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Analogical Reasoning in Learning Science: A Theoretical Perspective in the Context of NEP 2020

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ABSTRACT

Generally, learning science as a subject in the secondary school level of learning is associated with several serious challenges for learners, given the abstract nature of scientific concepts. Concepts of force, electricity, atomic structure, and biological systems, among others, require learners to go beyond what is directly observable, a cognitive task that is difficult for most learners. Science learning, as a result, is often associated with misconceptions, fragmented knowledge, and overdependence on rote memorization. In this regard, analogical reasoning has emerged as a promising cognitive and learning strategy for relating scientific concepts, which learners find difficult to understand, with concepts that learners find easy to relate with. The current paper presents a theoretical analysis of analogical reasoning as a cognitive strategy for learning science, with specific reference to the pedagogical philosophy of the National Education Policy (NEP) 2020. The current paper draws on major learning theories, including Ausubel's meaningful learning theory, Piaget's cognitive development theory, Gentner's structure mapping theory, and constructivist learning theory, in order to understand how analogical reasoning can be used as a cognitive strategy for learning science, facilitating knowledge transfer, and correcting misconceptions. The analysis indicates that effective analogies help students develop an understanding of abstract

scientific concepts, enhance their reasoning ability, and help them engage more meaningfully with the subject matter. The paper also indicates that the use of analogy-based instruction is very much in line with the policy directions outlined under the NEP 2020. The policy directions emphasize the use of conceptual clarity, inquiry-based learning, learner-centricity, and the development of 'scientific temper' as essential aspects to be infused into the teaching-learning process. Analogical reasoning is also seen as an effective means to ensure that the policy directions are translated into practice, as it encourages reasoning and engagement with the subject matter rather than mere memorization. The emerging role of generative artificial intelligence is also touched upon as a means to help teachers use analogies more meaningfully to enhance the quality of secondary science education. The theoretical synthesis highlights the role of analogical reasoning as an effective means to enhance the quality of secondary science education in the country.

Introduction

It has been observed that science learning in the secondary level of education is characterized by the presence of complex and abstract concepts that are difficult for the learners to comprehend (Landa et al., 2020). Concepts such as force, electricity, magnetism, and the structure of atoms, as well as biological processes, require the learners to go beyond their concrete experiences and indulge in higher-order thinking activities. The learners are often challenged with the problem of relating their prior knowledge with the newly introduced concepts in science, which may lead to misconceptions, rote learning, and poor conceptual understanding. To make learning more meaningful, there has been an emphasis on the use of innovative pedagogical tools, and among these, analogical reasoning has been found to be an effective tool for science learning. The use of analogical reasoning enables the learners to relate their prior knowledge with the newly introduced concepts, which in turn helps in the promotion of conceptual understanding, critical thinking, and the development of scientific reasoning.

The National Education Policy (NEP) 2020 has been formulated in a way to encourage the implementation of teaching strategies that could assist in enhancing the development of conceptual knowledge, inquiry skills, and scientific temper. Analogical reasoning in the science classroom could

assist in achieving these policy goals, and it could help in filling the gap between scientific knowledge and the experiences of the learner, thus enhancing the learning process.

The main purpose of this research work is to explore the theoretical background of analogical reasoning in the science classroom and its relevance to achieving the pedagogical goals of NEP 2020, providing a holistic view of its effectiveness in the secondary school curriculum.

Learning difficulties in science are a common phenomenon among secondary school students, and the main reason for this difficulty is the abstract and complex nature of scientific knowledge. Scientific knowledge, such as force, electricity, magnetism, atomic structure, and biological processes, demands a high level of thinking, which is difficult for students to achieve. This has often led to misconceptions, where learners have incomplete and inaccurate mental constructs, causing them to commit errors and have superficial knowledge of scientific concepts. Conventional teaching practices, which are often based on rote learning and passive learning, have failed to address these issues.

Research indicates that new cognitive approaches like analogical reasoning can be the game-changer in overcoming these learning issues. Analogical reasoning allows learners to connect known concepts to new and abstract ideas, making it easier to understand concepts, improve reasoning skills, and enhance knowledge transfer, thus reducing misconceptions.

Against the backdrop of the Indian education system, the National Education Policy (NEP) 2020 advocates teaching practices that promote critical thinking, inquiry-based

Need for innovative pedagogy (analogical reasoning): The nature of abstract and complex scientific concepts at the secondary level creates a challenge that requires the use of innovative approaches in teaching. Conventional approaches to teaching, which are mainly based on rote learning, lecturing, and passive learning, are ineffective in promoting deep conceptual understanding and do not effectively address students' misconceptions (Landa et al., 2020). Consequently, students are unable to connect new learning to their existing experiences, making it difficult for them to apply scientific concepts to problem-solving and everyday life situations.

Analogical reasoning is a highly effective teaching approach that can be used to overcome the challenges. The approach entails making connections between concrete experiences or concepts and new abstract scientific concepts, which helps to create meaningful connections in the cognitive structures of students (Holyoak, K. J., & Thagard, P. (1989). In the science classroom, analogies assist students to form mental

images of abstract events, promote conceptual change, and improve reasoning skills. For instance, making connections between the flow of electricity and water in pipes or the atom and the solar system helps to create cognitive scaffolding that makes abstract concepts concrete and easier to understand.

The application of analogy-based instruction is of particular importance in the Indian scenario, where the National Education Policy (NEP) 2020 places a strong emphasis on conceptual understanding, inquiry-based learning, and the promotion of scientific temper. The incorporation of analogical reasoning in science education is in line with the NEP 2020, providing a research-informed and theoretically sound solution to enhance conceptual understanding and cognitive engagement among learners. This method is not only effective in facilitating the transfer of knowledge but also helps to promote a sound appreciation of scientific principles among learners (Gray & Holyoak, 2021). Relevance to classroom practices. The Indian student population, with their diverse linguistic and cultural backgrounds, requires learning strategies that can span their pre-existing knowledge and experiences with scientific concepts, making analogy-based instruction a highly relevant tool in developing relatable and accessible learning (Tuveri et al., 2025). Policy context: NEP 2020 focus on conceptual understanding and scientific temper. The National Education Policy (NEP) 2020 is a major overhaul in the Indian education system, which promotes holistic, inquiry-based, and conceptually driven learning at all levels. The NEP 2020 recognizes the development of scientific temper, critical thinking, and problem-solving skills as the key focus areas of science education, NEP 2020 suggests teaching methodologies that help in developing conceptual understanding, experiential learning, and effective engagement with scientific phenomena. It is stressed that teaching should help students develop an understanding of underlying principles rather than just memorizing facts, thus helping in developing a better understanding of scientific processes and reasoning. Analogical reasoning is directly helpful in achieving these policy objectives by offering a cognitive tool to help associate new scientific concepts with existing knowledge. By using examples from familiar domains to describe abstract phenomena, students can develop an understanding of complex ideas by internalizing them, developing scientific reasoning skills, and reducing misconceptions. For instance, making analogies between water and electric currents or between the solar system and atomic structure would help students visualize and understand abstract ideas, thus helping in developing conceptual understanding and scientific temper, as emphasized by NEP 2020. Thus, incorporating analogical reasoning in science education would not only help in addressing learning difficulties but would also ensure that learning objectives are in line with the vision and objectives of NEP 2020, thus helping in developing cognitive skills and scientific literacy among secondary school-going students. Purpose of the study Given these difficulties, a relevant research question might include. This theoretical

investigation will also examine the potential use of large language models in the creation of effective analogies, thus helping both teachers and students in understanding complex scientific fields. This is especially relevant in the current context of widespread reforms under the National Education Policy 2020, which stresses the need for universal enrollment and equal access to quality learning, even in areas that are vulnerable to infrastructural challenges and digital divides (Goel & Bhatta, 2004). Thus, this research study will attempt to fill the existing gap between the theoretical formulation of analogical reasoning and its implementation in STEM education, especially in areas where conventional teaching methods may not be very effective. In addition, this research study will also attempt to investigate the use of generative AI in developing multi-modal analogies that are responsive to different learning needs, thus enhancing teaching practices and increasing student engagement. This investigation will examine how AI-based tools can be used to create personalized learning experiences, thus making complex scientific ideas more accessible and connectible to a broader student base (Cao et al., 2023).

Objectives of the Study

1. To examine the theoretical basis and cognitive processes involved in analogical reasoning in the learning of science concepts.

2. To analyze the relevance and potential of analogy-based learning in achieving the pedagogical objectives of NEP 2020.

Conceptual Framework:

Science learning in secondary schools can also be described as the use of abstract and complex science concepts that are difficult to comprehend for the learners. In this regard, it is important to develop innovative cognitive strategies that can help learners relate their existing knowledge with new science concepts. In this perspective, analogical reasoning has been identified as an essential tool that can help learners relate their existing knowledge of concrete concepts with new abstract science concepts (Gentner, 1983; Holyoak & Thagard, 1995). For example, the use of analogical reasoning can help learners relate the concept of electric current with the flow of water. In this perspective, the use of analogical reasoning can help learners visualize abstract concepts and enhance conceptual clarity.

The success of analogical reasoning can be explained by the cognitive process, which is sequential and networked. The process begins with mapping, whereby the learner tries to find the structural correspondence between the concept and the new concept. Then, the learner applies the existing

knowledge of the concept, referred to as the process of knowledge transfer. Finally, the learner abstracts the underlying concept and generalizes it, thus aiding the learner in the development of concept organization and flexibility.

Analogical reasoning not only facilitates cognitive processing but also helps the learner in the direct development of concept understanding in science education. It helps the learner relate the existing concept with the new concept, thus aiding the learner in retaining abstract concepts, thus improving the learner's understanding of abstract concepts in Physics, Chemistry, and Biology (Ausubel, 1968). In Physics, analogies like the flow of water as electric current and push/pull as force aid the learner in understanding abstract concepts. For example, analogies like the structure of an atom compared to the solar system or the structure of chemical bonds compared to partnerships are helpful in understanding the subject of Chemistry. In the subject of Biology, analogies like the heart being a pump or the structure of neurons compared to communication wires are helpful. By understanding these analogies, the students are able to form correct mental representations of the subject matter, thus avoiding errors and enhancing their ability to reason correctly. The relevance of analogical reasoning is further reinforced with the context of the Indian scenario as well, especially with the vision of the NEP 2020 that highlights the aspects of conceptual understanding, inquiry-based learning, and the development of scientific temper. The incorporation of the use of analogy-based learning strategies into the classroom practice would help to achieve the aims of the NEP 2020 as well, thus enhancing the cognitive abilities of the students to construct knowledge and visualize the subject matter while meaningfully reasoning. In this way, the use of analogical reasoning can be said to act as a cognitive as well as a pedagogical bridge that connects the theoretical with the practical aspects. From this conceptual framework, it is clear that there is a smooth transition from the difficulties encountered in abstract concepts of science to the need for new-age pedagogy, and analogical reasoning serves as a solution to this problem, where the cognitive processes involved in analogical reasoning are helpful for effective learning, and its implementation in secondary science education fulfills the NEP 2020 criteria, which focuses on both conceptual clarity and scientific temper.

Theoretical Foundations

The support for the application of analogical reasoning in science education is adequately obtained from well-recognized theories of learning, which explain the process of knowledge acquisition, organization, and application by the learner. In this case, Ausubel's Meaningful Learning Theory provides a theoretical foundation for the application of analogical reasoning in science education, which argues that new

knowledge is best acquired when it is possible to relate it to the existing knowledge in the cognitive structure of the learner (Ausubel, 1968). Analogical reasoning in science education, for example, relates electric current to water, thus enabling the learner to relate new knowledge to existing knowledge, thus enhancing the acquisition of knowledge rather than memorization. Based on Ausubel's cognitive structure theory, Piaget's Cognitive Development Theory provides a definition of the learner's readiness to apply the analogical reasoning process. Piaget argues that secondary school-going age students are in the stage of formal operations, thus enabling them to think abstractly, logically, and hypothetically-deductively (Piaget, 1972). This developmental capacity makes the learner prepared to be taught by analogy because the learner would be able to see the similarities, recognize the patterns, and apply the principles of the known situation to the unknown situation. Thus, Piaget's Theory not only justifies the application of analogical reasoning but also explains how the learner would be able to benefit from the application of the analogical reasoning at the secondary school level. Further expounding the cognitive process of analogical reasoning, the Structure-Mapping Theory developed by Gentner provides a thorough explication of the process of analogical reasoning (Gentner, 1983). The theory states that the learner is able to comprehend the new ideas by identifying the relational correspondences between the two domains, with the focus being the structures rather than the surface features of the two domains. This would provide an insight into the manner in which the learner would be able to apply the known situation, such as water flowing through the pipes, to the concept of electric current. This would provide a clear alignment with Ausubel's meaningful theory and Piaget's concept of developmental readiness, as highlighted in Gentner's theory. Finally, there is a constructivist approach to science education, which encompasses all of the above theories. Constructivism, as a theory, posits that learners construct their knowledge through their interaction with their environment (Fosnot, 2013). Analogical reasoning can thus be considered a constructivist approach to learning, as it enables learners to construct their own knowledge of scientific concepts through analogizing. This analogical reasoning can thus be considered a constructivist approach to secondary science education, as it enables learners to construct their own knowledge, think critically, and be able to solve problems, which are all considered to be the aim of education, as outlined in NEP 2020. Thus, in conclusion, these four theories based on Ausubel's Meaningful Learning Theory, Piaget's Cognitive Development Theory, Gentner's Structure Mapping Theory, and the constructivist perspective, taken together, form a robust knowledge domain that substantiates the importance of analogical reasoning in the context of science education. The theories of Ausubel, Piaget, Gentner, and the constructivist perspective, taken together, substantiate the importance

of analogical reasoning in the context of science education in accordance with the NEP 2020 perspective of conceptual learning, scientific temper, and inquiry-based learning.

Analogical Reasoning in Science Learning

Analogical reasoning is a crucial aspect in the promotion of the acquisition of concepts in various fields of science, such as physics, chemistry, and biology (Gray & Holyoak, 2021). Analogical reasoning is a cognitive process that allows the learner to make sense of abstract scientific concepts by making use of concrete experiences, hence allowing the conversion of complex scientific concepts to cognitive representations. This is a crucial aspect in the promotion of the acquisition of concepts in various fields of science, such as physics, chemistry, and biology. Analogical reasoning allows the learner to develop a mental model of unknown scientific concepts by mapping the familiar to the unfamiliar, hence allowing the acquisition of meaningful mental models. This ability to reason analogically helps the learner to visualize the scientific concepts, and this is a very important aspect of the different fields of study in the realm of science, such as physics, chemistry, and biology, where the different phenomena in these fields of study cannot be visualized and thus require the learner to have a very high level of visualization and interpretation skills (Cao et al., 2023; Petchey et al., 2023).

In addition to the important role played by analogical reasoning in the facilitation of the development of concepts, it has also been seen to be effective in the resolution of misconceptions, which has been a thorn in the side of science education for a very long time. By the systematic use of analogies, it has been possible for the students to make a distinction between the two. This is seen to have a direct link with the visualization of complex processes, thus fitting well with Gentner's structure-mapping theory, which focuses more on the relational correspondence rather than superficial features, as discussed in Petchey et al. (2023). This is also supported by the evidence provided through a systematic review of the literature, thus supporting the idea of the effectiveness of analogical reasoning as a pedagogical tool. Empirical and theoretical studies have revealed a trend towards improvement in terms of conceptual understanding, reasoning ability, and application of knowledge through the employment of analogical reasoning as a tool for instruction (Pedro & Edinson, 2021). In this regard, analogical reasoning not only works as a tool for instruction but also as a cognitive channel through which the acquisition of new scientific knowledge can be facilitated through its association with the knowledge already possessed.

In terms of its relevance to the overall scheme of learning, analogical reasoning as a means of instruction seems to resonate very well with the overall vision of NEP 2020. Analogical reasoning, as a means of

instruction, seems to resonate very well with a constructivist approach to learning. The constructivist approach to learning focuses on the construction of knowledge as opposed to the memorization of knowledge. Therefore, as a means of instruction in the context of enhancing learning in science, analogical reasoning seems to be highly relevant.

Alignment of Analogical Reasoning with NEP 2020

National Education Policy (NEP) 2020 is a paradigm shift in the educational paradigm of India, where there is an emphasis on conceptual knowledge, critical thinking, and experiential learning, as opposed to content and examination-oriented learning. This paradigm shift can be viewed with special significance with respect to the learning of science, as the conventional approach to the teaching and learning of science has been found to result in greater emphasis on rote learning rather than conceptual learning. NEP 2020 has emphasized the need to adopt a teaching and learning methodology which enables the learners to understand the underlying principles and mechanisms of the phenomena under investigation, which can be a meaningful and transferable learning experience. The major aim of NEP 2020 is to move from rote learning to conceptual learning, which can be achieved through analogical learning. Analogical learning can help achieve the aim of moving from rote learning to conceptual learning by relating abstract scientific concepts with the learners' knowledge and experiences. Students can create a cohesive mental model of complex scientific phenomena through the use of appropriate analogies, rather than attempting to assemble fragmented facts through rote learning. This cognitive approach is necessary to achieve a deeper level of understanding and allows students to apply scientific knowledge in a variety of contexts, which is a key element of the competency-based education system envisaged in the NEP 2020. Furthermore, the NEP 2020 places a great emphasis on inquiry-based and experiential learning, which encourages students to explore, investigate, and reason rather than merely receive information. The analogy-based method of learning is in complete sync with the NEP 2020, as it actively involves the students in the process of comparing, analyzing, and evaluating the relationship between the known and the unknown. This kind of cognitive learning process also helps the student to think reflectively and generate hypotheses, and it expands the scope of what we can accomplish with inquiry-based and hands-on science education. The focus on developing a scientific temperament in the new education policy also reiterates the importance of analogical thinking. Developing a scientific temperament requires the promotion of rational thinking, inquiry, and reasoning ability, and analogies play an important role in these activities by helping us identify patterns, reach logical conclusions, and develop concepts through proper comparisons. An examination of the limitations and applications of analogies also enhances the

student's analytical and thinking capabilities—important requirements in developing a scientific temperament. From the perspective of the teacher, the 2020 education policy emphasizes the importance of trained teachers and innovative methods to improve the teaching-learning process. In a classroom environment, to bring analogical reasoning into play requires that the teacher be conceptually sharp and pedagogically agile with an emphasis on how students learn. As an innovative tool for teaching, analogy has helped teachers break down complex scientific ideas without compromising on scientific content. Thus, it is an important step towards realizing the major objectives of NEP 2020. Simply stated, analogy-based instruction is an important step towards realizing the major objectives of NEP 2020. It bridges the gap between what is already known by the students and the abstract world of science. Thus, it is arguably one of the most important tools to realize the vision of NEP 2020.

Educational Implications

The theoretical analysis of analogical reasoning also brings to the attention some important implications with regard to the teaching and learning of science in the secondary school level. The abstract nature of the concepts taught in science makes the use of analogy as a teaching device an important tool that may bridge the gap between the world of science and the world of experience. Analogies may be well-structured and may be employed to teach complex science concepts such as the concept of electric current, chemical bonding, or biological systems. Analogies may also improve conceptual clarity and reduce the level of misconceptions. Regarding teacher training, the implications of the study may also highlight the importance of equipping the pre- and in-service teachers with the capacity to employ analogical reasoning as a teaching device. The study emphasizes the need to recognize the role of subject matter knowledge and the skill to apply analogies as a teaching aid. The training programs may include areas like teachers' familiarity with cognitive theories of analogical reasoning, opportunities to reflect on practice, and opportunities to experiment with analogy-based teaching strategies that can aid teachers in matching their teaching strategies to learner-centered and concept-based models.

The study’s results have reinforced the importance of training pre-service and in-service teachers to strategically apply analogical reasoning, viewed from the teacher training perspective. It is also important to note that there is a need to recognize that teacher training programs should emphasize both content and pedagogy, enabling the teacher to design, evaluate, and use analogies effectively in their science classes. This would involve exposure to the cognitive theories of analogical reasoning, opportunities for reflective practice, and opportunities to try out pedagogical strategies.

Conclusion

This paper explores the possibilities of analogical reasoning being used both as a cognitive device and a teaching strategy in learning science, with reference to the theories of meaningful learning, cognitive development, structure mapping, and constructivism. The theories collectively emphasize the role of analogies in relating new concepts with previously learned knowledge in building a coherent mental model. The theories clearly illustrate the potential of analogical reasoning in learning science in terms of concretizing abstract scientific concepts, increasing conceptual understanding, eliminating misconceptions, and increasing higher-order thinking. By way of inquiry, reflection, and relational thinking, the teaching of science through analogical reasoning can contribute significantly to the development of scientific temper in school children. In the context of the Indian education scenario, the idea of using analogical reasoning in learning science can be related to the National Education Policy 2020, which focuses on competency, inquiry, and student-centered learning. In the present study, analogical reasoning stands out as a promising strategy in achieving educational goals, which can bridge the gap between vision and reality. Although the study is purely theoretical in nature, it leaves no doubt that there is a vast scope for further research in the area in the future. The study can explore the impact of teaching science through analogical reasoning in terms of conceptual learning, eliminating misconceptions, and scientific reasoning in different domains of science, along with the preparedness of teachers in implementing the strategy in science teaching.

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