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The Implementation of A STEM-Integrated PjBL Model Focused on Heat and Temperature Topics to Enhance Students' Engineering Design Process (EDP)

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Abstract

The demands of the 21st century have had a significant impact on the field of education. Students should prepare themselves to meet the needs of the world of work and society. The engineering design process is a series of STEM learning processes that involve problem-solving and the design of effective solutions. One difference lies in students' understanding of the activities carried out compared to the theories put forward by experts. This study aims to describe students' understanding of the engineering design process following their participation in a STEM-integrated PjBL model on heat and temperature topics. The research subjects were 11th-grade students at Senior High School 1 Jember. Purposive sampling was employed as the students had not previously been trained in the engineering design process. This was a qualitative study using a case approach. Research data were collected through observation, interviews, and documentation. Data analysis utilized the Miles and Huberman model and triangulation techniques. The results indicate that the students demonstrated greater mastery of the design phase compared to the testing phase of the heating device. Consequently, the students have been trained in the engineering design process as preparation for the real world.

Keywords: STEM, PjBL, Heat and Temperature, Engineering Design Process

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INTRODUCTION

The demands of the 21st-century education system are designed to prepare students for roles in the workforce and society. Education is designed to prepare students for roles in the workforce and society (Puspa et al., 2023). The learning system has shifted from a teacher-centered approach to a student-centered one (Mardhiyah et al., 2021). The learning system equips students with essential 21st-century skills, including character, citizenship, critical thinking, creativity, collaboration, and communication. 21st-century learning must provide students with the skills and competencies necessary to meet the challenges of the modern era. One such skill to develop is the engineering design process.

Several studies indicate that the engineering design process is relevant to the needs of the 21st century. Engineering design as a context for integration was successful in terms of helping participants identify STEM content connections that could be implemented within these activities (Estapa & Tank, 2017). Familiarising students with the engineering design process is beneficial, as it enables them to plan and experiment extensively (Kelley & Knowles, 2016). Mastery of the engineering design process opens up a wide range of career prospects in the field of technology (Lin et al., 2021). Such technology

is closely linked to concepts in physics.

Heat and temperature form the basis for studying thermodynamics. The difficulties students experience in learning about heat and temperature require attention. Students are unable to relate their knowledge to everyday phenomena because they bring with them everyday understandings that conflict with the concepts of heat and temperature as understood by experts (Mustofa, 2021; Sumarni, 2020). A lack of understanding of the physical concept of heat means that students who are accustomed to performing tasks are less able to analyze which materials are most effective.

Various learning models have been widely used in teaching temperature and heat to enhance 21st-century skills. Previous research has found that learning models such as experiment-based discovery learning are effective in assessing students' critical thinking skills (Ruhana et al., 2023). Problem-based learning supported by virtual laboratories and project-based learning are effective in improving students' conceptual understanding (Aulia et al., 2025; Sukma & Diyana, 2024). Project-based learning is also effective in improving learning outcomes, conceptual understanding, generic science skills, and students' creativity (Maulida et al., 2024; Ratnasari et al., 2023). However, there has been no research on project-based learning models focusing on the engineering design process in the context of temperature and heat. Meanwhile, temperature and heat are frequently encountered in everyday phenomena that require real-world engineering design solutions.

The engineering design process is a pedagogical strategy used in STEM education. It is a series of steps undertaken by students to solve problems and design solutions (Najar & Abdullah, 2017). Problems are addressed in an open-ended manner so that students can generate creative ideas, design and finalize solutions, and develop alternative solutions to fall back on should they encounter obstacles. (Shahali et al., 2016). Consequently, students who are familiar with the engineering design process will develop a broader perspective (Lin et al., 2021).

The skill developed in students is the engineering design process. The engineering design process helps students improve their design thinking frameworks. The engineering design process includes the stages of problem identification, brainstorming, design, building, testing, redesigning, and solution. (English & King, 2015). The stages of STEM-integrated PjBL are used in this study to include signs of the engineering design process. The problem and brainstorm indicators are in the essential question stage. The essential question stage begins with identifying the problem and brainstorming indicators. The design indicator is located in the project's design phase. The build indicator is located in the schedule creation and project progress monitoring phase. The schedule for testing and monitoring the redesign indicators is established during the stage when students are monitored, and the project's progress is assessed. These indicators are visible through the students, the monitor, the test and redesign indicators, and the advancement of the project stage. The test and redesign indicators are located in the phase where the monitor, students, and project progress are evaluated. The solution indicator is located inside the stages for outcome assessment and experience evaluation.

One approach to addressing challenges in physics learning is to teach heat and temperature using a PjBL model integrated with STEM, enabling students to hone their skills in the engineering design process. Engineering activities in physics learning can serve as a valuable foundation for the future. This study aims to describe the engineering design process demonstrated by students who participated in PjBL-based physics learning, specifically focusing on designing a heating device to address health issues related to the "bediding" phenomenon in Jember.

METHODS

The research was conducted over three sessions (7 JP = 315 minutes) on 28 April, 5 May, and 8 May 2025, at Senior High School 1, Jember. The research subjects were 36 students in grade 11. The class was selected using purposive sampling, as the students had not yet had the opportunity to practice the engineering design process. This research is a qualitative study using a case study approach. The stages of the case study design, adopted from Yin (2018), include plan, design, prepare, collect, analyze, and share. The research stages carried out are illustrated in Figure 1.

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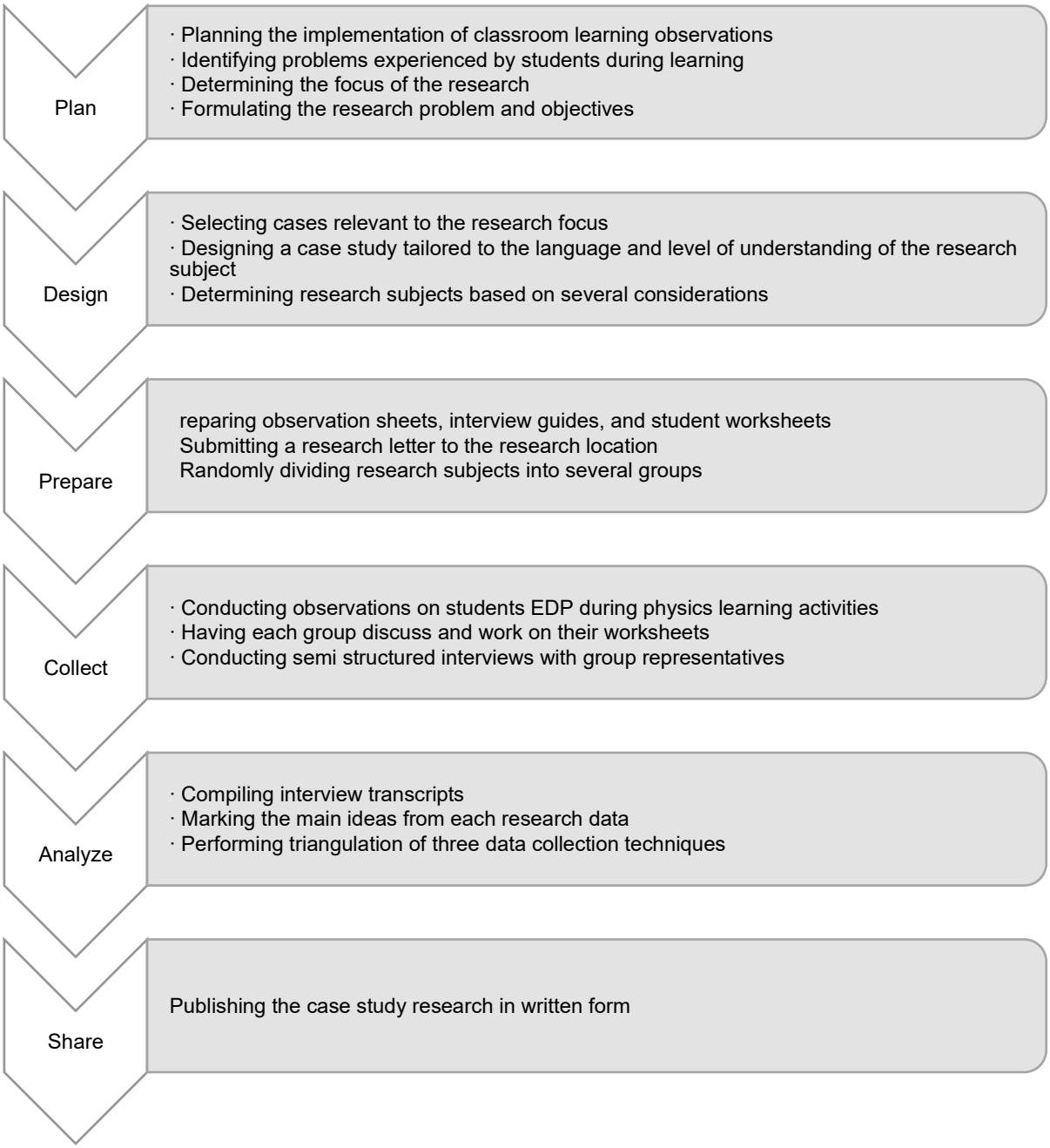


Figure 1. Research stages

The research instruments used by the researcher were a semi-structured interview guide, a student observation guide, and student worksheets that had been validated by experts. Data collection was carried out by observing student behavior during the learning process, while semi-structured interviews were conducted after the lesson and documentation was completed. The data collected by the researcher were analyzed using the Miles and Huberman model. The stages of qualitative data analysis included data collection, data reduction, data presentation, and drawing conclusions (Sidiq & Choiri, 2019). The results of student observations and the assessment of worksheets completed by each group can be used to calculate students' learning process scores. The assessment of students' engineering design process is based on three criteria aligned with the engineering design process indicators adopted from English & King (2015). The student observation sheet is presented in Table 1.

Table 1. Student engineering design process (EDP) observation sheet

Code	Aspects observed	Score	Items Observed
EDP 1	Problem	3	Students are able to identify problems related to the topic and define them accurately
		2	Students are able to identify problems related to the topic but lack understanding when defining the problem
		1	Students are able to identify problems related to the topic but have not yet defined the problem
EDP 2	Brainstorm	3	Students are able to develop complex approaches and produce plans for further investigation
		2	Students are able to develop moderately complex methods and devise plans for further investigation
		1	Students are able to develop simple methods and produce plans for further investigation
EDP 3	Design	3	Students are able to produce clear, detailed and easy to understand sketches
		2	Students are able to produce sketches that are reasonably clear and detailed
		1	Students are able to produce a sketch, but it is not yet clear or detailed
EDP 4	Build	3	Students produce a product in accordance with the designed plan
		2	Students create a product with minor modifications to the previously designed model
		1	Students create products that do not closely match the designed model
EDP 5	Test	3	Students are able to analyze data very well and in depth with accurate interpretations that correspond to the test results
		2	Students are able to analyze data well, but there are still some areas for improvement
		1	Students have begun to analyze the data, but the analysis isn't yet thorough enough, or there are errors in the interpretation of the data
EDP 6	Redesign	3	Students are able to evaluate the results of the experiment in depth, identify all problems, and plan effective improvements
		2	Students are able to evaluate the results of experiments well, identify most problems, and provide relevant solutions
		1	Students begin to evaluate the results of experiments, but their analysis is still superficial or not entirely accurate
EDP 7	Solution	3	Students are able to present the final product clearly, in a structured and effective manner
		2	Students are able to present the final product fairly clearly, although some parts could be improved
		1	Students are able to present part of the final product, but the way in which the solution is conveyed is unclear

The method for calculating students' scores in the Engineering Design Process was adopted from Akbar (2017), as shown in Equation (1). In this equation, P_k represents the student's learning process score, P is the total score obtained by the student for each engineering design indicator, and N is the maximum possible score for each engineering design indicator.

$$P_k = \frac{P}{N} \times 100$$

The research used several categories in Table 2 to measure students' success in the Engineering Design Process. The researcher analyzed the interview results by converting the audio recordings into written transcripts. The researcher highlighted statements that were deemed important and relevant to the research. The researcher highlighted statements deemed important and relevant to the research, then categorized the data into several groups. Irrelevant interview data could be omitted.

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Table 2. Categories of student learning process

Student learning process scores	Category
85-100	Good
65-84	Fair
33-64	Less

In presenting the data, the researcher grouped and presented the information gathered in the field. The presentation of data from observations and the student worksheet was written in narrative form and supported by graphs illustrating the students' EDP indicators. Meanwhile, the interview results were organized into tables to illustrate each respondent's responses. The researcher used triangulation to verify data from various sources (Sidiq & Choiri, 2019). This involved triangulating three data collection techniques: interview results from all informants, which were then confirmed using documentation relevant to the study, alongside field observation findings.

In the final stage, the researcher tested the validity of the research findings and then drew descriptive conclusions from them. The conclusions were derived from the essence of the data presentation and were then written in concise sentences with broad meanings. Consequently, the conclusions will assist readers in understanding the research findings.

RESULTS AND DISCUSSION

Results

The implementation of the integrated STEM project-based learning model on the subject of temperature and heat aims to train students in the Engineering Design Process (EDP). All stages of PjBL-STEM, including essential questions, project planning, activity scheduling, project creation, assessment, and evaluation of the experience, were carried out during the learning process. The research results pertain to the Engineering Design Process (EDP), which consists of seven indicators: problem, brainstorming, design, build, test, redesign, and solution. The results of this study are illustrated in Figure 2.

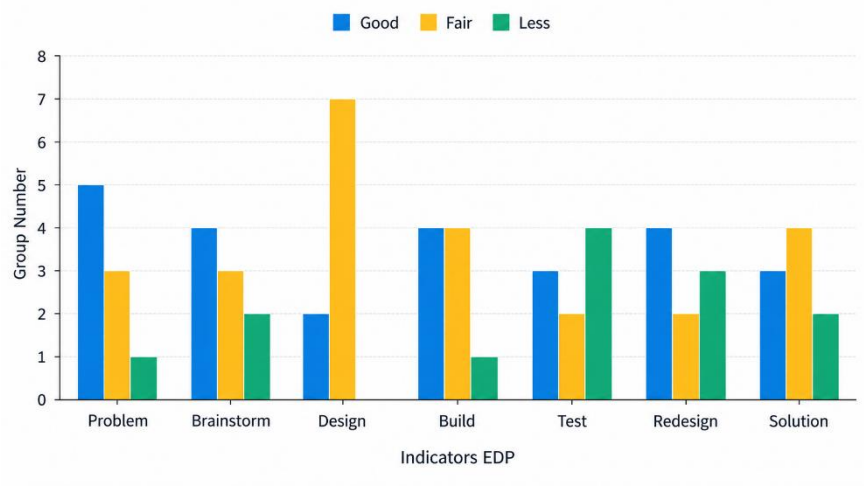


Figure 2. Engineering Design Process data in the worksheets

The questions presented in the student worksheets address the problems arising in the case study. Students' responses to the case study problems, when presented comprehensively and in detail, influence the *'problem'* indicator. The 'less' category group defined the problem occurring in the case study as temperature changes at the start of the season or extreme temperature changes. Meanwhile, the 'good' category group defined the problem as bedding or temperature changes occurring at the start of the dry season, which disrupts public health. Based on observation notes from the first session, there

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was a wide variation in students' abilities to define the problem. During the observation, it was evident that students in the 'less' category struggled to define the problem, as shown by their lack of initiative during group work. Conversely, some students demonstrated an ability to identify problems related to the topic and define them accurately. The results of interviews with group representatives confirmed the problem indicators identified by the students. Details of the interview results are presented in Table 3.

Table 3. Interview notes on problem indicator

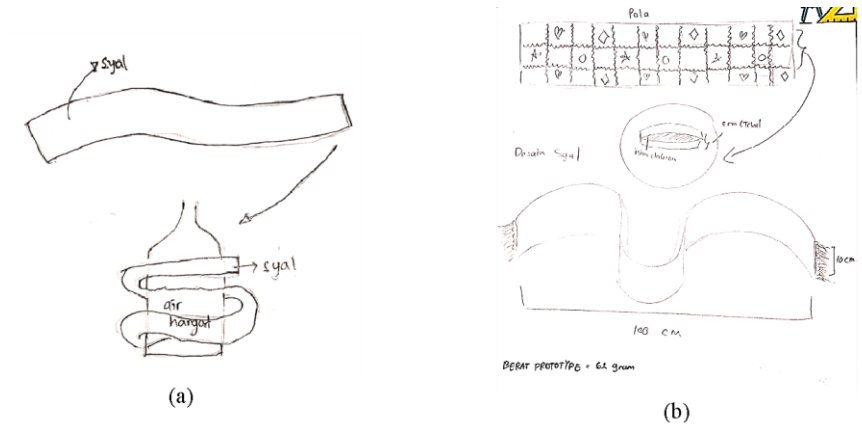
Category	Interview notes
Less	*"About the temperature getting colder."*
Good	*"When it feels very hot during the day, but cold at night. This causes problems in the community, namely hypothermia."*

The *brainstorming* indicators on the students' worksheets are divided into two items: proposed ideas and solutions the students intend to implement, accompanied by reasons. Brainstorming was classified as 'less' when students suggested wearing thick clothing. Conversely, brainstorming was classified as 'good' when students proposed making a scarf to keep warm whilst keeping costs to a minimum. Based on the observation notes from the first session, it was found that there was diversity in the students' abilities to develop ideas as solutions to the problem of bedding. During the observation, one group developed a simple method. Conversely, another group demonstrated a good ability to develop complex ideas. The results of interviews with group representatives confirmed the students' brainstorming indicators as shown in Table 4.

Table 4. Interview notes on brainstorming indicator

Category	Interview notes
Less	*"At first we made a scarf. Then we made a hand cushion from fabric, filled it with Dacron, and added a layer of bubble wrap. A cushion might be more effective, and there are materials that can retain heat better."*
Good	*"To create a product in the form of a scarf that can keep the body warm on a minimal budget and is affordable for the whole community."*

The results of the EDP research, using *design* indicators, showed that two groups were categorized as 'good' because the students were able to select more than three types of tools and materials with logical reasoning, design prototypes complete with dimensions, and write down the steps systematically. A total of 7 groups were categorized as fair because they selected three types of tools and materials with logical reasoning and designed a prototype without dimensions. The students' responses in the form of prototype plans as sketches are presented in Figure 3.



(a) (b)

Figure 3. Prototype designs for the heating device: (a) fair, (b) good

One group carried out design and functional planning, selected tools and materials, and drew up a prototype design. However, this design did not specify the dimensions or materials used in the prototype, as shown in Figure 3a. In contrast, another group demonstrated good design skills by considering and selecting tools and designing the prototype in detail, as shown in Figure 3b. The results of interviews with group representatives confirmed the *design* indicators possessed by the students, as shown in Table 5.

Table 5. Interview notes on design indicator

Category	Interview notes
Less	*"Our group used Dacron, thin foam and aluminium foil. Before we made the product, we carried out a comparison to determine the positioning of the materials to be incorporated into the scarf."*
Good	*"The layers are very simple because we're using cost-effective materials, so we're only using Dacron."*

The project's production was carried out in accordance with the manufacturing process plan that had been drawn up previously. The result of the heating device prototype is shown in Figure 4.



Figure 4. Prototypes of heating devices

The interview results from the group representatives confirm the *build* indicators possessed by the students, as shown in Table 6.

Table 6. Interview notes on build indicator

Category	Interview notes
Less	*"I originally wanted to make something to wear on the body, but as there wasn't enough fabric, I just made a square instead"*
Good	*"As far as I'm concerned, the design and the final result remain the same; there aren't any major changes that can be seen it's still the same."*

The results of the Engineering Design Process study, based on the test indicators, showed that three groups were categorized as good because their data collection was accurate and correct. Two groups were categorized as fair because their data collection was accurate, but the units were incorrect. However, four groups were categorized as less due to errors in their calculations. Based on the observation notes from the second session, the *test* indicators were less because one student in the group stood out whilst taking measurements. Conversely, another student explained to the others which temperature to record and how to identify changes in temperature. The results of interviews with group representatives confirmed the students' *test* indicators as shown in Table 7.

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Table 7. Interview notes on test indicator

Category	Interview notes
Less	*"We wrap the object around our hand, then just bring the fine and coarse sides of the friction paper together like that"*
Good	*"The product is usually wrapped around the neck or can be wrapped around any part of the body that feels cold."*

The challenges encountered with the prototype can serve as a basis for students to make improvements. These improvements may involve adjustments to the prototype design or an evaluation of the trials conducted during the second session. One group only mentioned the challenges they faced during project production, including difficulties in sewing the project without a sewing machine, the fabric being too small and not fitting, so they had to join the pieces using a sewing machine. Meanwhile, another group listed several challenges along with their solutions; one of these was a shortage of materials, which delayed the experiment, with the solution being to prepare materials in advance and provide comprehensive instructions. The low *redesign* indicator score was due to the students not analyzing the problem accurately. However, the *redesign* indicator was supported by the students' awareness that the prototype's filling was unevenly distributed, resulting in areas that did not retain heat effectively. Interview results from group representatives confirmed the students' *redesign* indicators as shown in Table 8.

Table 8. Interview notes on redesign indicator

Category	Interview notes
Less	*"Perhaps the fabric could be a little longer and slightly thicker"*
Good	*"The product we made was too large, so it wasn't very effective because it was too thick."*

The results of the *Engineering Design Process* study, using the *'solution'* indicator, showed that three groups were categorized as good because the students concluded from all the information regarding the project and the course material. Four groups were categorized as fair because their conclusions were relevant to the project and the course material. However, two groups were categorized as less because their conclusions covered only part of the information. Based on the observation notes from the third session, the *solution* indicator was rated as less if students did not participate in the discussion forum. The *solution* indicator was rated as 'good' because the students were able to communicate clearly and effectively, and other students explained the working process in detail, covering the prototype development from start to finish. The results of interviews with group representatives confirmed the students' performance on the *solution* indicator, as shown in Table 9.

Table 9. Interview notes on solution indicator

Category	Interview notes
Less	*"The thing is, there's external temperature, so the temperature fluctuates. Because the bottle isn't sealed, the temperature can get in and out"*
Good	*"Yes, it's in line with the theory of temperature and heat, because some materials in this world can prevent heat from escaping a container. I think it's more about the concept of heat transfer."*

Discussion

The findings of the study indicate that *the Engineering Design Process* occurs when students are actively engaged in the PjBL-STEM learning process (Handayani et al., 2024) . Students have undergone a process of problem-solving and designing solutions in the form of a heating device (Najar & Abdullah, 2017) . Learning is considered effective not only when it focuses on theoretical concepts, but also when students are given the opportunity to develop engineering design skills (Lin et al., 2021). Therefore, the Engineering Design Process is an effective strategy as it enables students to broaden their understanding and skills in the STEM fields.

The problem was presented in the form of a case study on the phenomenon of bediding occurring

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in the Jember region. On average, the students demonstrated good problem-identification skills, as they were able to describe the problem clearly and in detail. Kanza (2020) states that the PjBL model with a STEM approach trains students to analyze problems through essential questioning stages. Furthermore, collaborative learning encourages students to solve problems and achieve meaningful learning.

The students' *brainstorming*, which was classified as 'adequate', was evident in the small-group discussion activities. Several ideas showed potential as solutions to the problems, such as creating a prototype heating device and changing the community's lifestyle. According to Shahali et al (2016), students had the opportunity to contribute creative ideas to solve the problems. In fact, some students were not yet accustomed to generating alternative ideas independently. Previous research has shown that the diversity of solutions depends on students' ability to identify and develop ideas (Storina, 2022). Furthermore, students' differing perspectives are actually a key factor in initiating the design of practical and innovative solutions.

The majority of students demonstrated a reasonable level of *design* ability. The planned prototypes of the heating devices lacked detail, particularly regarding the quantity of materials and the dimensions of the final product. Nevertheless, students had the freedom to design their projects and consult with their teacher regarding the project designs they had created (Puspitasari et al., 2020). At this stage, students determine the tools and materials to be used for the prototype. Factors taken into consideration include the effectiveness of the materials, ease of procurement, and affordability. Students then begin to design the prototype in the form of drawings. Subsequently, they draw up systematic steps to facilitate the project's construction process.

The students demonstrated good *progress*, as evidenced by their prototyping activities in line with the initial plan. Each student had a different role, ensuring their active involvement. This was reinforced by the teacher's role in encouraging the students to work effectively and efficiently in groups, helping one another and taking responsibility (Puspitasari et al., 2020). The materials used by the students for the prototypes included scrap fabric, Dacron, foam, aluminum foil bubbles, polystyrene beads and rice. The students created products such as scarves, hot packs, gloves, heating pads and blankets, as shown in Figure 4. Thus, both the quantity and the layers of material influence the effectiveness of the prototype.

Tests were carried out to measure the effectiveness of the heating devices. The students actively conducted experiments on the initial prototypes they had made (Puspitasari et al., 2020). They measured changes in water temperature using a thermometer and observed the duration of the heat produced. However, the students' test results were inadequate due to a fundamental error in calculating the heat released, namely using the mass of the heating device prototype. The correct calculation should be based on the mass of the water in accordance with the specific heat capacity used. Subsequently, the initial prototype can be evaluated, and the students can make improvements.

If the amount of heat released by the water is greater, this indicates that the prototype requires improvement. On average, the students demonstrated a good level of redesign. This is supported by the answers provided in the worksheets, which detail the challenges the students faced during the construction of the initial prototype and their solutions. Based on the interview results, students hoped to add other materials such as foam and aluminum foil bubbles to improve the product's effectiveness. Students who carried out redesigns endeavored to ensure the final product functioned optimally (Xue et al., 2024). The methods used by students to refine the initial prototype included re-sewing and reducing the quantity of materials.

The students' solutions were clearly evident from their explanations of their work and the product demonstrations in front of the class. The detailed explanation of the product illustrates the students' understanding of their solution. This is consistent with the research by Puspitasari et al.(2020), who argue that students appear to make the most of the opportunity to explain what they have learned whilst completing the project. Furthermore, other students can provide feedback on the material studied (Maysyaroh & Dwikoranto, 2021).

The heating device is an insulator used to prevent the release of excess heat from water. Students

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linked the heating device to concepts of temperature and heat, such as temperature change, heat transfer and Black's principle. This statement demonstrates that the heating device is an appropriate solution to address the phenomenon of bedding in Jember. Students used effective materials to minimize waste (Xue et al., 2024). The students concluded that the product can maintain a stable temperature. The arguments presented in the worksheets were supported by evidence obtained from testing the heating device prototype. Previous research reinforces this view, stating that EDP is used to compare alternatives, formulate evidence from testing, and revise design solutions to determine the best solution (Kelley & Knowles, 2016). Although the evaluation was conducted briefly, the students' engagement made them feel happy and enabled them to apply their learning outcomes to create a final product within the PjBL-based physics learning model integrated with STEM (Kanza et al., 2020).

The success of the PjBL-STEM research on temperature and heat was not without its challenges. The challenges faced by the researchers included the considerable distance between the classroom and the physics laboratory, a shortage of laboratory equipment relative to the number of groups, and students failing to combine the main materials with other materials. Challenges in physics learning can be overcome through effective lesson planning, thereby ensuring that learning objectives are achieved.

CONCLUSION

The majority of student groups demonstrated a good level of the Engineering Design Process. The problem indicator was assessed as good in defining the problem of the heat transfer phenomenon. The brainstorm indicator was assessed as good in generating ideas relevant to the problem. The design indicator was assessed as satisfactory when planning tangible solutions. The build indicator was rated as good when creating a prototype of a heating device in accordance with the plan. However, regarding the test indicator, only a few groups demonstrated accurate data analysis. The redesign indicator was rated as adequate in evaluating the weaknesses of the initial prototype and providing relevant solutions. The solution indicator was rated as good when students communicated the product resulting from the design process they had undertaken. It is recommended that future researchers use the STEM-integrated PjBL model to focus on the improvement or redesign process when identifying students' Engineering Design Process.

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Conflict of Interest

The authors declare that they have no conflict of interest related to this study.

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Author Contributions

R.A.Y. contributed to conceptualization, methodology, investigation, data curation, formal analysis, and writing the original draft. A.D.L. contributed to conceptualization, methodology, validation, supervision, and reviewing and editing the manuscript. N.M.D. contributed to investigation, data validation, and reviewing and editing the manuscript. All authors reviewed and approved the final version of the manuscript and agreed to be accountable for their contributions.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to applicable confidentiality and ethical considerations.

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Ethics Approval and Consent to Participate

The research was conducted at SMA Negeri 1 Jember with permission from the relevant institution. Although formal ethical approval was not obtained, the study was conducted in accordance with applicable ethical principles for research involving human participants. Participation was voluntary, and informed consent was obtained from the participants and, where applicable, their legal representatives before data collection.

Generative AI Declaration

The authors did not use generative artificial intelligence (AI) tools in the preparation of this manuscript.

REFERENCES

Akbar, S. (2017). *Instrumen Perangkat Pembelajaran*. Bandung: Remaja Rosdakarya.

Aulia, R. S., Chusni, M. M., & Kariadinata, R. (2025). Efektivitas Model Pembelajaran *Problem-Based Learning* Dengan Media "Vlab Suhu Dan Kalor" Terhadap Hasil Belajar. *SEMESTA: Jurnal Ilmu Pendidikan dan Pengajaran*, *3*(3), 134–147. https://doi.org/10.70115/semesta.v3i3.334

English, L. D., & King, D. T. (2015). STEM learning through engineering design: Fourth-grade students' investigations in aerospace. *International Journal of STEM Education*, *2*(1), 14. https://doi.org/10.1186/s40594-015-0027-7

Estapa, A. T., & Tank, K. M. (2017). Supporting integrated STEM in the elementary classroom: A professional development approach centered on an engineering design challenge. *International Journal of STEM Education*, *4*(1), 6. https://doi.org/10.1186/s40594-017-0058-3

Handayani, R. D., Dewi, N. M., Lesmono, A. D., Supriadi, B., & Maryani, M. (2024). In-house Training Pembelajaran STEM Berbasis Engineering Design Process Kepada Guru SMK Darul Muqomah Kabupaten Jember. *Mitra Mahajana: Jurnal Pengabdian Masyarakat*, *5*(3), 324–330. https://doi.org/10.37478/mahajana.v5i3.4591

Kanza, N. R. F., Lesmono, A. D., & Widodo, H. M. (2020). Analisis Keaktifan Belajar Siswa Menggunakan Model Project Based Learning dengan Pendekatan Stem Pada Pembelajaran Fisika Materi Elastisitas di Kelas XI MIPA 5 SMA Negeri 2 Jember. *Jurnal Pendidikan Fisika*, *9*(2), 71. https://doi.org/10.19184/jpf.v9i1.17955

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education*, *3*(1), 11. https://doi.org/10.1186/s40594-016-0046-z

Lin, K.-Y., Wu, Y.-T., Hsu, Y.-T., & Williams, P. J. (2021). Effects of infusing the engineering design process into STEM project-based learning to develop preservice technology teachers' engineering design thinking. *International Journal of STEM Education*, *8*(1), 1. https://doi.org/10.1186/s40594-020-00258-9

Mardhiyah, R. H., Aldriani, S. N. F., Chitta, F., & Zulfikar, M. R. (2021). Pentingnya Keterampilan Belajar di Abad 21 sebagai Tuntutan dalam Pengembangan Sumber Daya Manusia. *Lectura : Jurnal Pendidikan*, *12*(1), 29–40. https://doi.org/10.31849/lectura.v12i1.5813

Maulida, Y., Siska, D., Safriana, S., Syafrizal, S., & Widya, W. (2024). Penerapan Model Project Based Learning Berbasis Diferensiasi Untuk Meningkatkan Hasil Belajar Siswa Pada Materi Suhu dan Kalor. *Relativitas: Jurnal Riset Inovasi Pembelajaran Fisika*, *7*(2), 130–138. https://doi.org/10.29103/relativitas.v7i2.16731

Maysyaroh, S., & Dwikoranto, D. (2021). Kajian Pengaruh Model Project Based Learning Terhadap Keterampilan Berpikir Kreatif Peserta Didik Pada Pembelajaran Fisika. *ORBITA: Jurnal Kajian, Inovasi Dan Aplikasi Pendidikan Fisika*, *7*(1), 44–53. https://doi.org/10.31764/orbita.v7i1.4433

Mustofa, Z. (2021). Pemahaman Siswa tentang Aplikasi Konsep Suhu dan Kalor yang Berkaitan dengan Komputer. *Jurnal Pendidikan Fisika Undiksha*, *11*(1), 56–65. https://doi.org/10.23887/jjpf.v11i1.24501

Najar, N. A., & Abdullah, S. (2017). *Fundamentals of Engineering Design* (1st edn). Jammu & Kashmir: JKERT FOUNDATION.

Puspa, C. I. S., Rahayu, D. N. O., & Parhan, M. (2023). Transformasi Pendidikan Abad 21 dalam Merealisasikan Sumber Daya Manusia Unggul Menuju Indonesia Emas 2045. *Jurnal Basicedu*, *7*(5), 3309–3321. https://doi.org/10.31004/basicedu.v7i5.5030

Puspitasari, L., Astuti, B., & Masturi, M. (2020). Penerapan Project Based Learning (PjBL) Terbimbing untuk Meningkatkan Keaktifan dan Pemahaman Siswa pada Konsep Momentum, Impuls, dan Tumbukan. *Physics Education Research Journal*, *2*(2), 69.

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https://doi.org/10.21580/perj.2020.2.2.4959

Ratnasari, R., Doyan, A., & Makhrus, Muh. (2023). Pengembangan Perangkat Pembelajaran Berbasis Proyek Terintegrasi STEM pada Materi Suhu dan Kalor untuk Meningkatkan Keterampilan Generik Sains Dan Kreativitas Peserta Didik: Instrumen Validasi. *Jurnal Penelitian Pendidikan IPA*, *9*(9), 6992–6999. https://doi.org/10.29303/jppipa.v9i9.4178

Ruhana, B. A., Meiliyadi, L. A. D., & Zaini, M. (2023). Pengaruh Model Discovery Learning terhadap Keterampilan Berpikir Kritis Siswa pada Materi Suhu dan Kalor. *Relativitas: Jurnal Riset Inovasi Pembelajaran Fisika*, *6*(1), 1. https://doi.org/10.29103/relativitas.v6i1.10375

Shahali, E. H. M., Halim, L., Rasul, M. S., Osman, K., & Zulkifeli, M. A. (2016). STEM Learning through Engineering Design: Impact on Middle Secondary Students' Interest towards STEM. *EURASIA Journal of Mathematics, Science and Technology Education*, *13*(5). https://doi.org/10.12973/eurasia.2017.00667a

Sidiq, U., & Choiri, M. M. (2019). *Metode Penelitian Kualitatif di Bidang Pendidikan* (Vol. 1). Ponorogo: Nata Karya.

Storina, R. (2022). Implementasi Model PjBL - STEM terhadap Kreativitas Siswa pada Mata Pelajaran IPA di SMP Negeri 5 Batam. *BIODIDAK*, *2*(2), 87–93.

Sukma, M. D. A., & Diyana, T. N. (2024). Analisis Kelayakan Modul Model Project Based Learning Berbasis Kearifan Lokal Dalam Upaya Meningkatkan Pemahaman Konsep Fisika Materi Suhu Dan Kalor. *MAGNETON: Jurnal Inovasi Pembelajaran Fisika*, *2*(2), 146–153. https://doi.org/10.30822/magneton.v2i2.3549

Sumarni, I. (2020). Penerapan Model Project Based Learning (PJBL) untuk Meningkatkan Aktivitas dan Hasil Belajar Siswa dalam Mata Pelajaran IPA tentang Sifat-Sifat Cahaya di Kelas V A Semester II bagi Siswa SD Negeri Bantarkemang 1 Tahun Ajaran 2017/2018. *Jurnal Teknologi Pendidikan*, *9*(1). https://doi.org/10.32832/tek.pend.v9i1.2764

Xue, X., Ahmad, N. J., & Liu, X. (2024). The Development and validation of an EDP-STEM module-taking heat transfer, mechanics, and buoyancy as examples. *Journal of Turkish Science Education*, *20*(4), 649–668. https://doi.org/10.36681/tused.2023.037

Yin, R. K. (2018). *Case study research and applications: Design and methods* (Sixth edition). Los Angeles: SAGE.

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