



Addressing Students' Science Misconceptions through Inquiry-Based and Experimental Learning: Evidence from Contemporary Science Education

Eka Muliati

ekamuliati@gmail.com

Universitas Mataram

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Abstract

Science misconceptions can interfere with students' understanding of scientific concepts and their ability to explain natural phenomena accurately. Inquiry-based and experimental learning give students opportunities to examine their initial ideas through investigation, observation, experimentation, and evidence-based reasoning. This article examines how these approaches can address science misconceptions and improve students' conceptual understanding. A literature review was conducted to synthesize recent studies on misconceptions, inquiry-based learning, experimental learning, and conceptual change. The findings indicate that inquiry and experimental activities can help students identify differences between their initial ideas and scientific evidence, while appropriate teacher guidance supports the development of scientifically accepted explanations. Therefore, integrating inquiry and experimental learning can support deeper conceptual understanding and scientific reasoning.

Keywords: science misconceptions, inquiry-based learning, experimental learning, conceptual understanding, science education

1. Introduction

Science learning is expected to help students understand natural phenomena and develop the ability to use scientific knowledge in everyday situations. However, students enter the classroom with prior ideas developed from their experiences, observations, and previous learning. Some of these ideas may differ from scientifically accepted explanations and can develop into misconceptions that influence subsequent learning (Siantuba et al., 2023).

Misconceptions are not simply incorrect answers but represent students' existing ways of explaining scientific phenomena. Because these ideas are often connected to everyday experiences, they can be relatively resistant to change. Science instruction therefore needs to provide opportunities for students to examine their existing understanding and compare it with scientific evidence (Pacaci, 2024).

Inquiry-based learning provides students with opportunities to actively investigate scientific questions rather than simply receive explanations from teachers. Through questioning, predicting, investigating, collecting evidence, analyzing data, and constructing explanations, students can participate more actively in the development of scientific understanding (Berie et al., 2022).

Experimental learning complements inquiry-based learning by allowing students to interact directly with scientific phenomena. Through experiments, students can observe events, collect data, compare results, and evaluate their initial explanations. Experimental activities can therefore become an important means of connecting theoretical concepts with observable evidence (Rahmina et al., 2024).

The relationship between inquiry and misconceptions is particularly important because inquiry can be intentionally designed to challenge students' existing ideas. When students investigate a phenomenon and obtain results that differ from their expectations, they are given an opportunity to reconsider their original explanations and develop new conceptual understandings (Siantuba et al., 2023).

However, inquiry-based learning should not be understood simply as allowing students to conduct experiments independently. Effective science inquiry involves different forms of reasoning, discussion, investigation, and explanation. Recent research emphasizes that well-designed science learning may combine inquiry with appropriate forms of teacher instruction rather than treating inquiry and direct instruction as completely separate approaches (de Jong et al., 2024).

Teacher support is particularly important when students encounter difficult scientific concepts. Students may require guidance to formulate meaningful questions, interpret evidence, and connect their observations to scientific explanations. Appropriate guidance can make inquiry activities more productive and help students move from initial ideas toward more scientifically accepted understandings (de Jong et al., 2024).

Research also indicates that inquiry can contribute to reducing science misconceptions by developing students' critical thinking. When students are required to examine evidence, question assumptions, and construct explanations, they become more actively involved in evaluating their own understanding rather than simply accepting information provided by the teacher (Julianto et al., 2023).

Experimental learning can similarly contribute to conceptual understanding because students are given opportunities to observe scientific principles directly. Research on experimental learning has shown that practical experiences can improve students' conceptual understanding when activities are connected to the concepts being studied rather than focusing only on completing experimental procedures (Rahmina et al., 2024).

Based on these considerations, this article aims to examine the role of inquiry-based and experimental learning in addressing students' science misconceptions. The discussion focuses on how students' prior conceptions, scientific investigation, experimental evidence, teacher guidance, and conceptual reflection can contribute to stronger scientific understanding.

2. Research Method

This article uses a literature review method to examine recent research concerning science misconceptions, inquiry-based learning, experimental learning, and conceptual understanding. The review was conducted to identify relevant findings regarding the ways inquiry and

experimental activities can help students reconsider their initial scientific ideas (Siantuba et al., 2023).

The literature was selected according to its relevance to the main focus of the article. Particular attention was given to studies discussing science misconceptions, inquiry-based instruction, experimental learning, critical thinking, conceptual understanding, and the role of teachers in supporting scientific inquiry (Berie et al., 2022).

The selected literature was analyzed thematically. The analysis focused on several recurring issues, including the nature of students' misconceptions, the role of inquiry in challenging prior ideas, the contribution of experimental activities to conceptual understanding, and the importance of instructional guidance. The findings were then synthesized to develop an overall explanation of how inquiry-based and experimental learning can support conceptual change in science education (de Jong et al., 2024).

3. Results And Discussion

Students' science misconceptions can influence how they interpret new information and scientific phenomena. When students already possess explanations that seem reasonable based on their everyday experiences, they may continue to use those explanations even when they conflict with scientific concepts. This makes the identification and examination of students' prior understanding an important part of science instruction (Siantuba et al., 2023).

Inquiry-based learning provides an opportunity to make students' initial ideas visible. Through questions, predictions, investigations, and discussions, students can explain what they believe will happen and why. These explanations provide teachers with information about students' existing conceptions and create a starting point for subsequent conceptual development (Berie et al., 2022).

Prediction is particularly useful because students are required to express their thinking before receiving the results of an investigation. When students compare their predictions with actual observations, they can identify whether their initial reasoning corresponds with the evidence. This comparison can create an opportunity for students to reconsider explanations that do not adequately account for the observed results (Siantuba et al., 2023).

Experimental learning strengthens this process by providing direct evidence about scientific phenomena. Instead of relying only on verbal explanations, students can observe changes, collect measurements, compare outcomes, and identify patterns. These experiences can make abstract scientific concepts more concrete and provide students with evidence for evaluating their initial understanding (Rahmina et al., 2024).

The effectiveness of experiments depends on how they are incorporated into the learning process. If students simply follow predetermined procedures without interpreting the results, the experiment may have limited effects on conceptual development. Experimental activities should therefore encourage students to think about the relationship between their predictions, observations, evidence, and scientific explanations (Rahmina et al., 2024).

Inquiry activities can be specifically designed to address known misconceptions. For example, students can be presented with a scientific situation in which their initial explanation is likely to differ from the scientifically accepted explanation. They can then investigate the situation and use the resulting evidence to evaluate their original thinking. Research has shown that inquiry environments intentionally designed around misconceptions can facilitate greater conceptual change than conventional inquiry activities (Siantuba et al., 2023).

The process of conceptual change requires more than simply exposing students to contradictory evidence. Students need opportunities to interpret the evidence and understand why their previous explanations may not adequately explain the observed phenomenon. Inquiry-based activities can provide this opportunity by encouraging students to formulate explanations and revise them based on evidence (Pacaci, 2024).

Critical thinking is also closely connected to the process of overcoming misconceptions. Students who are encouraged to question information, analyze evidence, and evaluate explanations are better positioned to recognize weaknesses in their initial understanding. Inquiry models can support these processes by making students active participants in investigating scientific questions (Julianto et al., 2023).

Teacher guidance remains an important component of inquiry-based learning. Although students should have opportunities to investigate independently, they may need support when deciding what evidence is relevant or how observations should be interpreted. Teachers can provide guiding questions, feedback, and explanations when necessary to help students connect their investigation with the scientific concepts being studied (de Jong et al., 2024).

Effective inquiry does not mean removing the teacher from the learning process. Instead, the teacher acts as a facilitator who determines when students should explore, when they need guidance, and when direct explanation may be useful. Contemporary research suggests that the most effective science learning environments can integrate inquiry with appropriate instructional support (de Jong et al., 2024).

The level of inquiry should also be adjusted according to students' abilities and learning needs. Open inquiry can provide students with greater independence, but it may also require stronger scientific reasoning and self-regulation. Systematic research on open inquiry indicates that inquiry can provide positive learning outcomes when students are adequately prepared and supported during the learning process (Dah et al., 2024).

Experimental learning can contribute not only to conceptual understanding but also to students' engagement with scientific practices. When students conduct experiments, analyze evidence, and discuss results, they experience aspects of how scientific knowledge is developed. This can help students understand that scientific knowledge is supported by evidence and investigation rather than simply being a collection of facts (Rahmina et al., 2024).

Inquiry-based learning can also be strengthened through digital laboratory environments. Digital laboratories allow students to investigate scientific phenomena and test hypotheses in environments where variables can be manipulated. When these environments are specifically designed to address misconceptions, they can support students in comparing their initial ideas with evidence and developing more scientifically accurate conceptual understandings (Siantuba et al., 2023).

Another important aspect is the integration of discussion after experimentation. Students need opportunities to explain their findings, compare interpretations with their peers, and consider alternative explanations. Such discussions can help students recognize differences between their original ideas and scientifically supported explanations (Julianto et al., 2023).

Reflection after an inquiry or experiment is equally important. Students can be asked to reconsider their original predictions, identify what they learned from the investigation, and explain how their understanding has changed. This reflective process can strengthen conceptual learning because students actively connect new evidence with their existing knowledge (Pacaci, 2024).

Nevertheless, the implementation of inquiry and experimental learning may face challenges. Limited instructional time, laboratory resources, teacher preparedness, and students' unfamiliarity with inquiry processes can affect the effectiveness of these approaches. Therefore, teachers need to carefully plan activities and provide appropriate support so that practical investigations remain focused on conceptual learning (Berie et al., 2022).

A further challenge is the tendency to equate inquiry with experimentation alone. Inquiry involves more than hands-on activities; it also includes questioning, reasoning, evidence evaluation, explanation, and reflection. Therefore, an experiment should be considered part of a broader inquiry process rather than the entire inquiry process itself (de Jong et al., 2024).

Overall, contemporary science education research indicates that inquiry-based and experimental learning can provide meaningful opportunities to address students' misconceptions. The strongest potential occurs when students are encouraged to reveal their initial ideas, make predictions, conduct investigations, examine evidence, discuss results, and reflect on their conceptual understanding. In this way, inquiry and experimentation can move science learning beyond memorization toward deeper conceptual understanding and scientific reasoning (Siantuba et al., 2023).

4. Conclusion

Inquiry-based and experimental learning can play an important role in addressing students' science misconceptions and strengthening their conceptual understanding. These approaches provide opportunities for students to express their initial ideas, make predictions, conduct investigations, observe scientific phenomena, collect evidence, and compare their findings with their previous understanding.

The effectiveness of these approaches depends on the quality of learning design. Experimental activities should not focus only on following procedures but should encourage students to question, predict, investigate, analyze evidence, construct explanations, and reflect on their findings. Teacher guidance is also important to help students interpret evidence and connect their observations with scientific concepts.

Therefore, inquiry-based and experimental learning should be integrated as meaningful components of science education. When students actively participate in scientific investigation and are supported in connecting evidence with scientific explanations, misconceptions can be challenged, and conceptual understanding can be strengthened.

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