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Cognitive Style-Based Mathematics Learning Strategies: A Literature Review

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***Abstract*—** Cognitive style influences how individuals process information and is crucial in student learning, especially in mathematics education. Research indicates that Field Independent (FI) students generally have a superior conceptual grasp of mathematics compared to Field Dependent (FD) students. Consequently, customized learning strategies that align with cognitive styles are vital for enhancing student learning outcomes. This study reviews the efficacy of cognitive-based learning strategies in primary school mathematics and their implementation to boost student performance. It is a systematic literature review using scientific articles from sources like Scopus and Google Scholar. Data was gathered with keywords such as "Cognitive Styles," "Field Dependent," "Field Independent," and "Mathematics Education," focusing on articles published between 2018 and 2023, which were then descriptively analyzed to identify key findings on the effectiveness of cognitive-based strategies. Results indicate that inquiry-guided instruction and STAD with Peer Tutoring are more effective for FI students than FD students, who excel in conceptual understanding, problem-solving, and mathematical communication. Furthermore, applying learning strategies tailored to cognitive styles significantly enhances student participation and learning outcomes. Cognitive-based learning strategies show substantial potential for improving mathematics education in primary schools. The study underscores the importance of teacher training in recognizing and accommodating students' cognitive styles to optimize academic potential. Further research is required to explore the application of these strategies in various educational contexts.

***Keywords*—** Cognitive Style, Mathematics Education, Field Dependent, Field Independent, Learning Strategy

I. INTRODUCTION

Cognitive style refers to an individual's preferred manner of processing information, which significantly influences problem-solving, decision-making, and learning outcomes. Research indicates that cognitive styles, such as reflective and impulsive, affect students' analytical abilities and research productivity. For example, reflective students tend to engage in thorough analysis and innovative problem-solving, while impulsive students may hinder effective organization of research findings [1][2]. Moreover, cognitive styles such as Field Independent (FI) and Field Dependent (FD) exhibit different approaches to solving mathematical problems, with FI students displaying better alignment between their thinking processes and problem representations [3]. Additionally, cognitive styles encompass various dimensions, including decision-making strategies and learning efficiency, highlighting its multifaceted nature [4]. Overall, understanding cognitive styles is crucial for adapting educational strategies to enhance learning and problem-solving skills in various contexts.

On the other hand, student-centered education has emerged as a paradigm that must be promptly implemented in 21st-century learning. This approach emphasizes the individual needs and potential of each student, increasingly recognized as an effective strategy within the framework of modern education. It focuses on nurturing the unique characteristics of every learner by taking into account their learning styles, interests, and backgrounds. According to [5], education should be oriented towards student experiences, where learners are actively engaged in the learning process and have a voice in their own education. Research indicates that when students feel valued and heard, they are more motivated to learn and participate in academic activities [6]. Furthermore, this approach fosters the development of critical and creative skills, which are essential in an ever-evolving world. By creating an inclusive and responsive learning environment that addresses individual needs, educators can assist students in reaching their maximum potential, thereby contributing to the formation of a more capable and competitive society. Consequently, student-centered education transcends mere teaching methods; it embodies a philosophy that underpins effective and sustainable educational practices.

Understanding the cognitive styles of students is of paramount importance for educators because cognitive styles significantly influence the way students learn, understand concepts, and solve problems, which ultimately affects their academic performance. Students

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with a Field Independent (FI) cognitive style tend to be more analytical and adept at breaking down problems into simpler components, while students with a Field Dependent (FD) cognitive style are more reliant on context and external cues to understand materia [7][8]. Research has consistently shown that students with a FI cognitive style outperform their FD counterparts in mathematics, a subject that requires analytical thinking and strong problem-solving skills [9]. Therefore, educators must understand and adapt their teaching strategies to the cognitive styles of their students to maximize their academic potential.

Understanding the cognitive styles of students in a class is an important aspect in creating an effective learning environment. Cognitive style refers to the unique way individuals process information and solve problems, which can significantly influence their learning outcomes. Research indicates that recognizing differences in cognitive styles allows teachers to tailor instructional methods that better suit each student's needs, increasing engagement and understanding [10]. For example, reflective cognitive style students tend to perform better in solving mathematical problems when given time to contemplate and plan solutions, while impulsive students may make quick decisions but are at risk of making mistakes [11][12]. Therefore, by understanding cognitive styles, teachers can design more inclusive and effective teaching strategies, such as using instructional methods that can accommodate various learning styles, so that every student has an equal opportunity to succeed in the learning process. Additionally, research also suggests that cognitive styles can influence students' problem-solving abilities, which is a crucial skill in education [13]. Therefore, a deep understanding of students' cognitive styles not only benefits learning outcomes but also develops critical and creative thinking skills necessary in daily life.

The influence of cognitive styles on student learning outcomes has garnered significant attention in educational research, indicating that cognitive styles can affect how students comprehend and process information. Studies have revealed notable differences in conceptual understanding between students with field-independent and field-dependent cognitive styles, with those exhibiting a field-independent style generally demonstrating superior comprehension [14]. Furthermore, research conducted by [15]underscores the critical role of cognitive styles in determining effective learning method choices for students, which subsequently impacts their academic performance. Cognitive styles also play a role in students' creative thinking abilities, as certain cognitive styles enable students to excel in solving complex problems [16]. Therefore, a comprehensive understanding of students' cognitive styles not only aids in the development of more effective teaching strategies but also contributes to an overall enhancement of learning outcomes.

The importance of focusing on elementary mathematics education cannot be overstated, as it is during this stage that essential foundational skills are developed. Early education provides the initial framework in which students begin to form a basic understanding of mathematical concepts that will influence their ability to learn more complex concepts in subsequent stages of education [7]. Understanding the cognitive styles of students at this stage can help educators design instructional strategies that not only improve their understanding of basic concepts but also build critical thinking and problem-solving skills that will be highly needed in the future [9].

This literature review contributes by collecting and analyzing previous research, providing a comprehensive perspective on the effectiveness of instructional strategies tailored to cognitive styles. By analyzing various approaches that have been implemented in different educational contexts, this study provides insights into which strategies are most effective to use in elementary school mathematics classes. This approach enables educators to understand how cognitive styles affect the learning process and how they can adapt teaching to optimize learning outcomes [17][8]. Thus, this comprehensive perspective not only helps educators identify appropriate teaching methods but also guides them in implementing more effective approaches in mathematics teaching, which will have a positive impact on students' academic achievement. Therefore, this article aims to conduct a literature review on Cognitive-Based Mathematics Learning Strategies and their Impact on Achieving Learning Goals among Students in Elementary School.

II. METHOD

The purpose of this research is to provide a comprehensive understanding of cognitive style-based learning strategies in early childhood mathematics education [18], This literature review is conducted systematically and aims to gather and analyze information from credible academic sources, including scholarly journals, reference books, and previous research studies that discuss related topics.

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This literature review is conducted systematically and aims to gather and analyze information from credible academic sources, including scholarly journals, reference books, and previous research studies that discuss related topics. The data for this study was collected from various public academic databases containing empirical and theoretical results related to the topic of cognitive style-based learning strategies and their application in mathematics learning at the primary level [19][3]. The primary data source is from scholarly journals accessed through prominent databases such as SCOPUS and Google Scholar [20][21]. The data collection technique used is literature review, where relevant articles are selected based on pre-determined criteria.

The research procedure commences with the initial step of identifying scholarly articles pertinent to the research topic. This search is conducted through academic databases utilizing keywords such as "Cognitive Styles," "Field Dependent," "Field Independent," "Mathematics Education," and "Primary School Students." The selection criteria for articles include those published between 2018 and 2023, emphasizing learning strategies grounded in cognitive styles within the realm of mathematics education.

Upon identifying the relevant journals, the subsequent step involves categorizing these articles based on their relevance and alignment with the research topic. Articles that primarily address the impact of cognitive styles on mathematics learning outcomes and the effectiveness of teaching strategies tailored to students' cognitive styles will be prioritized

Data analysis will be performed using a descriptive-analytical approach [22], aimed at uncovering the principal findings from the reviewed literature and elucidating how these findings enhance the understanding of the effectiveness of cognitive style-based learning strategies. Each pertinent article will undergo a thorough analysis to derive insights into the influence of cognitive styles on students' mathematical comprehension and learning outcomes.

The final step of this research involves compiling explanations and interpretations of the literature analysis results. The findings will be organized systematically to ensure clarity for the reader. The interpretation will concentrate on the effective application of cognitive style-based learning strategies in primary school mathematics education, along with their practical implications for educators.

III. RESULT AND DISCUSSION

The following are findings from various articles from referenced database sources and referring to the search keywords for scientific works that are the data sources.

Table 1. *Research Findings*

Author	Title	Findings
[7]	The Influence of Inquiry Learning Strategies and Cognitive Style on Mathematics Learning Outcomes of Grade V SD Pematangsiantar	The research findings indicate that fifth-grade students taught using guided inquiry strategies achieved higher math scores compared to those taught with free inquiry strategies, with an average score of 90.50. Students with independent cognitive styles also performed better than those with dependent styles, averaging a score of 89. Additionally, there is an interaction between inquiry learning strategies and cognitive styles affecting learning outcomes. In free inquiry classes, students with independent cognitive styles and those with dependent styles in guided inquiry classes had equal average scores of 87. Overall, guided inquiry strategies are more effective than free inquiry, especially for students with independent cognitive styles.
[17]	The Analysis of Students' Critical Thinking Ability with Visualizer-Verbalizer Cognitive style in Mathematics	This study found that students with the Visualizer cognitive style tend to use pictures and algebraic notation to understand and solve math problems, apply various strategies, and double-check their answers in detail. In contrast, students with the Verbalizer style rely more on math formulas without pictures or notation, use one-step strategies, and check each step of the solution by remembering the correct answer.

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[11]	The Effect of Learning Strategies and Cognitive Styles on Learning Outcomes of Mathematics after Controlling Intelligence	This study found that students who learned math using a modified free inquiry strategy performed better than those taught with a guided inquiry strategy, after accounting for intelligence. Additionally, students with a Field Independent (FI) cognitive style achieved better math results than those with a Field Dependent (FD) style, once intelligence was controlled. The research also revealed an interaction between learning strategies and cognitive styles on students' math performance, showing that FI students had better outcomes when taught with the modified free inquiry strategy compared to the guided inquiry strategy, after controlling for intelligence
[4]	Relationships Between Cognitive Styles and Indigenous Students' Mathematics Academic Outcomes	This article found that there was no significant correlation between cognitive style and mathematics academic outcomes in junior and senior high school students from West Papua, in contrast to the findings of previous studies. However, cognitive style showed a significant contribution to mathematics academic outcomes in students. This indicates that as the level of education increases, cognitive style has a greater influence on mathematics academic outcomes for students from indigenous communities.
[23]	Mathematical communication skills based on cognitive styles and gender	The study identified notable differences in mathematical communication skills between students with Field Independent (FI) and Field Dependent (FD) cognitive styles. FI students effectively explained information, used mathematical models appropriately, and articulated problem-solving strategies clearly and systematically. Conversely, FD students described information incompletely, used mathematical models appropriately, and explained problem-solving strategies incompletely. Additionally, the study found no significant gender differences in mathematical communication skills. Male students explained problem-solving strategies clearly but less systematically, whereas female students did so clearly and systematically.
[9]	Metacognition of Junior High School Students in Mathematics Problem Solving Based on Cognitive Style	This study found that middle school students with a Field Independent (FI) cognitive style have high self-confidence and can solve math problems correctly. They can plan their steps, make important decisions on their own, and solve problems effectively. In contrast, students with a Field Dependent (FD) cognitive style also believe their answers are correct, but they struggle to clearly explain the steps needed to solve problems and do not focus on their weaknesses in math problem-solving. As a result, their performance in math problem-solving tasks is often inaccurate.
[24]	Mathematical Reflective Thinking Process of Prospective Elementary Teachers Review from the Disposition in Numerical Literacy Problems	This qualitative study examines the reflective thinking process of prospective elementary school teachers in solving numerical problems, considering their mathematical disposition. The subjects were 26 prospective elementary school teachers who had completed basic mathematics courses. The study focused on the mathematical reflective thinking process in addressing story problems involving a system of linear equations with two variables, based on their level of mathematical disposition. Research instruments included a disposition questionnaire, a reflective thinking ability test, and the researcher as the primary instrument. Effective mathematical reflective thinking is supported by disposition, involving continuous

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		monitoring, reflection, rationalization of one's performance, consideration of the overall situation, analysis of relationships between variables, flexibility in finding alternative solutions, and persistent problem-solving. The findings suggest that lecturers can develop learning media, scaffolding, or teaching materials that accommodate prospective teachers' differing dispositions to enhance their reflective thinking process.
[25]	Integrated Social Cognitive Theory with Learning Input Factors: The Effects of Problem-Solving Skills and Critical Thinking Skills on Learning Performance Sustainability	This study aims to evaluate the relationship between social cognitive theory and learning input factors with inquiry-based learning and reflective thinking styles, as well as the indirect impact of students' problem-solving and critical thinking skills in the context of higher education in Saudi Arabia. By analyzing a conceptual model using SEM on data from 294 students, the results indicate that inquiry-based and reflective thinking styles significantly influence social engagement, human engagement, social power, social identity, and social support. Similar findings were observed regarding the impact of problem-solving and critical thinking skills on inquiry-based and reflective learning approaches. These results suggest that students' abilities in problem-solving and critical thinking greatly affect their learning success in higher education in Saudi Arabia. Therefore, this research can assist university policymakers in deciding whether to fully implement online learning systems to ensure the continuity of education across institutions in Saudi Arabia.
[26]	Cognitive style and gender differences in a conceptual understanding of mathematics students	This study aims to analyze students' understanding of mathematical concepts based on cognitive styles, focusing on gender differences in the topic of matrices. It is a descriptive research using a qualitative approach. Data was collected from 11th-grade high school students, both male and female, through tests, interviews, and documentation. Data analysis techniques included data reduction, data presentation, and conclusion drawing, with data validity ensured through triangulation. The findings indicate that both male and female students have similar understanding in providing examples or counterexamples of the studied concepts. However, there are differences in other areas of mathematical understanding, such as redefining concepts, connecting various mathematical concepts and those outside of math, identifying characteristics of procedures or theories, and presenting ideas in different mathematical representations. Based on the data analysis, it can be concluded that male students have a better understanding of mathematical concepts compared to female students.
[27]	Mathematics literacy ability reviewed from cognitive style on project based learning with rme approach assisted by schoology	This study found that project-based learning with the Realistic Mathematics Education (RME) approach assisted by Schoology improved students' mathematical literacy skills well. This was indicated by excellent planning, implementation, and evaluation of learning. Students with a reflective cognitive style mastered communication, representation, problem-solving strategies, and the use of mathematical tools very well. Students with an impulsive cognitive style mastered communication very well. Students with a fast-accurate cognitive style mastered communication, mathematization, reasoning, problem-solving strategies, and the use

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		of mathematical tools very well. Students with a slow-inaccurate cognitive style mastered communication very well.
[28]	Connected Mathematics Ability Seen from Student Cognitive Style on STAD - Peer Tutoring Learning Model	This study found that the STAD (Student Team Achievement Division) learning model combined with Peer Tutoring is effective in improving students' ability to connect mathematical concepts. In addition, the results of the study showed that students with Field Independent (FI) cognitive style were able to connect each mathematical topic, connect mathematical concepts with other disciplines, and apply mathematical concepts in everyday life based on the facts given. Meanwhile, students with Field Dependent (FD) cognitive style were able to connect mathematical concepts with other disciplines and connect mathematics with everyday life.
[8]	Cognitive Style, Operativity, and Mathematics Achievement	Students with Field Independent cognitive styles significantly outperformed Field Dependent students in total mathematics, conceptual, and problem-solving tests. Additionally, those with high operational development levels scored higher than their low operational peers across all tests. The study employed formal operational tasks (e.g., combination, propositional logic, and proportionality) to assess the impact of cognitive style and operational development on the mathematics achievement of sixth, seventh, and eighth graders. These results highlight the importance of tailoring instructional strategies to students' cognitive styles and developmental stages.

Source: Analysis of Literature Findings

Through a comprehensive review of various studies, this research identified and selected 12 relevant articles based on specific keywords that served as criteria for exploring different publications. The selected articles were sourced from multiple databases, including Google Scholar and Scopus. Several of these articles demonstrated that learning strategies tailored to students' cognitive styles, such as guided inquiry and STAD with Peer Tutoring, are more effective, particularly for students with a Field Independent (FI) cognitive style compared to those with a Field Dependent (FD) style. For instance, [7]found that FI students taught using guided inquiry strategies achieved higher mathematics learning outcomes than their FD counterparts, with average scores of 89 and 87, respectively. These findings suggest that FI students are better equipped to utilize guided inquiry approaches, enabling them to develop solutions independently, which aligns with their tendency towards greater independence in the learning process.

Furthermore, research by [28]also supports this finding by showing that a learning STAD model combined with Peer Tutoring is more effective in improving students' ability to connect mathematical concepts at FI. Students at FI in this study were able to connect each mathematical topic with other scientific disciplines and apply the concepts in their daily lives, which demonstrates their ability to integrate information from various sources and utilize it effectively. On the other hand, students at FD in the same learning context showed limitations in connecting concepts, especially in linking mathematics with broader contexts outside of mathematics class [29].

A noteworthy finding from the article survey is that cognitive style has a significant impact on various aspects of math learning outcomes, including concept understanding, problem-solving, and mathematical communication skills [25]. With regard to concept understanding, research by [8]demonstrates that FI students have a superior ability to understand and integrate mathematical concepts compared to FD students. FI students tend to be more analytical and can break down complex problems into simpler components, which facilitates a deeper understanding of the underlying mathematical concepts. Conversely, FD students often struggle to connect mathematical concepts and are reliant on external assistance to understand the material. Similarly, regarding problem-solving abilities, FI students also display significant advantages, such [9]found that FI students are more confident in solving math problems and can effectively plan problem-solving steps, make important decisions

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independently, and ultimately arrive at the correct solution. In contrast, FD students, although confident in their answers, often struggle to clearly explain the steps of the problem-solving process and tend to overlook crucial details required to arrive at the correct solution.

Other competencies, such as mathematical communication skills, have been highlighted in research conducted by [23]which indicates that FI students excel in articulating information, accurately employing mathematical models, and developing structured and clear problem-solving strategies. Conversely, FD students can describe information but often provide incomplete explanations and frequently struggle to formulate effective problem-solving strategies. This distinction underscores the impact of cognitive styles on how students process and convey mathematical information.

Although cognitive style-based learning strategies have been shown to effectively enhance student learning outcomes, their implementation in the classroom faces several significant challenges [3]. One of the primary obstacles teachers encounter is the difficulty in identifying and adapting teaching strategies to align with the diverse cognitive styles of students [30]. Each student possesses unique cognitive characteristics, and teachers often lack the time or resources necessary to conduct thorough assessments of each student's cognitive style [31]. This can lead to challenges in designing learning activities that effectively meet the needs of all students in a heterogeneous classroom.

Apart from that, differentiating instructions poses a significant challenge in classes with diverse cognitive styles. According to [17], Visualizer and Verbalizer students exhibit very different approaches to solving mathematical problems; Visualizer students rely more on visual representations, while Verbalizer students prioritize the use of formulas without visual assistance. To meet the needs of both of these groups, teachers must design instructional materials and content that can cover various media and methods, which often require extra time and effort. In the context of classes with students who have diverse cognitive styles, as reported by [23]and [11], teachers face challenges in balancing providing sufficient support for Field Dependent (FD) students who require more guidance and giving independence to Field Independent (FI) students who want to explore the material independently.

Furthermore, differentiating instruction in a heterogeneous classroom can present challenges related to time management. Educators must ensure that all students, regardless of their cognitive styles, can achieve the same learning objectives within a limited timeframe [32]. This often necessitates compromises on the part of teachers, which may diminish the effectiveness of the teaching strategies employed

The results from the examined research studies have substantial ramifications for educational practices, particularly with regard to the customization of mathematics instruction to cater to a variety of cognitive styles among students. A crucial consequence is the need for teacher training that acknowledges and appreciates the disparities in cognitive styles among learners. Educators who can determine whether a student is predominantly Field Independent (FI) or Field Dependent (FD) will be exceptionally prepared to craft instructional techniques that boost teaching efficiency and student achievement. For instance, training that hones teachers' capacity to devise instructional materials that integrate a range of media and approache will be highly valuable.

However, these findings also have limitations that need to be considered. Most of the studies reviewed used approaches that focused on specific groups, such as students with FI and FD cognitive styles, or on specific educational settings, such as primary or secondary education. This raises questions about the generalizability of these findings to broader student populations or to different educational contexts. For example, would strategies that are effective for students with FI cognitive styles at the primary level be equally effective at the tertiary level or in different learning environments? Furthermore, most of the studies reviewed used quasi-experimental or qualitative research methods, which, while providing in-depth insights, may not be fully representative of the larger population or sufficiently powerful to establish causal relationships.

IV. CONCLUSION

Tailoring learning strategies to cognitive styles, such as guided inquiry and STAD combined with Peer Tutoring, has proven effective in enhancing mathematics learning outcomes. Students with a Field Independent (FI) cognitive style demonstrate superior understanding of concepts, problem-solving abilities, and mathematical communication compared to their Field Dependent (FD) counterparts. The findings and analysis from this

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research aim to encourage educators to implement learning strategies that align with students' cognitive styles to improve academic performance. Furthermore, teacher training and the development of flexible resources are essential to support effective teaching practices. Additional research is necessary to reinforce these findings across various educational contexts.

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