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Research Article

Enhancing Learning Outcomes Through Neuropedagogy-Based Quantum Teaching

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Abstract

This study aimed to analyze the effectiveness of applying Quantum Teaching methods based on neuropedagogy in enhancing student learning outcomes. Quantum Teaching is a pedagogical approach that integrated social, emotional, and cognitive elements within the learning process, while neuropedagogy focuses on understanding how the brain learned optimally. By integrating these two approaches, this study explored how a holistically designed learning environment facilitated the enhancement of students' understanding and knowledge. The study conducted a mixed-method approach, utilizing both quantitative and qualitative methods to measure the impact of Quantum Teaching methods based on neuropedagogy on students' academic performance. The findings indicated that students engaged in Quantum Teaching-based learning with a neuropedagogical approach experienced significant improvements in their learning outcomes compared to those following conventional teaching methods. Additionally, this study found that this approach positively affected students' motivation, engagement, and the development of critical thinking skills. These findings contributed significantly to the field of education, particularly in the context of implementing innovative methods to enhance the quality of learning in the 21st century. The practical implications of this study included recommendations for developing more effective curricula and teaching strategies that educators could apply to achieve better and more holistic learning outcomes.

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INTRODUCTION

Innovation in teaching strategies can significantly improve students' learning outcomes. Quantum Teaching, as an innovative teaching model, has been proven effective in enhancing students' academic achievements at various educational levels. A study performed by Yanuarti and Sobandi (2016) indicated that Quantum Teaching facilitates students' understanding of lesson materials more effectively while also increasing their motivation and engagement in the learning process. These findings align with the study conducted by Tarwani and Herdiana (2021), which revealed that this method significantly impacts students' learning outcomes, particularly in Pancasila and Citizenship Education subjects.

Quantum Teaching integrates principles from quantum physics to create a more effective and holistic learning experience. This approach emphasizes the importance of connection, interaction, and differentiation in the learning process, allowing students to engage more deeply with the material being studied (Siahaan, 2022). Neuropedagogy, which focuses on understanding how the brain learns, provides a scientific foundation for developing more effective teaching strategies (Ebrahimi, 2022). By combining Quantum Teaching and neuropedagogy, educators can design a more adaptive and responsive learning environment tailored to each

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student's specific needs, ultimately enhancing their learning outcomes. The implementation of these approaches enables a more personalized and relevant learning experience for students, creating opportunities for greater academic achievement.

However, several challenges must be addressed to effectively implement Quantum Teaching in the classroom. One of the key issues highlighted in this study is the low student learning outcomes, often caused by ineffective and unengaging teaching methods. Yanuarti and Sobandi (2016) found that students frequently struggle to understand lesson materials when the teaching methods used are not interactive or engaging.

Quantum Teaching plays a crucial role in enhancing students' motivation and engagement in the learning process. Mufarrid et al. (2023) found that Quantum Teaching can create a more conducive learning environment, where students feel more motivated and actively engaged in every aspect of learning. This motivation is essential, as it is one of the key factors influencing students' academic achievement. Therefore, the implementation of Quantum Teaching not only improves cognitive learning outcomes but also affects students' affective aspects, including their motivation and involvement in the learning process. This makes Quantum Teaching a holistic and effective instructional model in supporting students' academic success.

With all its advantages, Quantum Teaching offers an effective solution to address various challenges in modern education. A neuropedagogy-based approach to Quantum Teaching can create a more adaptive and responsive learning environment tailored to each student's needs, ultimately maximizing their learning achievements. This study showed that Quantum Teaching is not only effective in improving students' academic performance but also in enhancing their motivation and engagement in the learning process. Thus, it is crucial for educators and policymakers to consider implementing Quantum Teaching as part of a strategy to improve education quality in Indonesia and create a more inclusive and effective learning environment.

METHOD

This study was conducted using a mixed-method approach that integrates both quantitative and qualitative methodologies to gain a comprehensive understanding of the effectiveness of the Quantum Teaching model and neuropedagogy. The quantitative method was applied to objectively measure students' learning outcomes through specially designed achievement tests, while the qualitative method was used to explore students' and teachers' experiences in implementing this model (Scholz et al., 2020). This mixed-methods aimed to integrate numerical data with in-depth insights from firsthand experiences, providing a richer and more thorough understanding of the studied phenomenon. Additionally, this method allowed the researcher to identify patterns that may not be detected if only one approach were used. As a result, this study can generate more valid and reliable findings.

The participants in this study consisted of elementary school students from various schools that had implemented the Quantum Teaching model. The sampling process was conducted randomly across different classes to ensure that the collected data was representative of the overall population (Siddiqui & Singh, 2017). A stratified random sampling technique was used to obtain a balanced sample that represents each class level. This technique was chosen to minimize bias in data collection and ensure that the study findings can be generalized to a broader population. Consequently, this study aimed to provide a clear understanding of the effectiveness of the Quantum Teaching model across different grade levels.

The instruments used in this study include achievement tests, questionnaires, and interviews. The achievement test was designed to measure the extent to which students understand the subject matter before and after the implementation of the Quantum Teaching model. Questionnaires were utilized to collect data regarding students' learning experiences, while interviews were conducted to gain in-depth insights into teachers' and students' perspectives on the implementation of this model. Additionally, direct classroom observations were carried out during the learning process to complement the data obtained from tests and interviews. The use of multiple instruments aimed to gather diverse and comprehensive data, providing a more holistic understanding of the effectiveness of the studied teaching model.

The data collection techniques in this study were carried out in a structured and phased manner to ensure the validity and reliability of the results obtained. This step-by-step approach allowed the researcher to continuously monitor the process and ensure that each stage of data collection proceeds as planned. Quantitative data were collected through achievement tests administered before and after the implementation of the Quantum Teaching model, aiming to objectively measure changes in students' learning outcomes. These tests were designed to assess various aspects of knowledge and skills that were expected to improve following

the intervention of the Quantum Teaching model. By comparing pre-test and post-test results, the researcher could evaluate the effectiveness of the intervention in enhancing students' academic performance.

One of the key data sources in this study is interviews, which allowed the researcher to explore emotional, cognitive, and social aspects that may not be revealed through quantitative data. For instance, interviews could uncover how students feel more motivated or confident after engaging in learning through this model. Additionally, interviews with teachers provided insights into the challenges and advantages they encountered when implementing Quantum Teaching, as well as how they adjusted their teaching methods to meet students' needs.

Direct classroom observations conducted during the learning process provided rich data on class dynamics and interactions between students and teachers. Through observations, the researcher could record student behaviors, such as participation levels, engagement in discussions, and responses to learning activities. Observations also enabled the researcher to directly examine how Quantum Teaching was applied in practice and to identify environmental factors that influenced the success or failure of the model.

In quantitative data analysis, descriptive statistics were used to illustrate data distribution and evaluate student learning outcomes before and after implementing the Quantum Teaching model. Descriptive statistics provided an overall picture of trends in the data, including mean, median, and standard deviation, which help in understanding how students' scores changed after the intervention. Furthermore, inferential analysis, such as Analysis of Variance (ANOVA), was conducted to test significant differences between the control and experimental groups. ANOVA enabled the researcher to determine whether the observed differences between the two groups were statistically significant or merely due to chance.

Meanwhile, qualitative data was analyzed using a thematic approach. This process involved categorizing data based on key themes emerging from interviews and observations. These themes were then interpreted to understand their contribution to students' comprehension and the effectiveness of the Quantum Teaching model. For example, potential themes may include "student motivation," "teacher adaptation," or "classroom social interaction." Thematic analysis allowed the researcher to explore deeper insights into how various factors influenced learning outcomes and how Quantum Teaching was perceived by both students and teachers.

Quantitative data was analyzed using appropriate statistical software, such as SPSS or R, to ensure the accuracy and reliability of the results. This step helped the researcher to manage large datasets and perform various statistical analyses with high precision. Inferential statistics, including ANOVA and t-tests, were utilized to assess significant differences between control and experimental groups, providing a robust evaluation of the effectiveness of the Quantum Teaching model. On the other hand, qualitative data was analyzed manually, allowing researcher to engage closely with the data and capture nuances that might be overlooked in automated analysis. Data categorization and interpretation were based on emerging themes from interviews and observations, offering in-depth insights into students' experiences and the effectiveness of the Quantum Teaching model.

By integrating both quantitative and qualitative analyses, this study could provide a comprehensive understanding of the effectiveness and implementation of Quantum Teaching in primary school education. The combination of these two approaches enabled the researcher to see the broader impact of Quantum Teaching—not only through statistical findings but also through the experiences and perceptions of individuals involved in the learning process.

This study utilized analysis of variance (ANOVA) and content analysis to evaluate the effectiveness of the Quantum Teaching model. ANOVA is crucial for determining the model's impact across different contexts and ensuring that the findings can be generalized to a broader population. By using ANOVA, the researcher could statistically assess whether the differences in student learning outcomes between control and experimental groups were significant. On the other hand, content analysis is used to examine qualitative data from interviews and observations, aiming to identify patterns and was related to students' learning experiences and the model's effectiveness. This method helped reveal essential aspects of the learning experience that might not be detected through quantitative approaches. Themes such as student motivation, teacher adaptation, and classroom interactions were analyzed to gain deeper insights into how Quantum Teaching influences both cognitive and affective learning outcomes.

By integrating these analytical techniques, this study aimed to provide more reliable and in-depth findings on the effectiveness of Quantum Teaching. The combination of quantitative and qualitative methods not only

offers a comprehensive picture of how Quantum Teaching impacts student achievement but also provides practical insights for educators looking to implement this model in their teaching practices. The findings of this study are expected to serve as a reference for the further development and application of Quantum Teaching in various educational settings.

RESULT AND DISCUSSION

The results of the quantitative data analysis indicated that the implementation of the Quantum Teaching model had a significant impact on students' learning outcomes. The average student score increased from 65.12 before the intervention to 84.88 afterward, reflecting an improvement of 19.76%. This increase not only confirmed the effectiveness of Quantum Teaching in creating a more engaging and dynamic learning experience but also aligns with previous study findings, which had demonstrated the model's ability to enhance student engagement and learning outcomes (Tarwani & Herdiana, 2021; Fayanto et al., 2019). These findings reinforced the argument that interactive and collaborative approaches like Quantum Teaching could serve as effective solutions for improving educational quality at various levels. The improved learning outcomes not only indicated a deeper understanding of the material but also reflected enhanced student motivation and engagement in the learning process, fostering a more positive and productive classroom environment.

Interviews with students and teachers regarding their experiences with Quantum Teaching and neuropedagogy revealed highly positive feedback. Students reported feeling more engaged and motivated during the learning process after the implementation of the Quantum Teaching model. They stated that this method made lessons more interesting and helped them understand the material better (Windasari, 2022; Mufarrid et al., 2023). Teachers also observed a notable increase in student engagement and comprehension. Additionally, they found that Quantum Teaching and neuropedagogy facilitated a more adaptive teaching approach, allowing them to respond more effectively to individual student needs (Dermawan, 2019). These findings highlighted that an interaction- and collaboration-focused approach, which characterizes Quantum Teaching, can create a more inclusive and effective learning environment.

Observation and Analysis of Student Behavior Changes During the Learning Process provided additional evidence of the positive impact of Quantum Teaching. Observations revealed that students became more active in class discussions and showed greater interest in the material being taught. They collaborated more frequently with their peers, indicating improved social and teamwork skills (Windasari, 2022; Mufarrid et al., 2023). This behavioral change reflected one of the core principles of Quantum Teaching, which emphasizes the importance of interaction and collaboration in the learning process (Fayanto et al., 2019). With increased student participation and engagement, not only did academic performance improve, but essential social skills were also developed. These findings suggest that Quantum Teaching fosters a learning environment that not only focuses on academic achievement but also promotes students' holistic development.

Tables and Graphs Comparing Learning Outcomes Before and After Intervention further illustrate the positive impact of Quantum Teaching. The table below presents a comparison of students' learning outcomes before and after the implementation of the Quantum Teaching model:

Category	Average Before Intervention	Average After Intervention	Increase (%)
Student Learning Outcomes	65,12	84,88	19,76

The accompanying graph clearly demonstrates a significant improvement in students' average scores following the application of Quantum Teaching. This visualization highlights that Quantum Teaching was not only effective in quantitatively enhancing learning outcomes, but it also played a crucial role in helping students develop a deeper understanding of the subject matter (Tarwani & Herdiana, 2021; Mufarrid et al., 2023). This improvement indicated a strong evidence that Quantum Teaching is a reliable and effective approach applicable across different education levels, fostering an environment that supports overall learning quality enhancement.

Overall, this study provided compelling evidence that the Quantum Teaching model had a significant positive impact on student learning outcomes. The notable increase in students' average scores after its implementation indicated that Quantum Teaching successfully created a more interactive, engaging, and

conducive learning environment, promoting better comprehension and student motivation. Findings from interviews and observations further reinforced that Quantum Teaching not only enhanced academic performance but also supports the development of social skills and active student participation in the learning process.

Interpretation of Findings

The analysis of Quantum Teaching's effectiveness revealed that this learning model had a significant impact on improving student learning outcomes. The increase in students' average scores from 65.12 to 84.88 after the implementation of Quantum Teaching not only demonstrated an improved understanding of the subject matter but also highlighted the success of this model in creating a dynamic, interactive, and student-centered learning environment (Tarwani & Herdiana, 2021; Dewi, 2018). Quantum Teaching is designed to actively engage students in the learning process by encouraging participation and collaboration, where teachers act as facilitators who effectively guide students in exploring and understanding concepts independently. As a result, students do not merely receive information passively but also develop critical thinking skills and the ability to apply knowledge in broader contexts (Habaridota, 2020). In this approach, learning occurs not only through direct instruction but also through meaningful experiences and interactions with teachers and peers (Fayanto et al., 2019). The significant improvement in learning outcomes can also be attributed to Quantum Teaching's integration of various learning modalities (visual, auditory, and kinesthetic), allowing students to learn in ways that best suit their individual learning styles (Gerke et al., 2022). Therefore, Quantum Teaching not only enhances students' learning experiences but also increases overall instructional effectiveness.

The discussion on the Role of Neuropedagogy in Supporting the Success of Quantum Teaching is essential to understand. Neuropedagogy, which focuses on understanding how the brain functions and processes information, provides a scientific foundation for the teaching strategies used in Quantum Teaching. By understanding the neurological mechanisms underlying learning, teachers can design more effective instructional activities that align with how students process information. (Gordon & Gordon, 2010). For example, this study indicated that teaching methods that consider how the brain processes information can enhance student motivation and engagement, ultimately contributing to improved learning outcomes (Yanuarti & Sobandi, 2016). Dalam konteks Quantum Teaching, prinsip-prinsip neuropedagogi diterapkan untuk menciptakan lingkungan belajar yang merangsang secara neurologis, sehingga memungkinkan siswa untuk menyerap informasi dengan lebih baik dan lebih cepat (Dewi, 2018). Therefore, integrating Quantum Teaching with neuropedagogy not only strengthens the effectiveness of this instructional model but also enables more holistic and comprehensive learning outcomes.

Relevance to Theories and Previous Studies

Establishing links with previous studies strengthens the validity of this study's findings. The effectiveness of Quantum Teaching in enhancing student learning outcomes aligns with earlier study demonstrating its success across various educational settings (Siahaan, 2022). Tarwani and Herdiana (2021) reported a significant improvement in student achievement after implementing Quantum Teaching. This approach allows educators to focus not only on delivering content but also on ensuring that students effectively absorb and retain the material. As a result, this study expands the understanding of Quantum Teaching's impact while offering a more comprehensive strategy for optimizing learning experiences.

The theoretical discussion on Quantum Teaching and Neuropedagogy confirms that this study's findings align with the principles of both frameworks. Quantum Teaching is based on the idea that active student participation and interaction are essential for effective learning (Windasari, 2022). This perspective emphasizes that knowledge acquisition is more effective in socially rich and dynamic environments. Meanwhile, Neuropedagogy focuses on understanding cognitive processes in learning and designing educational settings that support these mechanisms (Huwaida, 2022). When these two approaches are combined, students not only understand the material more effectively but also become more motivated and engaged. These findings highlighted the importance of teaching methods that integrate both social and neurological aspects to achieve better learning outcomes.

Implications for Educational Practice

The practical implications of these findings highlighted their significant impact on education. Quantum Teaching, emphasizing active interaction and student engagement, offers a flexible approach adaptable across various educational settings to enhance learning outcomes. Teachers, schools, and policymakers should consider incorporating this model into curriculum development and teaching strategies. Beyond improving academic performance, this approach fosters students' social and emotional skills (Senmay et al., 2021). Additionally, understanding Neuropedagogical principles enables educators to design learning experiences that are more responsive to individual student needs, fostering inclusive environments that support holistic student development (Krijtenburg-Lewerissa et al., 2017). Integrating Quantum Teaching with Neuropedagogy provides an effective strategy for improving education quality across different levels, addressing the increasing complexity and diversity of modern educational challenges.

Recommendations on the Integration of Quantum Teaching and Neuropedagogical Principles also emphasize the importance of teacher training that focuses on interactive methods based on an understanding of student learning processes. Educators should be trained to integrate Quantum Teaching and Neuropedagogical principles into their instruction (Gordon & Gordon, 2012). Schools should also provide the necessary resources and support to implement these strategies effectively, including access to educational technology that promotes interactive and collaborative learning. With proper training and institutional backing, Quantum Teaching and Neuropedagogy can be seamlessly integrated into daily educational practices, leading to significant improvements in student learning outcomes.

CONCLUSION

This study revealed that the implementation of Quantum Teaching had a significant positive impact on student learning outcomes. The increase in students' average scores from 65.12 to 84.88 after applying this model confirmed its effectiveness in creating a more interactive and engaging learning environment. This success was reflected not only in improved scores but also in increased student motivation and participation. Students became more engaged, and teachers found it easier to adjust their teaching methods to meet students' needs.

This study also highlighted the importance of integrating neuropedagogical principles into Quantum Teaching. By focusing on how the brain processes information, neuropedagogy provides a scientific foundation that enhances the effectiveness of Quantum Teaching. This understanding enables teachers to design learning experiences that align with how students absorb information, leading to significant improvements in learning outcomes. The findings suggest that Quantum Teaching, supported by neuropedagogical principles, not only improves academic performance but also fosters a more holistic and comprehensive learning experience.

Built on the theory that dynamic and rich social interactions enhance learning effectiveness, Quantum Teaching has proven to help students internalize lesson concepts more effectively. When combined with neuropedagogical principles, learning outcomes become more optimal, with students not only gaining a deeper understanding of the material but also demonstrating higher motivation and engagement.

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