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Integrating Thinking Styles into Differentiated Instruction: Enhancing Learning Outcomes in Science Education

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ABSTRACT

Purpose of the study: This research aims to advance science education by integrating Gregorc's Thinking Style Model into differentiated instruction, thereby accommodating students' diverse cognitive needs and improving their academic performance and learning outcomes in science education.

Methodology: This study employed a quasi-experimental design conducted at MTs Al-Khairaat Bora, involving 70 students (36 male and 34 female). Thinking styles were identified using the Gregorc Thinking Style Inventory. Differentiated learning modules were developed and implemented, supported by pre-test and post-test assessments, classroom observations, and feedback surveys analyzed quantitatively and qualitatively.

Main Findings: This study investigated the distribution of cognitive styles among 70 students, finding that Abstract Random (30.22%) and Concrete Random (28.30%) were the most predominant, followed by Abstract Sequential (16.48%) and Concrete Sequential (11.54%). Instruction tailored to these cognitive styles resulted in an increase in post-test scores for the experimental group (from 65 to 85), surpassing the control group (from 64 to 70).

Novelty/Originality of this study: This study integrates Gregorc's Thinking Style Model with differentiated instruction, offering a novel approach to adapting science education. By identifying students' thinking styles, it enhances engagement and understanding, aligning teaching methods with cognitive preferences. The study contributes to improving educational practices by fostering better learning outcomes for diverse student groups.

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1. INTRODUCTION

Science education today faces significant challenges in meeting the diverse learning needs of students [1]-[3]. Each student possesses a unique thinking style, which influences how they process information [4], solve problems [5], and comprehend scientific concepts [6], [7]. However, traditional teaching methods often overlook this diversity by adopting a "one-size-fits-all" approach, potentially hindering students from realizing their full potential [8]-[10].

Students' thinking styles are categorized into Abstract Random (AR), Concrete Random (CR), Abstract Sequential (AS), and Concrete Sequential (CS) [11]. These categories form a critical basis for implementing differentiated instruction that tailors teaching to individual student needs. Differentiated instruction requires teachers to address individual needs by identifying students' abilities, interests, and learning styles and selecting appropriate teaching strategies [12].

The practical implementation of this approach has yielded significant outcomes. A study conducted at Elementary school Adisucipto 1 Yogyakarta demonstrated the positive impact of differentiated instruction in Civics Education [13]. Additionally, this approach aims to align learning with students' interests and readiness levels, enhance motivation and academic performance, foster harmonious teacher-student relationships, and promote independence and respect for diversity [14].

Nevertheless, implementing differentiated instruction is not without challenges. Key obstacles include time management difficulties, the complexity of material preparation, and challenges in conducting fair assessments [15]. In this context, a thinking-style-based approach may offer a solution by aligning teaching strategies with students' cognitive preferences, as outlined in Gregorc's Thinking Style Model [16]. This model categorizes students' thinking styles into AR, CR, AS, and CS, which are crucial for creating inclusive learning environments [17].

This study is grounded in the integration of differentiated instruction theories and thinking style theories [18]. The principles of differentiated instruction, as developed by Carol Ann Tomlinson adjustments in content, process, product, and learning environment form the foundation [19]. These principles are complemented by Gregorc's Thinking Style Theory, which underpins the design of the learning modules in this study. With this approach, the study hypothesizes that aligning teaching strategies with students' thinking styles can enhance engagement, understanding, and performance in science education. Constructivist learning theory also underpins this approach, emphasizing active engagement and personalized learning pathways in knowledge construction [20]. Science education, with its focus on inquiry-based learning and concept application [21], is highly suited to such transformative strategies.

Most previous studies have focused on primary education [14], [22], [23] and specific subjects such as Civics Education [13]. In contrast, this study explores science education at MTs Al-Khairaat Bora, addressing the unique cognitive challenges of adolescents. The study utilizes Gregorc's Thinking Style Model to identify students' cognitive preferences and develop differentiated science learning modules. These modules are designed for Biology, Chemistry, and Physics, with learning activities tailored to each thinking style. Thinking styles such as analytical hadimu [24], creative [25], practical [26] , and reflective play a critical role in science education [27], [28]. Research indicates that accommodating students' thinking styles enhances their conceptual understanding [6], learning motivation [29], and academic performance [30]. In thi

The transformation of science education based on thinking styles not only supports students' intellectual diversity but also aligns with 21st-century education goals [31], which emphasize critical [32], creative [33], and collaborative thinking skills [34]. This study contributes to the body of knowledge by addressing key gaps in science education through the integration of differentiated instruction theories and Gregorc's Thinking Style Model. Specifically, it explores the following research questions: 1) How does the distribution of thinking styles among students influence their learning outcomes in science education? 2)To what extent can differentiated instruction based on thinking styles enhance students' engagement, conceptual understanding, and academic performance?

2. RESEARCH METHOD

This study employed a quasi-experimental design to explore the transformation of differentiated learning based on thinking styles in science education. The research took place at MTs Al-Khairaat Bora and involved 70 students (36 male and 34 female). The thinking styles of the students were identified using Gregorc's Thinking Style Model, which classifies thinking styles into four categories: Abstract Random (AR), Concrete Random (CR), Abstract Sequential (AS), and Concrete Sequential (CS).

The research procedure was carried out in several steps. First, the students' thinking styles were identified using the Gregorc Thinking Style Inventory [16]. This was followed by the development of differentiated learning modules tailored to the identified thinking styles. The modules were designed for science subjects and included learning activities that were aligned with the students' thinking preferences. In the implementation phase, science lessons were delivered using these differentiated modules. Teachers facilitated learning activities that catered to each student's identified thinking style. Group activities, discussions, hands-on tasks, and simulations were employed to ensure that learning was both engaging and effective.

The primary instrument employed in this study was the Gregorc Thinking Style Inventory, adapted from Gregorc [16], to classify students into four cognitive style groups: Abstract Random (AR), Concrete Random (CR), Abstract Sequential (AS), and Concrete Sequential (CS). The inventory was modified to suit the cultural and educational context of the students. Data collection methods included pre-test and post-test assessments to evaluate students' conceptual understanding, observation checklists to monitor engagement and participation, and student feedback surveys to capture motivation and learning experiences. The reliability of both the instrument and the data collection methods was assessed using Cronbach's Alpha, which yielded a value of 0.85, indicating high reliability across all measures.For data analysis, paired t-tests were used to compare pre-test and post-test scores to determine the effectiveness of the intervention. Descriptive statistics summarized the levels of student engagement and feedback responses, while qualitative data from observation notes and surveys were analyzed thematically to identify patterns and challenges during implementation.

This systematic approach ensured a comprehensive evaluation of differentiated learning transformation based on thinking styles, providing insights into how tailored instruction can optimize students' learning experiences in science education.

3. RESULTS AND DISCUSSION

The results of the study indicate that students can be categorized into four main groups: Abstract Random (AR), Concrete Random (CR), Abstract Sequential (AS), and Concrete Sequential (CS), as well as several combinations of these thinking styles. This data provides an overview of students' thinking preferences, which can be used to tailor learning activities to optimize their academic outcomes. Table 1 presents the distribution of thinking styles among students at MTs Al-Khairaat Boora.

Table 1. Distribution of Students' Thinking Styles at MTs Al-Khairaat Boora

Thinking style	Male	Female	Percentage (%)
AS	6	10	16.48
CS	7	5	11.54
AR	11	22	30.22
CR	9	21	28.30
AS and CS	0	1	1.37
AS and AR	0	1	1.92
AS and CR	0	1	1.37
CS and AR	0	1	0.82
CS and CR	0	1	1.10
AR and CR	2	2	5.22
AS, CS and CR	0	0	0.55
AS, AR and CR	0	1	1.10
Total	36	34	100

The distribution of thinking styles revealed that 16 students (6 male and 10 female) were categorized as having an Abstract Sequential (AS) thinking style, accounting for 16.48% of the total students. The Concrete Sequential (CS) thinking style was identified in 12 students (7 male and 5 female), representing approximately 11.54%. The Abstract Random (AR) thinking style emerged as the most dominant, identified in 33 students (11 male and 22 female), or 30.22%. Meanwhile, the Concrete Random (CR) thinking style was observed in 30 students (9 male and 21 female), or 28.30%.

In addition, a small number of students exhibited combinations of thinking styles, demonstrating flexibility in processing information. One female student was categorized with a combination of AS and CS (1.37%), reflecting the ability to blend complex analysis with concrete applications. Combinations of AS and AR, as well as AS and CR, were each observed in one female student (1.92% and 1.37%, respectively). A combination of CS and AR was identified in one female student (0.82%), while another female student exhibited a combination of CS and CR (1.10%). A combination of AR and CR was found in four students (2 male and 2 female), representing 5.22%. Combinations involving three thinking styles, such as AS, CS, and CR or AS, AR, and CR, were extremely rare, with each identified in only one student (0.55% and 1.10%, respectively).

In terms of percentages, the AR and CR thinking styles were the most dominant, accounting for 30.22% and 28.30% of the total students, respectively. Conversely, more complex combinations of thinking styles were rare, indicating students' preferences for specific thinking styles or the integration of two similar approaches. Gender-based analysis showed that female students were more dominant in the AR thinking style (22 out of 33) compared to male students (11 out of 33). Meanwhile, male students were more frequently found in the AS and CS categories, which focus on analysis and concrete applications, although the difference was not particularly significant. Overall, the majority of students displayed a preference for the AR and CR thinking styles, reflecting creative and practical approaches to processing information.

The combination of more complex thinking styles was found in very small numbers, indicating that the majority of students tended to prefer a single dominant thinking style. Although gender differences did not have a significant impact on the distribution of thinking styles, female students were more likely to adopt the Abstract Random (AR) thinking style, characterized by creativity and intuition. These findings provide important insights into students' information processing patterns and emphasize the need to implement teaching approaches tailored to their thinking style preferences to enhance the effectiveness of the learning process.

Figure 1 provides a visual representation of the distribution of students' thinking styles, including the combinations of thinking styles observed during the study. This diagram facilitates a better understanding of the relationships between dominant thinking styles and more complex combinations.

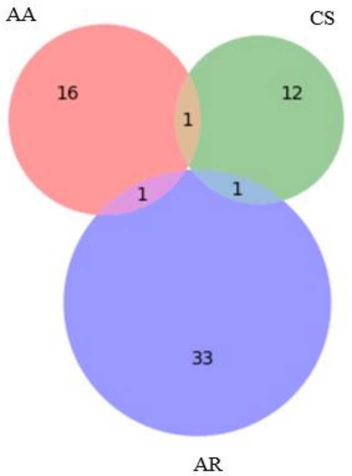

Figure 1. Venn Diagram of Students' Thinking Styles at MTs Al-Khairaat Boora.

Understanding differentiated teaching strategies aligned with Gregorc's thinking styles involves the use of diverse teaching materials, flexible teaching approaches, and assessments tailored to students' learning preferences. The involvement of teachers and school staff in training sessions is crucial to ensure a consistent understanding of Gregorc's thinking style concepts and the implementation of differentiated instruction in the curriculum and daily classroom practices.

Evaluation and feedback mechanisms were designed to assess the effectiveness of training and to improve the implementation of thinking-style-based differentiated instruction at MTs Al-Khairaat Boora. Feedback was provided to optimize learning activities based on students' thinking styles. The learning activities designed by teachers at MTs Al-Khairaat Boora reflect the success of professional mentoring. Teachers effectively implemented thinking-style-based approaches, demonstrating a deep understanding of individual students' needs and learning objectives. The variety of learning activities designed by the teachers not only showcased mastery of the material but also their ability to facilitate students in achieving expected competencies. This success serves as clear evidence that the mentoring provided has had a positive impact on improving the quality of the learning process at the school.

Differentiated teaching strategies aligned with Gregorc's thinking styles include the use of diverse teaching materials, varied instructional approaches, and assessments tailored to students' learning preferences. The involvement of teachers and school staff in training sessions is crucial to ensure a uniform understanding of Gregorc's thinking style concepts and the implementation of differentiated instruction based on thinking styles in the curriculum and daily classroom practices. Evaluation and feedback mechanisms were carefully planned to assess the effectiveness of training and to enhance the implementation of thinking-style-based differentiated instruction at MTs Al-Khairaat Boora. Feedback was provided to optimize learning activities according to students' thinking styles.

The learning activities designed by teachers at MTs Al-Khairaat Boora reflect the success of professional mentoring. Teachers effectively implemented thinking-style-based approaches, demonstrating a deep understanding of individual students' needs and learning objectives. The variety of learning activities developed highlights that teachers not only master the subject matter but also have the ability to facilitate students in achieving expected competencies. This success serves as clear evidence that the mentoring provided has positively impacted the quality of the learning process at the school.

The implementation of learning activities based on thinking styles (Abstract Random, Concrete Random, Abstract Sequential, and Concrete Sequential) enables more effective and personalized learning (Table 2). Matching students' thinking styles to science content such as biology and physics facilitates easier understanding of concepts and their practical application. Creative activities like mind mapping and simulations support students with abstract or concrete thinking styles, while the use of tables and systematic steps aligns better with students with sequential thinking styles. This approach helps achieve learning objectives in a varied and engaging manner, maximizing student involvement and enhancing comprehension based on their individual needs.

In implementing learning activities, it is essential to provide relevant reading materials and tools. Additionally, ensuring the involvement of all stakeholders—including principals, teachers [35], staff, and students is crucial to fostering a strong commitment to a shift toward more inclusive and effective learning based on differentiated instruction.

Table 2. Differentiated Learning Activities Based on Thinking Styles in Science Education

Subject	Thinking Style	Activity
Biology	AR	Create a mind map about the functions of the skeletal system.
	CR	Conduct a simulation using anatomical models of the human body.
	AS	Study a handout on the skeletal system and complete structured exercises.
	CS	Fill out a table identifying bones and their functions.
Physics	AR	Develop a concept map of the laws of motion.
	CS	Perform a step-by-step experiment on force and acceleration.

To evaluate the effectiveness of the differentiated learning approach, a comparison of pre-test and post-test scores was conducted. The results are presented in Table 3.

Table 3. Pre-Test and Post-Test Score Comparison

Group	Pre-test Mean	Post-test Mean	Gain
Experimental	65	85	20
Control	64	70	6

The data in Table 3 show a significant improvement in the experimental group, where differentiated learning was applied. The mean score increased from 65 in the pre-test to 85 in the post-test, indicating a gain of 20 points. In contrast, the control group, which followed traditional instructional methods, showed a smaller increase of only 6 points (from 64 to 70).

Differentiated learning is conducted with the belief that every individual has the right to grow. Carol Dweck, in her research on students' attitudes toward failure, emphasized the importance of adopting a "growth mindset," where students are unafraid of failure and ready to learn from it [36]. This highlights the critical role of teachers and students in creating an inclusive and supportive learning environment that upholds the belief in every student's potential for growth. The principle of enjoyable learning through cognitive engagement emphasizes the importance of accounting for students' thinking style variations in implementation. Research indicates that the effectiveness of learning is influenced by the adopted learning model, types of media used, and interactions with individual thinking styles [37].

Previous studies have revealed a significant relationship between individual thinking styles and academic achievement [38]-[40]. Furthermore, interactions between thinking styles and types of academic assessments, thinking styles of students and teachers [41], and thinking styles and academic subjects [40] also have implications for students' academic performance. Several studies have urged educators to revise teaching strategies and assessments to accommodate students with diverse thinking styles [40]-[42]. The factors influencing individual reasoning modes are complex and often multidimensional, involving variables such as life experiences, interpretation of situations, and intelligence. Thinking styles not only reflect pure cognitive abilities but also individual preferences in expressing creativity and potential [39], [40] .

Differentiated instruction encourages active student engagement in the learning process and enables them to present discussion results in product forms. Differentiation is understood as an approach to addressing student diversity while supporting the vision of education for all. International literature analysis reveals that differentiation is a complex concept encompassing individualization, adaptation for specific groups, and system-level implementation [43]. Effective implementation requires an integrative definition of differentiation focusing on teachers' decision-making regarding activities [9].

4. CONCLUSION

The findings of this study reveal that implementing differentiated instruction based on Gregorc's Thinking Style Model effectively caters to the diverse cognitive needs of students in science education. The identification of dominant thinking styles Abstract Random (30.22%) and Concrete Random (28.30%) enabled the development of tailored learning activities that significantly enhanced students'academic performance. This is evidenced by the 20-point improvement in the experimental group's post-test scores compared to the control group. The integration of thinking-style-based modules, such as mind mapping for Abstract Random thinkers and structured exercises for Concrete Sequential thinkers, provided students with personalized and meaningful learning experiences that aligned with their cognitive preferences.

These results underscore the importance of recognizing and addressing individual cognitive differences in the classroom. Differentiated instruction based on thinking styles not only improves academic performance but also fosters engagement and deeper understanding by aligning teaching methods with students' cognitive strengths. Educators are encouraged to integrate Gregorc's Thinking Style Model into their instructional design to create more inclusive and student-centered learning environments. Future research could explore the application of this approach in different subjects, grade levels, or educational contexts to examine its broader applicability. Additionally, further studies could investigate the long-term impact of thinking-style-based differentiated instruction on students' problem-solving skills, critical thinking, and motivation. This approach could also be expanded with technology-driven tools, such as adaptive learning platforms, to further enhance personalized learning experiences and support diverse learners in an increasingly complex educational landscape.

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