions.

*Idea Creation*

In the Idea Creation stage, students engaged in brainstorming and evaluating various possible designs for their solar ovens. The teacher encouraged creativity and critical thinking by setting constraints, such as using recycled materials and ensuring that the total cost of materials did not exceed IDR 50,000. Students worked in groups to discuss their designs and compile a list of required materials.

> *Several groups simplified their initial designs, for instance, replacing wood with cardboard to make their solar ovens more practical and environmentally friendly* (Researcher's Notes, May 6, 2026).

The classroom atmosphere became dynamic as students raised critical questions and refined their designs based on feedback from both the teacher and their peers. For example, during one discussion:

> *Student 14: Can we replace black cardboard with black fabric?*
> *Teacher: Yes, as long as the base material is dark or black.* (Researcher's Notes, May 6, 2026).

Other questions that emerged included:
- Can we design the oven with three reflectors?
- Will the oven still work if the weather becomes cloudy?
- Does the shape of the oven affect the amount of heat it captures?

These questions reflected the students' growing engagement with the scientific and technical aspects of the project. To enrich their ideas, students also searched for inspiration from online platforms such as YouTube, TikTok, and Instagram, demonstrating their independence in the design process.

After summarizing their ideas and receiving feedback, each group selected the most feasible design to implement. For instance, Group 1 designed a solar oven with one reflector and two tiers, while Group 2 developed a model with three reflectors. This stage not only encouraged creativity and collaboration but also trained students to connect scientific principles with real-world applications. Overall, the Idea Creation stage fostered critical thinking, problem-solving, and innovation, laying the foundation for the construction stage.

*Designing and Constructing*

During the designing component of this stage, students began translating their ideas into technical designs. The teacher first reviewed the previous lesson on light and heat energy to strengthen students' conceptual understanding before they moved on to designing. Each group created sketches of their solar oven designs, including measurements, shapes, and details based on the challenges provided in the student worksheets. The teacher also prepared essential materials such as plastic, aluminum foil, and black cardboard. Students divided tasks within their groups to draw sketches, write annotations, and prepare the required materials.

> *Some students struggled with writing the scientific explanations in their designs, particularly when connecting STEM principles such as reflection, absorption, and conduction* (Researcher's Notes, May 15, 2026).

For instance, one student asked:

> *Student 5: "Can we add a cooking pot in our sketch?"*
> *Teacher: "Yes, adding a pot will make your oven design clearer"*

Through group discussions and teacher guidance, students refined their sketches and ensured that their designs were scientifically accurate. The resulting designs varied across groups; some created ovens with one reflector and two levels, while others opted for designs with three reflectors to direct more sunlight into the oven. This stage served as a bridge between conceptual thinking and practical application, training students to connect scientific concepts with real-world solutions.

During the constructing component of this stage, students began building their solar ovens according to the designs they had created. The materials used included cardboard, aluminum foil, plastic wrap, black paper, tape, and thermometers. This stage provided students with valuable opportunities to apply theory into practice while integrating science, technology, engineering, and mathematics (STEM) elements into their project.

During construction, students connected scientific concepts with their designs. For example, the inner surface of the cardboard was lined with aluminum foil to maximize light reflection, black paper was used to absorb heat, and plastic wrap was placed on top to trap heat inside the oven. Thus, students were not only building a product but also learning to link the theory of light and heat energy to practical applications.

> *Each group divided the construction tasks among its members, such as preparing the materials, assembling the cardboard frame, attaching aluminum foil and black paper, installing the transparent plastic, and positioning the thermometer. During this process, students encountered several technical problems, including stabilizing the cardboard frame, positioning the thermometer accurately, and creating an additional opening so that food could be placed inside the oven* (Researcher's Notes, May 15, 2026).

One classroom interaction highlighted this process:

> *Student 10: "Sir, our food cannot fit on the second level. Can I add a reflective panel or a door on the second tier so the food can go inside?"*

*Teacher: "Yes, you may. Use a cutter to make it easier to create a door or reflective surface so the food can be placed inside."* (Classroom Observation, May 9, 2026).
*Design variations also appeared among groups. Group 2, for example, built a solar oven without a black base. This led to reflective discussions on the importance of dark surfaces for heat absorption. Students noted that the experience was enjoyable because they could work together and solve problems collaboratively.* (Researcher's Notes, May 13, 2026).

The project assessment results showed that three of the four groups achieved an A grade, while one group received a B grade. The project scores ranged from 88 to 96, as presented in Table 1.

**Table 1**. Project Assessment Results

| Project | Planning | EDP-STEM Product | Report | Total Score | Grade |
|---|---|---|---|---|---|
| Group 1: Solar oven with one reflector | 21 | 40 | 27 | 88 | B |
| Group 2: Solar oven with three reflectors | 24 | 45 | 27 | 96 | A |
| Group 3: Solar oven with one reflector | 22 | 45 | 25 | 92 | A |
| Group 4: Solar oven with three reflectors | 24 | 45 | 27 | 96 | A |

Overall, the Designing and Constructing stage provided students with opportunities to translate their ideas into designs, apply scientific concepts in constructing a product, collaborate within their groups, and respond to technical problems encountered during the project.

*Assessing Design*

In the Assessing Design stage, students tested their solar ovens to evaluate the performance of the designs they had constructed. Each group brought its solar oven to the schoolyard and positioned it under direct sunlight. Students used thermometers to measure the temperature inside the ovens and recorded temperature changes every 30 seconds. They also observed the functions of aluminum foil, transparent plastic, and black paper in reflecting light, absorbing heat, and retaining heat inside the oven.

During the testing process, students adjusted the position of the ovens to obtain direct sunlight. One classroom interaction illustrated this activity:

*Student 23: "Can I place our solar oven facing south?"*
*Teacher: "Yes, place it directly under the sunlight."*
*Student 18: "This spot gets the most sunlight."* (Field Observation, May 20, 2026).

After the testing process, students returned to the classroom and conducted peer evaluations. Each group interviewed another group to identify the strengths and weaknesses of its solar oven design and to determine whether the temperature inside the oven had increased by more than 10 °C. The discussion also encouraged students to propose possible improvements based on the results of the testing.

*Student 4: "What is the weakness of your solar oven project?"*
*Student 8: "The weakness is that the lower tier doesn't get hot. The marshmallows on the bottom didn't melt like the ones on top."*
*Student 10: "How will you improve that design?"*
*Student 1: "The plastic we used is too thick, and there was no reflective panel on the sides. We plan to replace the plastic with a thinner one."* (Field Observation, May 20, 2026).

The testing revealed several limitations in the students' designs, including insufficient heat in the lower tier, thick plastic covers, unstable reflector positions, and sunlight that did not reach all parts of the oven evenly. At this stage, students used the testing results to identify the weaknesses of their products and propose possible improvements. The actual modifications were carried out during the Redesigning and Reconstructing stage.

*Redesigning and Reconstructing*

In the Redesigning and Reconstructing stage, students revised their solar oven designs based on the weaknesses identified during the previous testing process. Each group discussed the testing results and selected modifications that corresponded to the specific problems found in its design.

*Students revised their solar oven designs based on the weaknesses identified during the previous testing process. Each group discussed the testing results and selected modifications that corresponded to the specific problems found in its design. Some groups added reflectors to the sides of the oven to direct more sunlight toward the lower tier. Other groups replaced the thick plastic cover with thinner and clearer plastic, while some adjusted the angles of the aluminum foil to direct reflected light more effectively into the oven* (Field Observation, May 23, 2026).

A classroom interaction illustrated how students considered the relationship between the identified problem and the proposed modification:

*Student 7: "If we add a reflector on the side, more light can reach the lower level."*
*Student 15: "Yes, and the plastic we used before was too thick, so the heat couldn't get in properly."*
*Teacher: "Good, now try testing it again with the new materials to make the design more effective."* (Field Observation, May 23, 2026).

The modifications made by the groups were not identical because each solar oven had different weaknesses. Students selected changes based on the evidence obtained during testing, rather than merely following one solution provided by the teacher. Through this stage, students learned that an engineering design can be reviewed and improved when the initial product does not function as expected. The process also provided opportunities for students to reflect on their decisions, reconsider the functions of the materials, and reconstruct the product according to the problems they had identified.

Overall, the Redesigning and Reconstructing stage supported students' problem-solving, creativity, and collaboration by engaging them in cycles of testing, reflection, and design improvement. The findings indicate that students began to recognize that an unsuccessful initial design was not the end of the process, but a basis for identifying weaknesses and developing more appropriate modifications. This iterative process reflects the central characteristics of the Engineering Design Process.

*Discussion*

*EDP-STEM Supported Students' Problem-Solving Skills*

The findings indicate that EDP-STEM supported students' problem-solving skills because each stage required them to make, test, evaluate, and revise decisions based on evidence. From an experiential learning perspective, understanding develops through concrete experience, observation, reflection, and active experimentation (Kolb, 1984). In the solar oven project, Problem Scoping and Idea Creation connected students' prior knowledge with contextual problems; Designing and Constructing transformed their ideas into testable products; Assessing Design provided evidence about product weaknesses; and Redesigning and Reconstructing encouraged students to reconsider and modify their initial decisions. This sequence reflects the iterative nature of engineering design, in which problems and solutions are repeatedly reviewed through designing, testing, and redesigning (English et al., 2017; Kelley & Knowles, 2016).

Previous studies similarly indicate that engineering design, STEM-based projects, and problem-based science activities can support critical, creative, collaborative, and solution-oriented thinking by engaging learners in examining problems, developing ideas, testing designs, and evaluating possible responses (Herlita et al., 2023; Nuraeni & Zahra, 2021; Purwaningsih et al., 2020; Rahman, 2022; Safitri et al., 2024; Wahyudiana et al., 2021).

The clearest qualitative evidence concerned problem identification and consideration of possible solutions. Students identified visible weaknesses in their solar ovens, including insufficient heat, unstable reflector positions, thick plastic covers, and uneven sunlight distribution. They then proposed modifications by adding reflectors, replacing the plastic cover, and adjusting the aluminum foil. Identifying visible weaknesses was relatively direct, whereas selecting appropriate solutions required students to connect evidence with scientific concepts, material functions, and design constraints. Question formulation and conclusion drawing therefore emerged as connected processes that helped students understand problems and evaluate the suitability of their proposed solutions. This relationship is consistent with the close connection between critical thinking and science problem-solving (Lismayani et al., 2017).

*Problem Identification and Question Formulation*

Problem identification and question formulation became evident when students compared the expected and actual performance of their solar ovens. During testing, they observed that the lower tier received insufficient heat and that the marshmallows placed at the bottom did not melt as effectively as those on the upper tier. This discrepancy prompted a student to ask, "Why don't the marshmallows on the lower tier melt, while the ones on the upper tier do?" (Classroom Observation, May 20, 2025). This response reflects the problem identification and question formulation indicators in Greenstein's problem-solving framework (Greenstein, 2012).

EDP-STEM supported these processes because students encountered problems through concrete evidence produced by their own designs. Constructing and testing the ovens allowed them to observe weaknesses, compare expected and actual results, and formulate questions about possible causes. From an experiential learning perspective, concrete experience followed by observation and reflection enables learners to reconsider their understanding and respond to the problems they encounter (Kolb, 1984). Engineering design activities similarly involve examining information, identifying problem constraints, and moving iteratively between problem and solution phases, with questioning serving as a bridge to designing possible responses (Handayani et al., 2024; Sung & Kelley, 2023).

Identifying a visible problem was relatively direct because students could observe unstable reflectors, insufficient heat, or uneven sunlight distribution. Selecting an appropriate solution required more complex reasoning because students needed to connect these observations with scientific concepts, material functions, design constraints, and possible consequences. Thus, question formulation functioned as a bridge between recognizing a problem and developing a solution. This relationship reflects the roles of Problem Scoping and Idea Creation in helping students clarify problems and generate possible responses through integrated STEM activities (English et al., 2017; Kelley & Knowles, 2016; Rosiningtias et al., 2023).

*Consider and Find Solutions*

Students considered possible solutions by connecting the identified weaknesses of their solar ovens with scientific concepts and material functions. When the lower tier received insufficient light and heat, they proposed adding side reflectors, modifying the divider between the tiers, replacing the plastic cover with a clearer material, and adjusting the angle of the aluminum foil. These alternatives reflect the third problem-solving indicator proposed by Greenstein (2012), which requires students to generate and consider possible responses to an identified problem.

Students also generated alternative ideas when responding to the worksheet scenario concerning cloudy weather. Some suggested using a lamp, flashlight, or fire as a substitute for sunlight. Although these responses demonstrated the ability to propose more than one idea, not every solution was scientifically appropriate, safe, or feasible for operating a solar oven. Thus, considering solutions involved not only generating alternatives but also evaluating their relevance, availability, safety, and compatibility with the project constraints. Contextual STEM and PjBL-STEM activities similarly support solution development by encouraging learners to apply scientific concepts, generate alternative ideas, and evaluate possible responses to real-life problems (Istiana et al., 2023; Nurita et al., 2024; Subekti et al., 2025; Sukma et al., 2023).

EDP-STEM supported this process by connecting Idea Creation, Designing and Constructing, Assessing Design, and Redesigning and Reconstructing. Students transformed initial ideas into products, examined their effectiveness through testing, and modified the selected solutions based on evidence. This iterative movement between ideas and evidence reflects engineering design, in which solutions are developed, evaluated against constraints, and revised when they do not achieve the intended purpose (English et al., 2017; Kelley & Knowles, 2016). It also demonstrates the importance of learning materials that guide students explicitly from defining problems toward developing and evaluating solutions (Atina et al., 2025).

*Make and Determine Conclusions*

Students formulated conclusions by connecting the testing results with the concepts of light and heat energy. They concluded that transparent plastic allowed sunlight to enter the oven, black materials supported heat absorption, and aluminum foil reflected light toward the inside of the product. These conclusions reflect the fourth problem-solving indicator proposed by Greenstein (2012), in which students use evidence to determine whether their ideas and solutions correspond to the initial problem.

Students' conclusions were not limited to recalling scientific concepts. One student explained, "Light can pass through transparent objects. By using transparent plastic on the cover and sides of the oven, sunlight can enter the oven." Another stated, "Using black cardboard and aluminum foil helps capture solar energy and makes the oven hotter" (Student Interview, June 5, 2025). These responses show that students connected material functions with the observed performance of their designs. Assessing Design provided evidence for this interpretation, while Redesigning and Reconstructing encouraged students to reconsider which design decisions should be maintained or changed. This process reflects experiential learning, in which reflection on concrete experience contributes to the development of new understanding (English et al., 2017; Kolb, 1984).

The quality of students' conclusions varied. Some mainly described scientific concepts, whereas others connected concepts, testing evidence, material functions, and design decisions more clearly. This variation indicates that conclusion drawing requires students to interpret evidence and justify their judgments rather than merely describe what occurred. Process-oriented project assessment and learning activities that strengthen critical thinking can support students in evaluating solutions and producing evidence-based conclusions (Hamimi et al., 2024; Viyanti et al., 2025). Thus, conclusion drawing connected the initial problem, the proposed solution, the testing evidence, and the lessons obtained from revising the product.

*Integration of EDP-STEM Stages and Problem-Solving Skills*

Taken together, the findings show that students' problem-solving processes emerged across interconnected and iterative EDP-STEM stages rather than through a linear sequence. Problem identification and question formulation were evident during Problem Scoping and Idea Creation, and problem identification re-emerged during Assessing Design when students used testing results to recognize design weaknesses.

Consideration of possible solutions extended from Idea Creation through Designing and Constructing, Assessing Design, and Redesigning and Reconstructing. Conclusion drawing was particularly evident during Assessing Design and Redesigning and Reconstructing, when students interpreted evidence and determined which design decisions should be maintained or changed.

These relationships indicate that the four problem-solving indicators developed through repeated connections among problems, questions, ideas, actions, evidence, and revisions. Students moved from recognizing visible weaknesses toward applying scientific concepts, evaluating material functions, and revising their design decisions. This iterative process reflects engineering design and experiential learning, in which understanding develops through concrete experience, reflection, and active experimentation (English et al., 2017; Kolb, 1984). Integrating EDP into renewable-energy STEM projects can also support students in examining relationships among different components of a problem (Abdurrahman et al., 2023).

Previous studies similarly indicate that project-based and experiential STEM learning can support higher-order thinking and problem-solving through authentic experiences, reflection, knowledge application, and solution development (Almujaddid et al., 2025; Mutakinati et al., 2018). Design-based STEM and renewable-energy projects also provide relevant contexts for connecting scientific concepts with designed products and practical experiences (Lidya et al., 2024; Rahmayanti et al., 2024). Based on these findings, Figure 3 presents the relationships between the EDP-STEM stages and students' problem-solving skills.

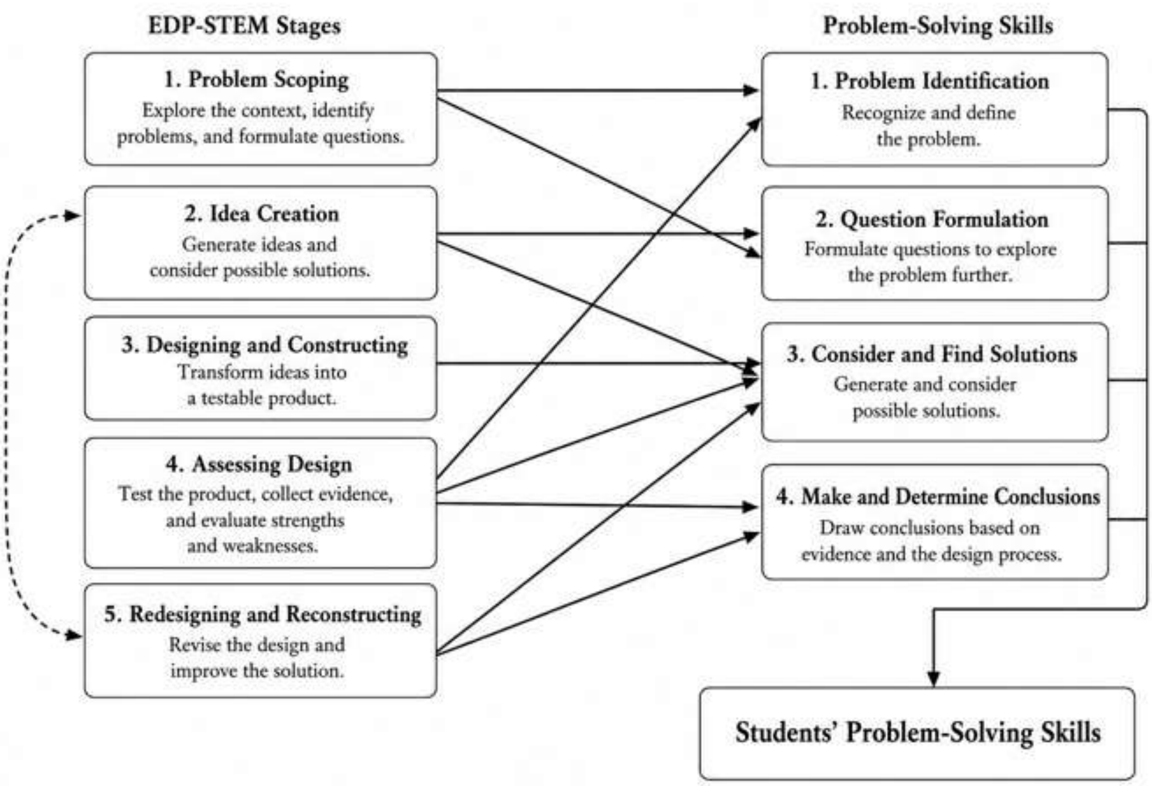


**Figure 3.** Conceptual model of how EDP-STEM stages support students' problem-solving skills

## Conclusion

This study shows that the implementation of EDP-STEM through a solar oven project supported fifth-grade students' problem-solving skills in learning light and heat energy concepts. The iterative stages of Problem Scoping, Idea Creation, Designing and Constructing, Assessing Design, and Redesigning and Reconstructing provided opportunities for students to identify contextual problems, formulate questions, consider possible solutions, evaluate their designs, and draw conclusions based on evidence. The clearest qualitative evidence concerned two problem-solving indicators: problem identification and consideration of possible solutions. Students identified visible weaknesses in their solar ovens, proposed alternative modifications, and connected the testing results with scientific concepts and the functions of materials. Nevertheless, the four problem-solving indicators did not emerge separately or through only one EDP-STEM stage. Problem identification, question formulation, consideration of possible solutions, and conclusion drawing emerged through interconnected cycles of designing, testing, evaluating, reflecting, and revising. Therefore, EDP-STEM provides a contextual approach for supporting problem-solving skills in elementary science learning. Further research may examine its implementation in other science topics and use quantitative evidence to complement the qualitative findings.

**Acknowledgments**
The authors express their gratitude to the classroom teacher and fifth-grade students of SD Negeri Bawakaraeng 1, Makassar, for their participation and support during this study.

**Author Contributions**
R.H.A.: conceptualization, methodology, investigation, data analysis, visualization, and writing (original draft). T.S.: methodology, supervision, validation, and writing (review and editing). M.Y.: supervision, validation, and writing (review and editing). All authors have read and approved the final version of the manuscript.

**Funding**
This research received no external funding.

**Conflicts of Interest**
The authors declare no conflict of interest.

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