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Students' Critical Reasoning Activities in Working on the Mechanical Lung Model Project in Science Learning

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Abstract: This study aims to describe and analyze the emergence of students' critical thinking activities during the implementation of Project-Based Learning (PjBL) through a mechanical lung model project in elementary school science learning (IPAS). The study employed a descriptive qualitative approach with a descriptive case study design, involving 25 fifth-grade students at SDN Kranding. Data were collected through passive participatory observation, semi-structured interviews, and documentation, including photographs, videos, and students' project products. The data were analyzed using the Miles, Huberman, and Saldaña model, consisting of data condensation, data display, and conclusion drawing and verification. The findings reveal two main contexts in which students' critical thinking activities emerged. First, problem-solving activities occur when the mechanical lung model does not function as expected, prompting students to identify problems, formulate possible explanations, examine components, and consider corrective actions. Second, the exchange of ideas during group work involved proposing solutions, providing reasons, responding to peers' opinions, and considering alternatives before making decisions. These activities were particularly associated with the indicators of elementary clarification, inference, and strategies and tactics proposed by Ennis. This study contributes an empirical description of how critical thinking activities emerge through concrete problem-solving and collaborative interactions during project completion. It concludes that project-based learning provides opportunities for students to demonstrate critical thinking processes, although these findings do not establish an improvement in their overall critical thinking abilities.

Keywords: *critical thinking, project based learning, mechanical lung model, IPAS, elementary school*

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INTRODUCTION

Critical thinking skills are an important competency that needs to be developed in elementary school learning, particularly in Natural and Social Sciences (IPAS) (Saputra et al., 2024). This ability is necessary so that students not only master the material but also are able to identify problems, analyze information, provide reasons, draw conclusions, and determine solutions based on logical considerations (Hidayati & Purwaningsih, 2023). However, the development of these skills needs to be supported by learning experiences that provide space for students to engage in discussions, investigations, and problem-solving (Osborne, 2010). Based on the researcher's initial observations and interviews with fifth-grade teachers at Kranding Elementary School, it was discovered that students tend to be quiet and experience difficulties when engaging in discussions during learning. Furthermore, the learning of IPAS, including the human respiratory system, still relies on textbooks as learning resources without the support of visual aids or concrete learning media. This condition is an issue that requires attention because the respiratory system material is not only related to the introduction of organs, but also the working mechanisms of the lungs that occur within the body and cannot be directly observed. This situation demonstrates the need for learning experiences that allow students to understand concepts through concrete activities while simultaneously utilizing their thinking skills (Badrawati et al., 2026).

Several studies have examined the application of Project-Based Learning (PjBL) in elementary school learning and its relationship to critical thinking skills. A systematic review (Putri et al., 2025) shows that PjBL has the potential to support students' skills in analyzing, evaluating, and solving problems. Meanwhile, a study Azizah et al. (2026) identified the contribution of PjBL to the development of 21st-century skills, including critical thinking and problem-solving. In the human respiratory system topic, Jatnika et al. (2024), examined the application of the RADEC model to develop conceptual understanding in fifth-grade students. Research closer to the focus of this study was conducted by Fakhriyah et al. (2026) , which examined PjBL assisted by diorama media to improve elementary school students' critical thinking skills in the respiratory system material. However, these studies have not specifically explained how the critical thinking indicator groups according to Robert H. Ennis emerged in student activities at each stage of the mechanical lung model project. Thus, there is still room for research to understand the process of the emergence of students' critical thinking activities qualitatively, not just measuring changes or results of critical thinking abilities.

Based on this gap, this study aims to describe and analyze the emergence of indicators of critical thinking skills of fifth-grade students of Kranding Elementary School in Project-Based Learning -based science learning on the human respiratory system. The project used is the

creation of a mechanical lung model using plastic bottles and balloons. Specifically, this study is directed to answer the question: how do the five groups of critical thinking indicators according to Robert H. Ennis appear in student activities during the design, creation, testing, and repair of the mechanical lung model? The five groups of indicators include providing simple explanations (elementary clarification), building basic skills (basic support), concluding (inference), providing further explanations (advanced clarification), and arranging strategies and tactics (strategies and tactics).

This study is based on the argument that project activities not only produce learning products but also provide a context for students to demonstrate their thinking processes when facing problems during project work. In creating a mechanical lung model, the activities of designing, building, testing, and refining the model can provide a space for students to express opinions, provide reasons, use information, draw conclusions, and determine steps for solving. Therefore, the contribution of this study lies in presenting an empirical picture of the emergence of Ennis's five groups of critical thinking indicators in student activities during the project-based learning process. The results of this study are expected to enrich the study of project-based science learning, especially on the human respiratory system material, while also providing considerations for teachers in designing concrete learning activities that provide opportunities for students to engage in critical thinking processes.

METHOD

The unit of analysis in this study is the emergence of students' critical thinking indicators during Project-Based Learning (PjBL) based science learning on the human respiratory system. The aspects analyzed include students' behavior, statements, arguments, and problem-solving actions during the mechanical lung model project. The analysis refers to Ennis's five groups of critical thinking indicators: elementary clarification, basic support, inference, advanced clarification, and strategies and tactics . The study focuses on the emergence of these indicators, not on measuring the improvement of critical thinking skills (Ennis, 1996).

This study uses a descriptive qualitative approach with a descriptive case study design to understand the phenomenon in its natural context (Dewi & Rohani, 2026) . The research case is limited to the emergence of critical thinking indicators in PjBL-based science learning in grade V of Kranding Elementary School, which was implemented in the odd semester of the 2025/2026 academic year. Data sources include primary data and documentation. Primary data were obtained from the activities of 25 grade V students and information from class teachers. Several students were selected as group representatives for interviews.

Documentation data includes photos, videos, and mechanical lung model products made by students.

Data were collected through two rounds of passive participant observation, semi-structured interviews, and product documentation and analysis. Observations were conducted throughout the project, including project presentations, recording activities related to critical thinking indicators. Interviews with student representatives and class teachers were conducted to elicit reasons, considerations, and information regarding the learning process. Documentation in the form of photos, videos, and products served as supporting data to analyze the project process and results.

Data analysis used the model (Miles et al., 2014) , which includes data condensation, data presentation, and drawing and verifying conclusions. Data from observations, interviews, and documentation were selected and grouped based on Ennis's five critical thinking indicators, then presented descriptively according to project work activities. Furthermore, findings were interpreted and compared across data sources to obtain an overview of the emergence of students' critical thinking indicators during learning.

RESULTS AND DISCUSSION

Results

Science learning on the human respiratory system in fifth grade at Kranding Elementary School was implemented using the Project-Based Learning (PjBL) model through a mechanical lung model creation project. Based on the results of passive participant observation, semi-structured interviews, and documentation of project activities and products, two forms of student activities were found related to critical thinking indicators. These two activities included problem-solving when the model did not function as expected and exchanging ideas during the design and creation process.

Problem Solving Activities in Project Work

In the process of making a mechanical lung model, students used a used 1,5 liter plastic bottle, two small balloons to represent the lungs, one large balloon to represent the diaphragm, two straws as air channels, insulation, and plasticine to close the air gap. After the components were assembled, students tested the model by pulling on the balloon part attached to the bottom of the bottle. In the test, several groups found that the small balloon inside the bottle did not inflate or only inflated weakly.



Figure 1. Students Discuss to Solve Problems

One incident demonstrating problem-solving activity, as shown in Figure 1, was observed in Group 2. When the model did not perform as expected, group members identified possible causes and examined the model's components. The context of this conversation occurred while students were testing the assembled model. A transcript of the verbal interaction obtained through observations of this activity is presented in Table 1.

Table 1. Transcript of Group 2's Verbal Interaction in Identifying and Solving Problems

Subject	Excerpt from transcript of verbal interaction	Observed reasoning activities
Student A	"Hey, look, why is this balloon inside so limp? Even though I pulled the rubber band at the bottom so tight that it was about to come off."	Identify discrepancies between test results and expected model functionality.
Student B	"Yeah, right, how come the balloon from the other group got so fat right away when you pulled it? There must be something wrong with ours. Check the straw, is it clogged?"	Compare test results and make initial guesses about possible causes of the problem.
Student C	(While feeling the bottle cap) "It's not the straw, Bro. You see, there's not enough wax (plasticine) in the hole in the bottle cap. The straw is still shaking. That means there's outside air coming in through the gaps in the bottle cap, that's why the wind doesn't want to go in through the main straw."	Check the condition of the components and identify possible leaks in the bottle cap.
Student B	"Oh yeah, that's right! If the air leaks from the top, it means that when you pull the bottom, the pressure inside the bottle won't decrease, so you can't suck the balloon inside. Here, I'll add some plasticine until it's really thick so it's airtight."	Relate suspected leaks to changes in air pressure and propose corrective actions.

The conversation in Table 1 illustrates the sequence of reasoning activities that took place during the model testing. Student A first recognized the discrepancy between the action of pulling the bottom balloon and the response of the small balloon inside the bottle. Student B then compared his group's model results with those of the other groups and suggested that the straw might be blocked. Student C then verified this suspicion through direct observation

of the bottle cap. This examination led to another suspicion: a gap in the area where the plasticine should have been.

Student B's response demonstrates that the hypothesis was considered by connecting it to the principle of air pressure changes in the model. The student then proposed adding plasticine to fill the gap. Thus, the conversation demonstrates the process of identifying the problem, proposing a hypothesis, examining the components, and planning corrective action. The addition of plasticine was part of the student's proposed solution based on the results of the model examination.

Similar activities were also found in the component adjustment process during the project, including checking straw connections, adding plasticine, and adjusting the balloon position. Based on observations and product documentation, these adjustments were made when students found parts of the model that were not functioning as expected. This finding indicates that the project involved testing and repair activities, not just component assembly.

Exchange of Ideas and Considerations in Group Work

In addition to problem-solving activities in the product, activities related to critical thinking were also found through the exchange of ideas between students during the project. Students submitted suggestions, provided reasons, responded to the opinions of group members, and considered alternative actions before making a joint decision. One such incident occurred in Group 5 when students discussed which parts of a plastic bottle to cut. The conversation took place during the preparation stage of model making, specifically when group members were determining the size and parts of the bottle to be used. The transcript of the discussion is presented in Table 2.

Table 2. Transcript of Group 5 Discussion on Consideration of Ideas and Decision Making

Subject	Excerpt from transcript of verbal interaction	Observed reasoning activities
Student D	"Just cut the bottle in the middle, so you get a straight section, so it's easy to attach the balloon at the bottom."	Submit proposals based on considerations of ease of execution.
Student E	"Don't cut it in the middle, it will make the chest cavity too small! The lungs need a lot of space to expand. If you cut it too high, the small balloon will hit the side of the bottle, so it won't be able to blow up fully. It's better to cut it a little lower, close to the bottom of the bottle."	Respond to the initial proposal by providing alternatives and reasons regarding the balloon's movement space.
Student F	"Oh yes, you're right. If the bottle is too short, when the bottom balloon is pulled, there won't be enough space inside to create a difference in air pressure. So, only a little air will get in. We'll just cut 3/4 of the top."	Consider the reasons of the group members and convey the decision regarding the size of the bottle parts to be used.

The conversation in Table 2 shows the different considerations in determining which part of the bottle to cut. Student D proposed cutting in the middle, considering the ease of attaching the balloon. This suggestion was responded to by Student E, who proposed the alternative of cutting further down. Student E included reasons regarding the space inside the bottle and the possibility of hindering the balloon's movement if the bottle was too short. Student F then expressed his agreement with Student E's response and related the bottle's size to the available space in the model. The conversation ended with the announcement of the decision regarding which part of the bottle to use. This series of interactions shows that the group's decision was not only based on the initial proposal, but also took into account the reasons given by other group members.

Based on these two events, student activities related to critical thinking were observed in two project work contexts: when students faced problems in the model and when they considered ideas in determining group actions. Both contexts exhibited different forms of reasoning, but both occurred in concrete activities during the process of creating the mechanical lung model.

Discussion

Mechanical Problem Solving and Students' Critical Reasoning Activities

Research findings show that critical reasoning activities emerge when students encounter a discrepancy between the function of the mechanical lung model and the expected results. In Group 2, the balloon not inflating prompted students to examine the condition of the model, compare test results, propose possible causes, and consider corrective actions. This sequence demonstrates that project work involves not only component assembly skills but also provides students with the opportunity to use observations as a basis for determining problem-solving steps (Rizmayannudin & Nuroh, 2025) . Thus, the crucial aspect of this event lies not in the act of adding plasticine, but in the reasoning process that precedes it.

When linked to Ennis's critical thinking indicators, Group 2's activities primarily demonstrate a connection between providing simple explanations (*elementary clarification*) and drawing conclusions (*inference*). Students attempt to explain the model's inconsistency by proposing possible causes, such as a clogged straw or a gap in the bottle cap. When Student B connects the air leak to changes in pressure inside the bottle, there appears to be an attempt to draw conclusions based on observed conditions. This activity demonstrates that students are beginning to use cause-and-effect relationships to explain the problem at hand(Kumala et al., 2022). Meanwhile, the suggestion to add plasticine is a follow-up to consideration of the suspected cause of the problem. This mapping should be understood as identifying activities related to Ennis's indicators, not as determining that students have mastered all of them.

The distinction between reasoning and technical skills is important in interpreting these findings. Repairing a model does not necessarily demonstrate critical thinking if it is simply a matter of following instructions or mindless trial and error. In the Group 2 incident, the basis for identifying reasoning activity is evident in the students' conversations as they speculate and relate the possibility of a leak to changes in air pressure. This means that the analytical value of the incident lies in the reasoning students used to determine their actions, not solely in the success of the repaired model. However, these conversations are insufficient to determine the extent to which students understand the relationship between volume, pressure, and air flow.



Figure 2. Explanation using Educational Props

This finding is more accurately interpreted as an indication of initial reasoning related to the concept of air pressure. In figure 2, when the balloon at the bottom of the bottle is pulled down, the volume of the space inside the bottle increases, thereby decreasing the air pressure inside. This pressure difference allows outside air to enter through the straw, causing the small balloon to expand. If there is a gap in the bottle cap, air can also enter through the gap, reducing the pressure difference required to flow air through the straw. Based on this principle, the students' assumptions about the leak in the bottle cap are relevant to how the model works. However, the bottle, balloon, and straw model is only a simple mechanical representation of the respiratory process. While it helps students observe changes in volume and balloon expansion, it does not depict the entire anatomical structure and physiological processes of human respiration. Therefore, the students' reasoning in repairing the demonstration equipment cannot be directly equated with a comprehensive understanding of the human respiratory mechanism.

These findings align with the study by Putri et al. (2025), which demonstrated that project-based learning has the potential to support elementary school students' analysis, evaluation, and problem-solving activities. These similarities are evident in students' involvement in addressing problems during project work and considering alternative solutions.

However, this study places a more specific emphasis on the reasoning processes evident in students' conversations when testing and refining the product. This emphasis is important because problem-solving activities in projects can be seen not only in the final product but also in the reasons and considerations that accompany the process. Thus, this study demonstrates a concrete form of the emergence of critical thinking activities in the implementation of Project-Based Learning (PjBL).

The use of concrete models can also be understood through Piaget's cognitive development perspective. The mechanical lung model provides an object that students can observe and manipulate to connect explanations about breathing with the changes occurring in the prop. This experience is relevant to elementary school students, who still need the support of concrete objects when learning abstract concepts (Gafiria et al., 2025) . However, the presence of concrete objects does not automatically result in conceptual understanding. The discovery of a suspected air leak demonstrates an opportunity for students to connect observations with explanations, but the depth of their scientific understanding still requires further testing. In this case, the teacher's role is to guide students in connecting the results of the experiment with the scientific principles underlying how the model works (Setiani et al., 2026) .

Exchange of Ideas and Reasoning in Group Collaboration

The findings in Group 5 show that group work provides a space for students to express and consider alternative actions. Differences of opinion regarding which part of the bottle to cut demonstrate that group decisions are not formed directly from a single suggestion. Student D proposed cutting the middle section, considering the ease of attaching the balloon. Student E then expressed objections, arguing that the balloon needs room to expand. Student F considered these reasons before presenting the group's decision. This sequence demonstrates that group interaction involves more than just dividing up the work, but also exchanging reasons for determining the course of action (Vrikki et al., 2019).

Within Ennis's framework, these activities primarily relate to the indicators of strategies and tactics, specifically determining a course of action based on available considerations (Afandi et al., 2021). Student E presented reasons supporting the bottle-cutting alternative, while Student F considered those reasons in decision-making. The reasoning activity also demonstrated elements of explanation for the proposed choice. However, linking this event to the advanced clarification indicator *requires* caution. The available data more strongly suggests the presentation of reasons and consideration of alternative courses of action than the activities of defining terms or identifying assumptions. Therefore, the *strategies and tactics indicator* becomes a more prominent basis for interpretation in this event.

From Vygotsky's social constructivism perspective, the exchange of ideas can be understood as part of the learning process that occurs through interactions with others (Ardani et al., 2026) . In the Group 5 incident, Student E's reasoning regarding the balloon's required space became a consideration for Student F when the group was deciding which part of the bottle to cut. This demonstrates that a student's ideas can become a source of consideration for other group members. This interaction can be understood as peer cognitive support , as students obtain considerations through explanations provided by group members (Febriant et al., 2025) . However, these data are not sufficient to state that this interaction constitutes *scaffolding* or occurs within the Zone *of Proximal Development* (ZPD). Both concepts require more detailed evidence regarding students' initial abilities, the form of assistance provided, and changes in understanding or abilities after assistance is received. Therefore, the interpretation of this study is limited to the exchange of ideas and the use of reasoning in group decision-making.

These findings also indicate that collaboration in PjBL is not simply seen as students working together in a group. The collaborative process needs to be observed through how students convey ideas, provide reasons, respond to opinions, and consider alternative courses of action (Pahmi et al., 2025) . In Group 5, this process was evident when initial proposals received responses accompanied by reasons, which then became considerations in making decisions. In other words, group work provided a context for the emergence of reasoning activities through interactions between students. However, this single event cannot be used to conclude that all group members have the same level of engagement or critical thinking skills.

Comparing the two findings, two contexts demonstrate the emergence of critical reasoning activities during project work. In Group 2, reasoning emerged in response to problems with the product's functionality, while in Group 5, reasoning was evident through the exchange of ideas and consideration of alternatives in decision-making. Both contexts demonstrate that critical thinking activities in PjBL can be observed through the processes that accompany project work, not just through the resulting product(Rineksiane, 2022). The contribution of this study lies in the empirical description of these forms of reasoning activities in the mechanical lung model project. These findings are not intended to prove an increase in students' critical thinking abilities, but rather to demonstrate how several indicators related to critical thinking can be observed in the learning situations studied.

CONCLUSIONS

This study shows that during the implementation of project-based science learning on the creation of a mechanical lung model in grade V of Kranding Elementary School, there

were two forms of student activities related to critical thinking indicators. First, problem-solving activities when the model did not function as expected, which were observed through activities to identify discrepancies, propose suspected causes, examine components, and consider corrective actions. Second, the activity of exchanging ideas in group work, which was seen through submitting proposals, providing reasons, responding to group members' opinions, and considering alternatives before making decisions. Both findings show that project work provides opportunities for students to engage in solution testing and reasoning through group interactions.

These findings describe reasoning activities observed within a single classroom context and cannot be used to draw conclusions about improvements in critical thinking skills or the effectiveness of PjBL in general. In practice, project activities need to be accompanied by teacher guidance so that students focus not only on the product's functionality but also on the underlying scientific concepts. Future research could examine the relationship between reasoning activities, argumentation quality, and students' conceptual understanding through more in-depth observations across different groups and learning contexts.

Author's Declaration:

Artificial Intelligence Statement: During the preparation of this work, the authors used AI-assisted tools (such as ChatGPT, Gemini, and Claude) in order to help structure ideas, brainstorm concepts, and refine the academic writing style. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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