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The Implementation of Analogies in Science Instruction and Their Effect on Students Understanding

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Abstract
Science education often faces challenges in explaining abstract concepts, which can be difficult for students to understand. One strategy that can be used to address this issue is the use of analogies in the learning process. This article aims to examine the characteristics of analogies, their application to various science topics, their benefits, and the challenges involved in their implementation. This study employed a literature review method, collecting data from various books, scientific articles, and relevant previous research findings. The data were analyzed using content analysis techniques through the stages of data reduction, data presentation, and drawing conclusions. The results of the study show that analogies serve as a cognitive bridge connecting abstract concepts with students' real-world experiences, thereby facilitating conceptual understanding. The application of analogies in physics, chemistry, and biology can enhance students' conceptual understanding, learning motivation, and thinking skills. However, the effectiveness of analogies depends heavily on the teacher's ability to select appropriate analogies, explain the similarities and differences between the analogous concept and the target concept, and clarify the limitations of the analogy to prevent misconceptions. Therefore, the use of well-designed analogies can be an effective learning strategy for creating science instruction that is more meaningful, contextual, and student-centered.

1. INTRODUCTION

The learning process is a reciprocal interaction between teachers, students, and learning resources within an educational setting, so that the knowledge conveyed can benefit students and serve as an ongoing guide. During the learning process, educators must be able to enhance teaching and learning activities—both directly and indirectly—to create effective and creative learning experiences. The learning process is a joint effort by teachers and students to distribute and manage information, with the hope that the knowledge provided will be of lasting benefit to students. In this way, a teacher is expected to support the development of students' physical

and mental abilities. In the learning process, there are several types of learning models, such as discovery learning, project-based learning, self-directed learning (SDL), contextual learning, and analogy-based learning (Prayudi et al., 2023).

Science is one of the subjects taught in school. Generally, science is viewed as a phenomenon, a collection of facts, and a set of concepts and principles within the field of knowledge. One of the characteristics of science is its abstract and intangible nature, which requires in-depth analysis to be understood. This poses a challenge for students in learning science in an accessible way. One method to improve students' science understanding and skills is through the application of models. Science literacy can be enhanced for science students through the process of thinking about models, which is one of the key learning objectives. A model is a representation of an object, phenomenon, process, idea, and/or system. Models serve as ideal, multi-representational depictions of real objects—a pedagogical translation of scientific explanations into various forms, such as visual, theoretical, mathematical, and symbolic representations (Nurafina et al., 2024).

In physics instruction, teachers may encounter several difficulties or challenges. Understanding the subject matter is somewhat more difficult due to its abstract nature, as it cannot be observed with the human senses. If students' understanding or mastery of the material is low, misconceptions or misperceptions may arise. To anticipate this situation, teachers are expected to find solutions to these problems. One solution to these difficulties or problems is to improve students' conceptual understanding of the subject matter. One way to enhance students' conceptual understanding is by using an analogy-based learning model that incorporates experimental methods (Apriliani et al., 2015).

One method frequently used in teaching natural sciences is the use of analogies. Analogies serve to illustrate information and objects around us as relationships that can be compared, distinguished, and combined in new ways in accordance with the topic being studied. With the help of analogies, the presentation of instructional material can become clearer and easier for students to understand, especially for abstract or large-scale concepts such as atoms and the solar system. Research and expert opinions indicate that the use of analogies can effectively improve conceptual understanding and reduce misunderstandings when applied through a structured method. This approach also aims to present and visualize concepts so that they are easier for students to grasp. Analogies can be used to describe complex events or phenomena related to learning material that go beyond common sense, the limitations of the senses, or visual aids (Kurniawan, 2023). One learning strategy that can be used in the classroom is the analogy approach. This theoretical approach helps teachers expand students' thinking skills. The learning objectives in analogy-based instruction can be presented verbally, through images, or through a combination of both; as a result, students will find it easier to understand the lesson material well (Kurnianti et al., 2024).

The use of analogies is very useful, especially when the material being taught involves aspects beyond the capabilities of human senses or visual aids for observation. By relying on analogies, we can link difficult and abstract scientific concepts to real-world examples that make it easier for students to understand scientific objects and processes. There are several benefits to teaching with analogies, including serving as a tool to foster shifts in understanding, providing visualization and comprehension of abstract concepts through everyday examples, sparking students' interest in learning by boosting their motivation, and encouraging teachers to consider students' prior knowledge of the material to be taught, while also reducing misunderstandings related to the subject matter. The use of analogies can help students better visualize the material.

In physics instruction, there are several challenges or issues that teachers may face, one of which is presenting an understanding of the concepts of the direction of electric current and potential difference or voltage. Understanding these concepts is somewhat more difficult due

to their abstract nature; they cannot be observed with the human senses. If students' understanding or mastery of these concepts is low, misconceptions or misperceptions regarding this subject matter may arise. To anticipate this situation, teachers are expected to find solutions to address these issues (Apriliani et al., 2015).

If analogies are applied correctly, they can greatly help students understand concepts. However, without thorough preparation, they can lead to misunderstandings. These misunderstandings can arise if students are unaware of the limitations of the analogies used. Various studies have been conducted on science learning using the analogy approach. Analogy-based chemistry instruction using the FAR method has proven effective in improving students' conceptual understanding. The application of the analogy bridge model in chemistry instruction has a significant impact on students' understanding of microscopic aspects. From this, it can be concluded that the use of the analogy bridge model in chemistry instruction can help students better understand microscopic aspects. Furthermore, research shows that physics instruction using analogies has also successfully improved students' cognitive learning outcomes (Fatimah, 2017).

In addition to contributing to conceptual understanding, analogies can also help develop students' higher-order thinking skills. By applying analogies, students not only receive information directly but also engage in the thinking process to identify similarities and differences between two concepts. This activity can help develop analytical, reasoning, and problem-solving skills. Such thinking skills are crucial in science education, which emphasizes the scientific process and conceptual understanding. The use of analogies also supports students in building a more organized knowledge structure. In this way, students not only understand concepts individually but can also see the connections between the concepts they are learning. This ability will be very useful when facing various scientific problems as well as in everyday life. Therefore, analogies can serve as an alternative learning strategy that supports the achievement of 21st-century educational goals.

Based on the explanation above, this article aims to examine the use of analogies in science education and explain their role in helping students understand abstract concepts. This article also seeks to identify the benefits of using analogies in improving the quality of science learning. Furthermore, the discussion will focus on various examples of applying analogies to science topics commonly taught in schools. This study is expected to provide teachers with an understanding of the importance of utilizing analogies in the teaching-learning process. By understanding the characteristics and functions of analogies, teachers can select and apply analogies that are more appropriate for the material they teach. This article is also intended to serve as a reference for researchers or education practitioners seeking to develop innovative learning strategies. Finally, the appropriate use of analogies is expected to enhance students' conceptual understanding, learning motivation, and learning outcomes in science education.

2. METHOD

This study is a descriptive study aimed at describing students' analogical reasoning; that is, a descriptive study is one that aims to describe conditions under specific circumstances. The strategy employed is a qualitative approach, as the data obtained are qualitative (Nurma, 2021). This study is a descriptive study, which aims to describe conditions under specific circumstances. The strategy employed is a qualitative approach, as the data collected are qualitative in nature. This research employs a literature review method with a descriptive qualitative strategy. This approach was chosen because it allows the researcher to systematically, critically, and comprehensively explore existing findings in order to build a conceptual understanding based on empirical and theoretical data (Hanifah et al., 2025). Qualitative research is a type of research conducted by examining relevant research sources to

identify new findings through the use of sentences or phrases (Idris & Rahayu, 2024). The analysis and depth of qualitative research greatly influence the power of the words and sentences used. This qualitative study presents conclusions regarding the stages and interpretation of the findings. Qualitative research focuses more on human elements, objects, and institutions, as well as the relationships or interactions among these elements, in an effort to understand an event, behavior, or phenomenon (Lestari & Mualifah, 2024). As stated by J. Supranto, as quoted by Ruslan in his book "Methods of Research in Public Relations and Communication", a literature review is the process of gathering research data or information by reading scientific journals, reference books, and other materials available in libraries. A literature review is used to examine written sources that provide relevant information on the research topic at hand (Nurhakiki & Yahfizham, 2024).

A literature review is a research method used to gather information and data by utilizing various types of materials available in libraries, such as documents, books, magazines, historical accounts, and others. This research also involves analyzing various reference books and previous studies on similar topics, which are essential for establishing a theoretical foundation regarding the issue under investigation. Additionally, a literature review refers to a data collection method that involves examining books, literature, records, and various reports related to the topic being studied. Meanwhile, according to other experts, a literature review is a theoretical analysis of references and other scientific literature related to the culture, values, and norms within the social context under study. In other words, a literature review involves studying various references and similar previous research findings to establish a theoretical foundation for the issue to be further investigated (Khaesarani & Hasibuan, 2021).

In practice, a literature review involves the following steps:

1. Topic Selection

   The researcher will select a topic at this stage. Topic selection is based on several considerations. In addition to the researcher's interest, the chosen topic is also related to the researcher's experience and surroundings. Consequently, the topic selected for this study is analogies in science education.
2. Information Exploration

   After identifying the topic to be studied, at this stage the researcher will explore information regarding the relationship between the nature of analogies in science education, 3.2 The Role of Analogies in Enhancing Conceptual Understanding in Science Education, the application of analogies to various science topics, and their benefits, as seen through the findings of previous research.
3. Defining the Research Focus

   This stage serves to narrow the scope of the research. The topic selected by the researcher will be further refined to produce a well-focused study. Defining the research focus helps the researcher identify specific data sources, thereby simplifying the analysis process. Based on the topic outlined above, the researcher has determined the research focus to be analogies in science education.
4. Data Source Collection

   In this stage, the researcher collects data from books, journals, and articles relevant to the chosen topic. The researcher utilizes several online sites that provide e-books, scientific journals, and related articles to gather the necessary data sources.
5. Data Presentation Preparation

   At this stage, the researcher reviews the data that has been collected. The data sources obtained are analyzed based on the research requirements.
6. Report Preparation

   After the analysis is complete, the researcher prepares the report following the established structure (Rosdiana et al., 2022).

This type of research is known as library research, which refers to a series of studies related to the collection of library data, or research in which the subject matter is explored through various library resources (books, encyclopedias, scientific journals, newspapers, magazines, and documents) (Ramadani & Herdi, 2021). The data collection method involved identifying, selecting, and documenting various sources that discuss the use of analogies in science education. The selected sources were relevant to the research objective, which was to describe the role of analogies in helping students understand abstract concepts in science. Subsequently, the obtained data were analyzed using content analysis, which involved reviewing, comparing, and interpreting information from various sources. The data analysis process consisted of several steps: data reduction, data presentation, and drawing conclusions. In the data reduction step, the researcher selected information relevant to the study's focus. The next step was to present the data in a structured descriptive format to facilitate the interpretation process. Finally, conclusions were drawn based on the findings from the analysis of the various sources. Through this approach, it is hoped that a comprehensive understanding of the benefits and application of analogies in science education will be gained. The objective of this research is to determine how the use of analogies is implemented in science education, particularly in enhancing students' conceptual understanding and creativity, which can enrich their learning experiences, as explained in various references from educational journals (Rahayu et al., 2025).

3. RESULT AND DISCUSSION

3.1 The Nature of Analogy in Science Education

Based on research from various sources, analogies have proven to be one of the most effective learning methods for helping students understand difficult science concepts. Analogies work by linking concepts that students have not yet mastered (the target) with concepts that are already familiar to them (the analog). The skill of using analogies involves the ability to draw conclusions from two different objects based on their similarities—known as the source problem and the target problem in the context of mathematical analogies. The ability to engage in analogical reasoning is a fascinating topic of discussion because it significantly influences students' success in understanding and solving problems (Agusantia & Juandi, 2022). An analogy is a similarity in the way two different ideas are understood. The first idea is one that is already well known, while the second idea is one that is still new or less familiar. An analogy is a similarity in the way two different ideas are understood. The first concept is one that is already well known, while the second is one that is still new or less familiar. By connecting these two concepts, students can develop new understandings based on their existing experiences and knowledge.

In science education, there are many concepts that cannot be observed directly, such as atomic structure, magnetic fields, gravitational force, the solar system, and electromagnetic waves. These concepts require abstract thinking skills, which often pose challenges for students. The findings (Kania et al., 2026) indicate that the analogy approach has consistently proven successful in overcoming the challenges that arise in visualizing microscopic genetic concepts. Using the analogy learning method helps students be more creative in understanding the subject matter. Students are motivated to analyze, discuss, and evaluate the concepts they have learned so that they can generate new ideas in the form of appropriate comparisons or analogies related to the material being taught. This process helps students understand the material better, allowing them to retain it longer and improve their learning outcomes (Kurniawan, 2023). As a result, it can be seen that analogies serve as a teaching method that can help students achieve their science learning objectives, particularly in reinforcing their conceptual understanding.

Nevertheless, the success of using analogies depends heavily on the teacher's ability to select and apply them appropriately. Effective analogies must share similarities in structure or characteristics with the concept being explained, be easy for students to understand, and be appropriate for their stage of cognitive development. On the other hand, an inappropriate analogy can lead students to assume that all the characteristics of the analogy are the same as those of the actual scientific concept, thereby leading to misconceptions. Therefore, teachers must not only point out the similarities between the analog concept and the target concept but also explain the differences or limitations of the analogy. By taking these factors into account, analogies can serve as an effective learning strategy to improve the quality of science education while reducing the risk of conceptual misunderstandings.

3.2 The Role of Analogies in Enhancing Conceptual Understanding in Science Education

Various research findings indicate that the use of analogies has a significant positive impact on improving understanding of abstract concepts in science education. Science concepts, such as atoms, gravitational force, electric fields, waves, and the solar system, cannot usually be observed directly and therefore require a high level of abstract thinking. This often makes it difficult for students to develop a conceptual understanding if they rely solely on verbal explanations. Analogies serve as cognitive bridges that connect abstract concepts to students' existing experiences or knowledge. In this way, students can form clearer mental images, making it easier to understand the concepts being studied.

According to the results of a study, the use of analogies can help students connect their prior knowledge with new information by comparing the similarities between the concept in the analogy and the concept they are trying to understand. According to (Mutia et al., 2022), analogies improve the quality of learning because they involve problem-solving activities based on a thought process that leads to a conclusion. On the other hand, a study (Putri & Masriyah, 2022) shows that analogies serve as a reasoning strategy that helps students connect concepts they have learned to new problems through the process of identifying, comparing, and applying concepts to solve problems. In physics, analogy-based learning is used by applying similarities that students have previously learned to reduce their level of math anxiety, such as in the topic of linear motion kinematics. In the topic of linear motion kinematics, analogies can be used by linking mathematical equations as the source idea and the equations encountered in linear motion kinematics as the target concept (Cholila & Sajiman, 2023).

Analogies in science are often related to the simplification of complex systems. From Isaac Newton's analogy between a falling apple and the moon's orbit to Richard Feynman's analogy of subatomic particles behaving as "waves," these comparisons shape the way we understand both physical and abstract phenomena (Wibowo, 2023). Findings from previous research also indicate that the use of analogies can reduce the occurrence of misconceptions among students. (Hutajulu & Bunawan, 2026) reported that the use of analogies helps students gain a deeper understanding of the concept of sound waves. However, the selection and design of analogies must be carried out with great care to avoid leading to misinterpretations. These findings suggest that the use of analogies can help explain scientific concepts more clearly, as they provide examples that are closer to students' everyday experiences. The empirical evidence regarding the effectiveness of analogies hinges on the teacher's ability to select analogies that are appropriate for the concepts being taught.

In addition to deepening conceptual understanding, the use of analogies also supports student-centered learning. When teachers introduce an analogy, students are motivated to make comparisons, identify similarities, and assess differences between the concept in the analogy and the target concept. Analogies also encourage students to recognize similarities in the structure between concepts, allowing them to build a more solid and comprehensive mental representation, which makes it easier for them to understand complex mathematical ideas

(Mashuri & Nurvita Yudasari, 2025). This activity makes students more active in developing their knowledge, rather than merely passively receiving information. This process aligns with constructivist theory, which posits that knowledge is formed by integrating new experiences with existing knowledge. Thus, the use of analogies not only helps students understand abstract concepts but also improves the quality of their thinking processes throughout the learning process.

Based on the combined results of the research, it can be concluded that using analogies is an effective learning method for clarifying students' understanding of abstract concepts in science education. This effectiveness is evident in its ability to connect new ideas with students' prior experiences, help them visualize scientific concepts, reduce misunderstandings, and increase student participation during learning. Thus, using analogies can serve as an alternative teaching strategy that helps create more meaningful science learning focused on conceptual understanding.

3.3 The Use of Analogies in Various Science Topics

Research conducted on various texts shows that analogies are frequently used in various science topics to help students understand abstract concepts that are difficult to observe directly. Analogies are used by connecting the concept being studied to another concept that students are already familiar with from their everyday experiences. This strategy helps students develop a clearer mental picture, so that complex and difficult-to-understand concepts can seem more tangible and easier to grasp. Based on the research findings, the use of analogies is frequently observed in the learning process for physics, chemistry, and biology because these three fields involve concepts that cannot be observed directly.

3.3.1 The Analogy Between Electric Current and Water Flow

In the topic of dynamic electricity, one analogy that can be used is that between electric current and water flow. This analogy helps students understand the relationship between voltage, current, and resistance—a concept that has long been considered difficult because it cannot be observed directly.

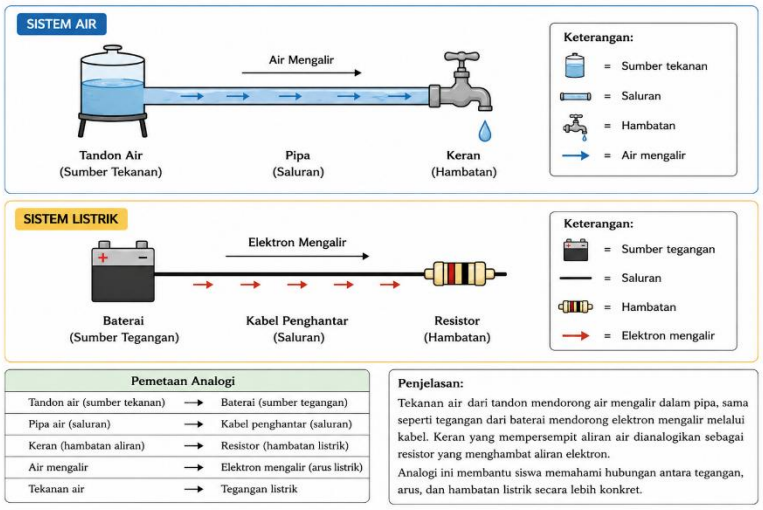

Figure 1. Analogy Between Electric Current and Water Flow

Based on Figure 1, water pressure is likened to electrical voltage because both function as driving forces. Water flowing through a pipe is compared to electrons flowing through a wire, while a faucet that restricts water flow is similar to a resistor that reduces electric current. This analogy helps students understand that the higher the water pressure or electrical voltage, the greater the resulting flow; conversely, the greater the resistance, the more the flow

decreases. Thus, the relationship between voltage, current, and resistance becomes easier to grasp conceptually.

3.3.2 The Cell-as-a-Factory Analogy

In biology classes, the structure and functions of cells are often compared to those of a factory. This analogy helps students understand the roles of organelles within cells by relating them to activities commonly encountered in everyday life.

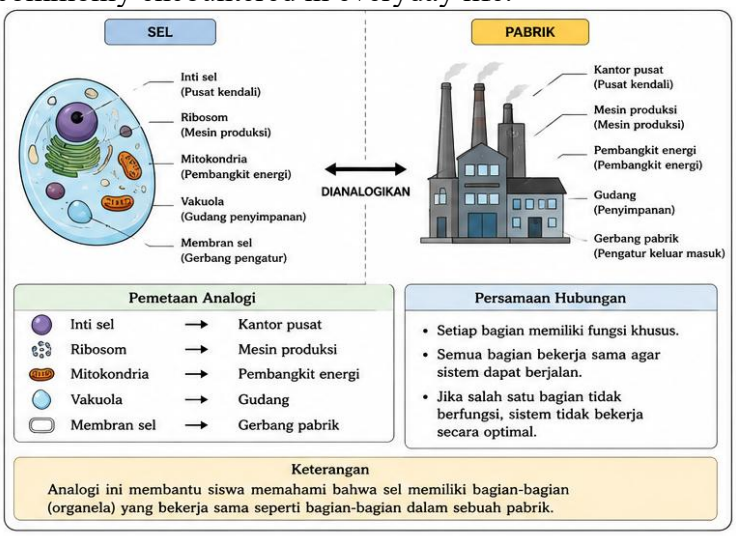

Figure 2. The Cell-as-a-Factory Analogy

In Figure 2, the cell nucleus is likened to a central office that controls all factory activities. Mitochondria function as power plants, ribosomes as production machines, vacuoles as storage warehouses, while the cell membrane acts as a gate that regulates the flow of materials in and out. This analogy helps students understand that each organelle has a specific function and that they work together to sustain the cell's life.

3.3.3 An Analogy Between the Circulatory System and an Urban Transportation System

The circulatory system is another topic that frequently uses analogies because it involves the relationships between components within a system.

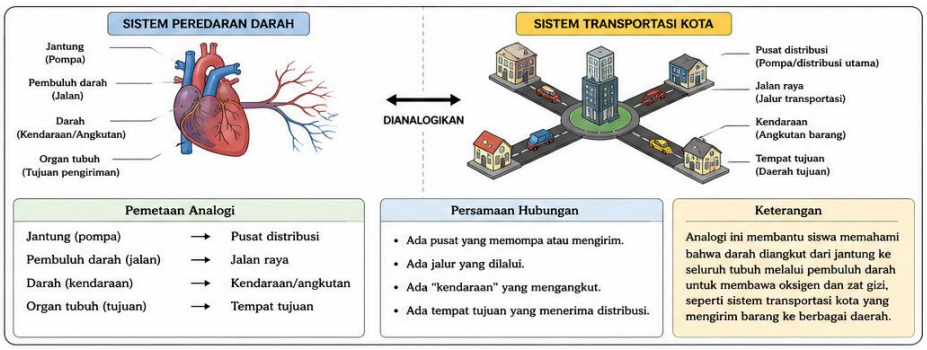

Figure 3. An Analogy Between the Circulatory System and an Urban Transportation System

In Figure 3, the heart is likened to a distribution center, blood vessels to highways, and blood to vehicles that transport oxygen and nutrients to all the body's tissues. This analogy helps students understand that each component has interrelated functions, enabling the circulatory system to function optimally.

In general, research findings show that the use of analogies in various science topics can help students form mental representations of abstract concepts based on their prior experiences. However, the effectiveness of analogies depends heavily on teachers' ability to select appropriate analogies and to explain the similarities and differences between the analog concept and the target concept. Thus, analogies serve not merely as a means of visualization but also as a learning strategy that can strengthen conceptual understanding while reducing the likelihood of misconceptions.

3.4 The Benefits of Using Analogies in Science Education

Research findings show that the use of analogies offers many benefits in the science learning process. One of the main benefits is that it improves students' conceptual understanding. By connecting new ideas to their existing experiences, students can more easily grasp difficult and abstract material. Analogies help reduce students' cognitive load because new information is not processed in isolation but is linked to knowledge already present in their minds. In addition to improving conceptual understanding, analogies can also boost students' motivation to learn. By using examples relevant to everyday life, learning becomes more engaging and meaningful. Students become more actively involved in the learning process because they can see the connection between the material being studied and the real-life experiences they have had.

One of the main benefits of using analogies is that students can connect prior knowledge with new concepts they are learning, thereby creating meaningful connections. For example, in science education, analogies such as "electric current flows like water through a pipe" are often used to explain the abstract concept of electric current. Effective analogies not only support conceptual understanding but also provide a foundation for the development of critical thinking in children (Mubarok, 2024).

In addition to improving conceptual understanding, the use of analogies can also enhance students' critical thinking skills. Generally, during the learning process, a student who is active or seeks attention tends to distract other students by engaging in activities unrelated to the lesson or by disrupting their classmates. However, by applying the analogy-based discussion method, such students will become "active" in presenting interesting and thought-provoking analogies, thereby capturing the attention of their peers and fostering positive interaction among them. By using an analogy-based learning model, the issues mentioned above can be addressed. This model creates a more dynamic learning atmosphere and makes it easier for students to understand the material (Farida et al., 2022).

Other studies have also shown that analogies can help reduce the occurrence of misconceptions, particularly in abstract and microscopic concepts. Many misconceptions are related to scientific laws in science education. This is caused by a number of challenges faced by students. To address these misconceptions, efficient learning strategies are needed, such as the use of visual demonstrations, hands-on experiments, group discussions, and the application of analogies. Therefore, it is very important for educators to identify potential misconceptions and design effective learning strategies to address them in order to improve the quality of education (Tanamar et al., 2024).

3.5 Challenges and Implications of Using Analogies in Science Education

Based on an analysis of various references, the use of analogies in science education offers many benefits, but their application also presents a number of challenges that educators need to be aware of. The success of analogies depends not only on the availability of interesting examples, but also on the appropriateness of the analogy chosen, the method of presentation, and the educator's ability to explain the relationship between the concept in the analogy and the target concept. If analogies are used inappropriately, learning objectives may be hindered

because students develop a misunderstanding of scientific concepts. Therefore, educators need to have a good understanding of the characteristics of analogies before implementing them in the learning process (Kartomo, 2025).

A study (Fauzi et al., 2025) found that in learning using the analogy model, students had difficulty identifying concepts and finding connections between the source and target problems. Teachers reported that one contributing factor was a lack of practice in solving analogy-based problems, which left students less accustomed to identifying patterns and relationships between concepts. A study (Syafitri et al., 2021) noted that a challenge in using analogy models is comprehension errors, where students may understand the problem presented in a question but fail to identify what is required, leading to an inability to solve the problem. In addition, another common error is a transformation error, in which students already have a correct understanding of the question but fail to select the appropriate steps to solve the problem.

Based on these research findings, it can be concluded that the use of analogies in science instruction has significant potential to help students understand abstract concepts. However, its success depends heavily on the accuracy of its application. Teachers need to select analogies that are relevant to the characteristics of the material and students' learning experiences, as well as clearly explain the similarities and differences between the analogy concept and the target concept. When applied correctly, analogies not only help improve conceptual understanding but also reduce the occurrence of misconceptions, making the science learning process more efficient and meaningful.

4. CONCLUSION

Based on the findings of the literature review, it can be concluded that analogies are an effective learning strategy for helping students understand abstract science concepts. Through analogies, concepts that are difficult to observe can be linked to experiences or phenomena already familiar to students, making the process of developing conceptual understanding easier and more meaningful. The study's results also show that the use of analogies in various science subjects—such as physics, chemistry, and biology—can enhance students' conceptual understanding, learning motivation, and thinking skills. However, the success of using analogies is greatly influenced by the teacher's ability to select appropriate analogies, explain the similarities and differences between the analog concept and the target concept, and clarify the limitations of the analogy to prevent misconceptions. Therefore, analogies need to be designed and applied systematically and supported by appropriate media or visualizations to ensure their benefits are fully realized. Consequently, analogies can serve as an alternative learning strategy that supports the creation of more effective, contextual, and meaningful science learning.

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