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The Impact of Synectics Learning Model Implementation with Mind Mapping Assignments on Reducing Misconceptions and Enhancing Students' Cognitive Learning Outcomes

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Abstract: Innovative learning models are essential to enhance students' cognitive abilities and address misconceptions in physics learning**.** This study aims to provide an overview of the influence of implementing the Synectics learning model with mind mapping assignments on the quantity of misconceptions and the cognitive learning outcomes of senior high school students. The research employed a quasi-experimental method using a randomized control group pretest-posttest design. The study was conducted on 11th-grade students at a senior high school in Palu, Central Sulawesi, during the 2023/2024 academic year. A cluster random sampling technique was used to select the sample. Data collection was carried out using pretests and posttests to measure the improvement in cognitive learning outcomes, while posttests were used to assess misconceptions experienced by students during learning with the Synectics model with and without mind mapping assignments. Observation sheets were also used to monitor the implementation of the learning process. The results showed an improvement in cognitive abilities for the experimental class, with an average normalized gain (N-Gain) of 0.63 (high), compared to 0.50 (moderate) for the control class. Based on a significance test at the 0.05 level, the findings revealed that the Synectics learning model with mind mapping assignments significantly outperformed the Synectics model without such assignments. Additionally, descriptive analysis of the misconceptions indicated that the Synectics model with mind mapping assignments resulted in fewer misconceptions compared to the model without mind mapping assignments.

Keywords: Cognitive Learning; Mind Mapping; Misconception; Synectic Learning Model.

Introduction

Natural sciences are essential for developing students' systematic understanding of the natural world, with physics playing a pivotal role in building a strong foundation for engaging with scientific and technological advancements (Firdaus, 2018). Despite its significance, physics education faces ongoing challenges in improving cognitive learning outcomes and addressing misconceptions, which hinder students' deeper understanding of key concepts. Effective physics instruction requires teachers to adopt strategies aligned with scientific and technological advancements. However, conventional teaching methods, which prioritize memorization and calculation over active learning, dominate classrooms. This teacher-centered approach limits student engagement, often benefiting only auditory learners, while others remain passive. As

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a result, students may experience boredom and become overly dependent on teacher guidance, hindering their development of independent learning skills (Hadist, 2021). To address challenges in physics instruction, educators should emphasize hands-on learning, process skills, and scientific attitudes to foster deeper engagement and understanding beyond memorization (Munawaroh, 2017). The Synectics Learning Model, which utilizes analogy-based learning, promotes creative thinking and problem-solving by drawing parallels between concepts (Karwati, 2012). This approach not only encourages critical analysis and systematic problem-solving but also enables students to apply classroom knowledge to real-life situations, enhancing their ability to transfer skills effectively (Suratno Suratno, 2019). The Synectics Learning Model fosters creativity, critical thinking, and reduces misconceptions, particularly in physics, where abstract concepts often pose challenges. Analogical reasoning in Synectics helps students form clearer mental models, enhancing understanding, retention, and problem-solving skills (Hofstadter, 2013). By aligning with the shift towards student-centered learning, Synectics engages all learners, regardless of style, promoting active participation and independent thought (Munawaroh, 2017; VYGOTSKY, 1978). This dynamic approach moves beyond rote learning to equip students with essential 21st-century skills, including creativity, critical thinking, collaboration, and communication (Trilling, 2009).

This study employs mind mapping assignments to help students organize and present concepts in a non-linear, hierarchical structure, fostering associations between ideas and enhancing cognitive engagement (Dewantara, 2019). Sharing similarities with the Synectics Learning Model, mind mapping supports problem-solving through idea connections. Research highlights its cognitive benefits, including improved organization, creativity, memory retention, and the integration of new and prior knowledge, making it particularly effective in science education (Sri Sukaesih, 2022; Z.Gagić, 2019). The Synectics Learning Model also aligns with recent educational theories that promote analogical reasoning and creativity in problem-solving. Synectics encourages students to approach problems from multiple perspectives, improving their critical thinking and cognitive flexibility (Eko Setyadi Kurniawan, 2024). This model allows students to engage in creative thinking, which enhances their ability to connect abstract scientific concepts to real-world applications, an essential skill in physics education (Gregorcic, 2021).

Enhancing students' cognitive abilities and reducing misconceptions are critical goals in physics education. By implementing the Synectics Learning Model with mind mapping assignments, students are expected to engage more actively in the learning process, gain a deeper understanding of physics concepts, and connect their knowledge to real-life applications. Furthermore, this instructional approach supports the development of scientific thinking skills and fosters increased interest and enthusiasm for science. These findings are consistent with the broader push toward active learning strategies in science education. Interactive teaching models such as Synectics and mind mapping can significantly improve student outcomes by fostering engagement and deeper conceptual understanding (Salwa Rufaida, 2023). This combination of instructional techniques can be particularly effective in addressing the misconceptions that often hinder student performance in p (Kaniawati, 2020).

The insights gained from this research provide a valuable foundation for teachers, researchers, and policymakers to improve the quality of physics education. Integrating mind mapping with Synectics offers a more dynamic and engaging learning environment, ultimately leading to better student outcomes.

Method

This study employed a quasi-experimental method alongside a descriptive approach. The quasi-experimental design was utilized to assess the improvement in students' cognitive abilities. Additionally, the descriptive method was used to examine the extent of misconceptions among students and to evaluate the effectiveness of the learning process when using the Synectics learning model with mind mapping assignments, as compared to the Synectics model without mind mapping.

The population in this study consisted of all 11th-grade students at SMAN 7 Palu, which is made up of five classes. The sample was selected using a cluster random sampling technique. The chosen sample for this study included students from classes XI-A and XI-B, ensuring a representative and unbiased selection for the experiment.

The cognitive learning outcomes were assessed using an essay test consisting of 14 questions. This test was administered twice, once before the learning process (pretest) and once after (posttest). The questions were developed based on specific learning indicators aligned with cognitive learning objectives.

To measure misconceptions, a three-tier test was used. This test was designed to identify misconceptions among students based on various aspects and indicators relevant to the learning material. A total of 10 questions, each with five answer options, were provided to the students. The misconception test was administered only once, after the learning process.

For analyzing cognitive improvement, a randomized control group pretest-posttest design was applied. This design allowed for a comparison between the experimental group, which received the Synectics model with mind mapping assignments, and the control group, which did not.

To explore the quantity of misconceptions and the overall execution of the instructional model, the descriptive method was employed throughout the learning process. This included observing student participation and documenting any misconceptions that arose during the use of both instructional models. The descriptive data provided a detailed picture of the learning process and helped to evaluate the differences in educational outcomes between the two groups.

The research procedure was divided into three main stages: preparation, implementation, and final analysis. During the **preparation stage**, several activities were conducted, starting with identifying the research problem. This was accomplished through preliminary observations of physics lessons, administering attitude scales to students, and interviewing physics teachers and selected students. A literature review was also conducted to gather relevant theoretical insights. Additionally, a curriculum analysis was performed to determine the learning competencies required for the research topic. The research team then developed detailed lesson plans and instructional scenarios based on the Synectics learning model with mind mapping assignments. Research instruments were designed, followed by an expert judgment process involving three faculty members. Instrument trials were carried out, and the results were analyzed to select appropriate questions for use in the study.

The **implementation stage** included administering a pretest to both groups of students to measure their initial cognitive abilities. The experimental group received instruction using the Synectics learning model with mind mapping assignments, while the control group followed the same model without the mind mapping component. After the treatment, a posttest was administered to both groups to assess the impact of the intervention.

In the **final stage**, the data from the pretest and posttest were processed and analyzed to determine the cognitive gains and evaluate the research instruments. Conclusions were drawn based on the data analysis, and recommendations were provided to address any shortcomings observed during the study.

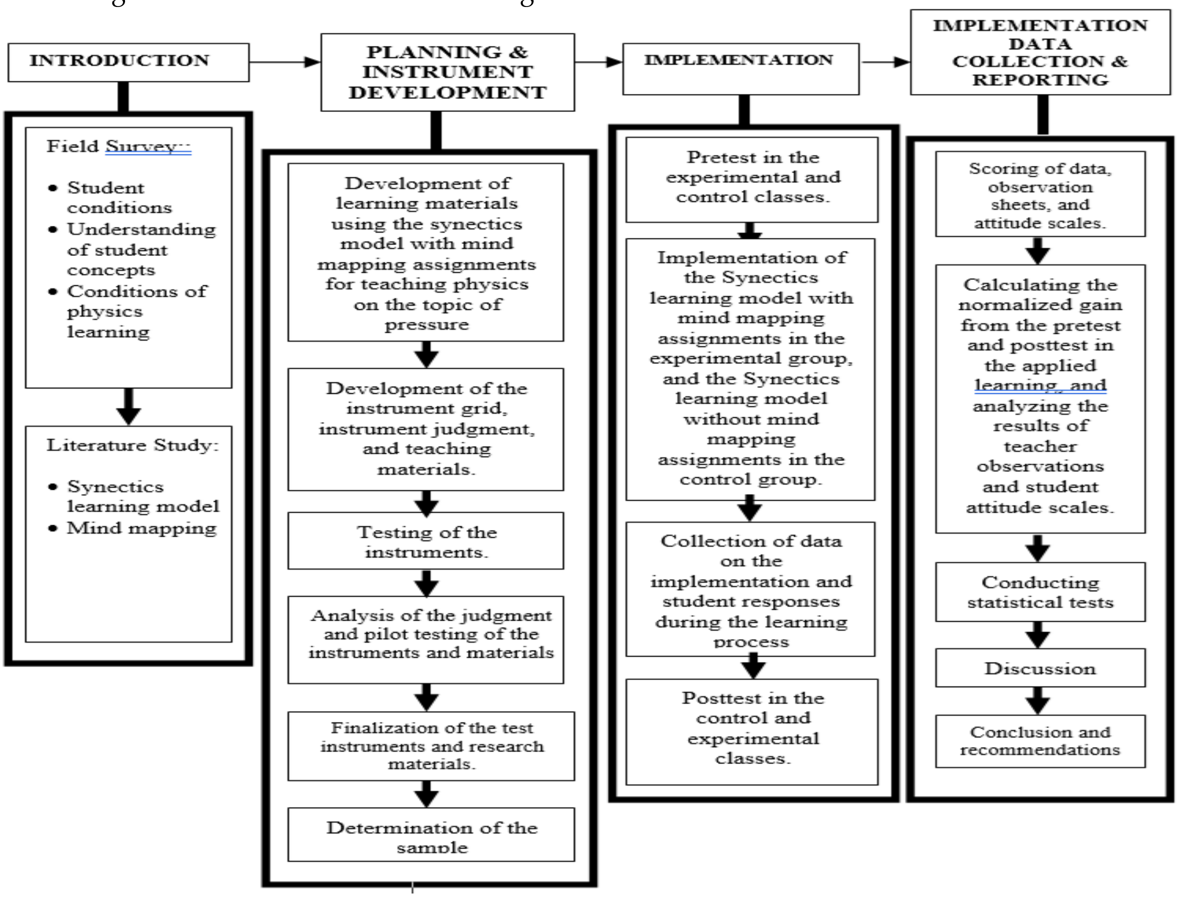

Figure 1. Research Flowchart

Result and Discussion

The results of this study indicate that the implementation of the Synectics learning model, both with and without mind mapping assignments, significantly enhances students' cognitive abilities, as evidenced by normalized average gain scores of 0.52 and 0.44 for the Synectics model, and 0.64 and 0.38 for the Synectics model with mind mapping. These gains fall within the moderate category of cognitive improvement. In the Synectics class, the most substantial growth was observed in the applying (C3) dimension, followed by evaluating (C5) and analyzing (C4). Conversely, in the Synectics with mind mapping class, the order of improvement was evaluating (C5), analyzing (C4), and applying (C3). This finding deviates from the Revised Bloom's Taxonomy proposed by Anderson and Krathwohl (2001), which organizes the cognitive hierarchy from applying (C3) to analyzing (C4) and then evaluating (C5), suggesting that higher levels of the taxonomy are more challenging to master. This discrepancy highlights the need for further exploration into the effectiveness of the Synectics model in fostering higher-order thinking skills.

From the perspective of knowledge dimensions, the conceptual knowledge aspect (K2) achieved the highest scores, while factual knowledge (K1) received the lowest scores, which does not align with the expected hierarchy of knowledge taxonomy. This cognitive enhancement can be attributed to the use of analogies in the synectics learning model, which assists students in grasping more complex concepts. However, it is important to note that in specific subtopics, such as Archimedes' principle, the analogies employed were not fully optimized.

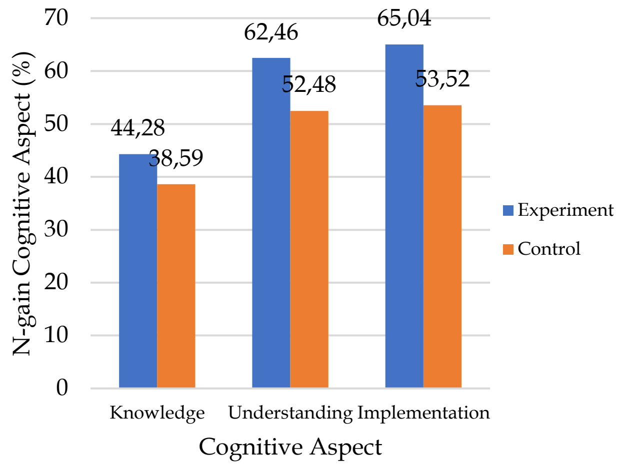

Figure 2. Bar Chart of Average N-Gain Scores (g) for Each Cognitive Aspect

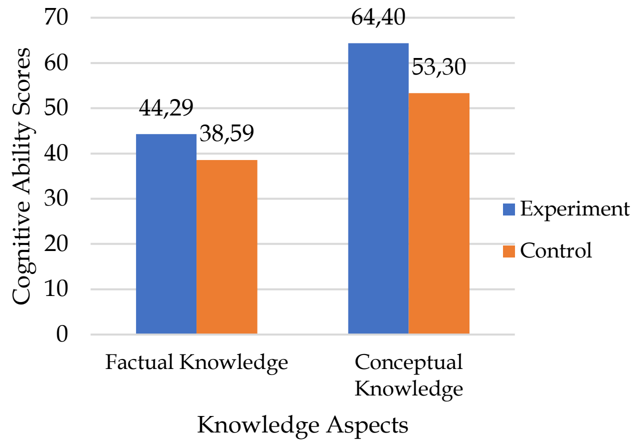

Figure 3. Comparison Diagram of Average Scores for Factual Knowledge and Conceptual Knowledge in Cognitive Abilities of Students in Experimental and Control Classes.

Table 1. Comparison of Mean N-Gain Scores in Cognitive Abilities between Experimental and Control Classes

Data Sources	Class	Average	Std. Dev	t-tes	Sig.	Decision
N-Gain	Experiment	0.63	0.15	3.015	0.004	Significant
	Control	0.50	0.13			

Based on the table, the significance value (sig.) was found to be 0.004. Since the significance is less than 0.05, it can be concluded that the improvement in students' cognitive abilities in the group that received the Synectics model with mind mapping assignments was significantly higher compared to the improvement in learning outcomes of students who were taught using the Synectics model without mind mapping assignments. These results suggest that mind mapping has a positive influence on enhancing students' cognitive abilities.

This finding aligns with the growing body of evidence demonstrating that instructional strategies that promote structured visualization and active engagement, such as mind mapping, are effective in improving cognitive learning outcomes. The significant difference in cognitive improvement between the experimental and control groups further reinforces the role of mind mapping in facilitating deeper conceptual understanding and retention. Mind mapping appears to enhance the learning process by allowing students to organize and relate ideas more effectively, which in turn leads to better cognitive development.

The findings of this research corroborate previous studies indicating that the synectics model enhances cognitive learning outcomes (VANI M., 2012). Furthermore, it demonstrates that mind mapping can significantly improve cognitive learning outcomes compared to traditional methods (Ying Liu, Guoqing Zhao, 2014). The combination of synectics and mind mapping results in a more significant improvement in learning outcomes than the use of synectics alone. This aligns with research suggesting that the integration of synectics with mind mapping or problem-solving strategies is effective in enhancing learning outcomes across various physics topics (Valdez & Sobremisana, 2021).

For Misconception, in question 1 on hydrostatic pressure, the Synectics class had 73.35% understanding, 0.06% insufficient knowledge, 0.09% error, and 25.5% misconceptions, while the Synectics with mind mapping class had 76.68% understanding, 0.03% insufficient knowledge, 0.09% error, and 21.2% misconceptions. Similarly, in question 2 on buoyant force, the Synectics class showed 52.81% understanding and 47.1% misconceptions, whereas the Synectics with mind mapping class had 66.67% understanding and 33.3% misconceptions.

For other questions, the Synectics class generally showed lower understanding and higher misconceptions compared to the Synectics with mind mapping class. In question 9 on air pressure and altitude, the Synectics class had 64.55% understanding and 35.3% misconceptions, while the Synectics with mind mapping class had 81.74% understanding and 18.2% misconceptions. Overall, the addition of mind mapping assignments improved students' understanding and reduced misconceptions across all topics.

The findings of this study indicate that the percentage of students experiencing misconceptions in classes utilizing the Synectics model and Synectics with mind mapping were 39.34% and 30.29%, respectively. The lower percentage of misconceptions in the group using mind mapping can be attributed to the method's ability to help students organize their knowledge through associative thinking. Mind mapping facilitates the analogy-based activities in Synectics learning, enabling students to connect the concepts they learn more effectively. This mapping process supports cognitive structuring, which aids in reducing conceptual misunderstandings by providing clearer, more organized pathways to knowledge retention and application. These results align with prior studies that suggest mind mapping is an effective tool for reducing misconceptions by fostering deeper conceptual understanding and promoting better cognitive integration of ideas.

Despite these positive results, some students still experienced misconceptions, particularly on topics such as Archimedes' principle, likely due to inaccurate analogies. This highlights the importance of using precise and relevant analogies in teaching to prevent misconceptions. Moreover, a higher number of students in the control group fell into the error or low-knowledge categories compared to the experimental group, indicating that mind mapping had a positive impact in reducing both misconceptions and conceptual errors.

Previous research has demonstrated the effectiveness of mind mapping and analogy use in reducing misconceptions (Samsudin, 2024; Gurel, 2015). Mind mapping not only aids conceptual understanding but also enhances students' ability to logically explain concepts while minimizing incorrect responses due to misconnection of ideas or insufficient comprehension. Nevertheless, eliminating misconceptions remains challenging, particularly with abstract concepts such as gas pressure, Pascal's law, and Archimedes' principle.

Accurate use of analogies across various physics topics can significantly improve students' understanding of difficult concepts (Bozdoğan & Demirbaş, 2009). This study revealed that both Synectics and mind mapping were not only effective in teaching pressure concepts but could also be applied to other complex topics such as dynamic electricity and electromagnetic waves, which require deep conceptual understanding.

The findings suggest a strong relationship between students' cognitive learning outcomes and the level of misconceptions they experience. Students with a solid grasp of concepts tend to achieve higher academic results, while those who struggle with misconceptions generally exhibit lower performance. In the class that applied the Synectics model with mind mapping assignments, cognitive learning outcomes were notably higher compared to the class that used only the Synectics model. This corresponds to the lower percentage of misconceptions in the experimental group. Mind mapping helped students organize their ideas more structurally and reinforced conceptual understanding through visual mapping, thereby reducing misconceptions.

Furthermore, these results indicate that more interactive and association-based learning models, such as Synectics with mind mapping, can decrease the likelihood of misconceptions arising during instruction. For instance, on the topic of Archimedes' principle, students in the experimental group experienced fewer misconceptions because the use of analogies combined with mind mapping helped them better grasp abstract relationships between concepts. In contrast, students who were not supported by mind mapping were more prone to misconceptions and struggled to relate new concepts to prior knowledge. Thus, employing appropriate instructional strategies can enhance conceptual understanding and reduce misconceptions, positively influencing students' learning outcomes.

Conclusion

Based on the research findings and data analysis regarding the implementation of the Synectics learning model combined with mind mapping assignments, it can be concluded that the integration of the Synectics model with mind mapping assignments significantly enhances students' cognitive achievement compared to the application of the Synectics model alone, without these assignments. Additionally, the use of the Synectics model in conjunction with mind mapping demonstrates a more pronounced reduction in the occurrence of misconceptions among students, in contrast to the Synectics model applied without mind mapping assignments.

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Author Contributions
In this study, the author makes a different contribution. Theory analysis, data collection, analysis, and paper writing were carried out by authors 1 and 2, while the supervision and review of writing was carried out by authors 3 and 4.

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Conflicts of Interest
The authors declare no conflict of interest.

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