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JOURNEY FROM THINKING TO DOING: THE UNCHARTED ROLE OF METACOGNITION IN MATHEMATICS ACHIEVEMENT

Tej Bahadur*

Research Scholar, Department of Education
University of Lucknow, Lucknow, UP
Email Id: bahadurtej347@gmail.com

Dr. Hemendra Kumar Singh**

Associate Professor, Department of Education
University of Lucknow, Lucknow, UP
Email Id: hemendra0013@gmail.com

Abstract

The journey from thinking to doing in Mathematics is a dynamic and transformative process, where learners are often struggled with complex problem-solving tasks. While cognitive skills such as logical reasoning and procedural fluency are typically emphasized in Mathematics Education but the role of metacognition, (controlling one's own thinking processes) remains an underexplored dimension in this transition. This paper is an attempt to examine the uncharted role of metacognition in enhancing Mathematics Achievement. It highlights the interconnectedness between thinking and doing, focusing on how metacognition bridges the gap between conceptual understanding (thinking) and effective problem-solving execution (doing) in Mathematics. This study explores the various types of challenges and opportunities in integrating metacognitive practices in Mathematics Education. The rise of digital tools and apps offers a promising avenue for promoting metacognitive practices in mathematics. It this paper, National Educational Policy (NEP) 2020 advocates for integration of metacognitive practices in existing Mathematics curriculum for the development of higher-order thinking skills, such as critical thinking, logical reasoning and problem-solving skills.

Keywords: *Metacognitive Practices, Mathematics Achievement, NEP 2020, Problem -Solving Skills*

Introduction

Mathematics is a discipline characterized by its logical structure, problem-solving, and abstract concepts, it demands more than just procedural knowledge and the ability to recall facts. It is a subject that demands not only the mastery of concepts and procedures but also the ability to apply that knowledge effectively in problem-solving and decision – making tasks. The transition from abstract thought (thinking) to concrete execution (doing) is where many learners face problems, despite having adequate content knowledge. Success in Mathematics is influenced by both cognitive and metacognitive factors. Cognitive processes such as memorization, recall, information – gathering and calculation are essential, but these are insufficient without the capability of monitor, evaluate and regulate one's own thinking process.. The concept of metacognition, or the capability of reflection and regulation of one's cognitive processes, plays a pivotal role in guiding students from understanding mathematical concepts to successfully applying them in problem-solving tasks. One major barrier is the lack of teacher training on how to incorporate metacognitive strategies into lessons (Carr, 2002).

Metacognitive skills allow learners to execute better plan, monitor, and evaluate their approaches to problem-solving, enhancing both the depth of their understanding and the accuracy of their results. This paper aims to examine the uncharted role of metacognition in Mathematics learning, specifically its ability to bridge the cognitive processes of “thinking” and the practical execution of “doing” Mathematics. We explore how metacognitive strategies help learners not only conceptualize mathematical concepts but also they engage in self-regulation during problem-solving and test-taking situations. For instance, during solving a complex word problem, a student with high level of metacognitive skills might first assess the problem, recognize the need for specific strategies (e.g., drawing diagrams, breaking down the problem into smaller parts), actively monitor their progress, and, if feel necessary, change their approach. This contradiction with students who may only rely on rote memorization or procedural methods without considering alternatives or checking their work. However, the integration of metacognitive strategies into traditional Mathematics curricula has been inconsistent. Most mathematical instruction tends to focus on algorithmic methods without offering students an explicit opportunity to reflect on their cognitive processes. As a result, students often struggle with complex problem-solving tasks that require higher-order thinking skills.

Review of Related Literature

Utkun Aydin & Meriç Özgeldi (2024) found that both test anxiety and metacognition were significantly related to mathematics achievement. Wen et al. (2022) explored that anxiety and gender attributes were negatively correlated with mathematics performance whereas enjoyment, self-concept, confidence, perceived value, and behavioural intentions were positively related to achievement . Kumar, Jitendra (2015) revealed that there is a strongly positive and significant correlation among metacognition, problem solving ability and self-esteem. Czerkawski (2015) examined the use of digital math platforms, such as Khan Academy and Desmos, to support metacognitive learning. White & Ruiter (2011) explored how explicit instruction of metacognitive strategies improved students' ability to solve complex mathematical problems. Leong et al. (2011 examined that students who actively engaged in problem-solving tasks showed a better grasp of abstract mathematical concepts and performed significantly better on mathematics achievement tests. Dehaene (2011) explored how the brain processes logical operations and found that students who include in logical reasoning activities such as puzzles, logic games, and deductive reasoning tasks improve their ability to solve mathematical problems.

Hacker et al. (2009) examined the gap between metacognitive awareness (thinking) and actual metacognitive performance (doing) and found that while scavenged that students were aware of their thinking processes, they often struggled to apply these processes effectively during problem-solving tasks. Dunlosky & Metcalfe (2009) argued that while metacognitive practices have been demonstrate to improve learning outcomes, they identified significant barriers to effective implementation. Whitebread et al. (2007) explored that when teachers fascilitated structured opportunities for students to grab in metacognitive activities (such as reflective thinking and self-assessment), students showed significant improvement in both conceptual understanding and procedural application. Artzt & Armour-Thomas (2002) focused on the importance of metacognitive awareness during problem solving in mathematics classrooms. They found that students who were trained to recognize and regulate their thinking, they improved problem-solving skills. Flavell (1979) revealed that the concept of metacognition includes both knowledge of cognition (understanding one's own cognitive processes) and regulation of cognition (the ability to monitor and control one's learning processes).

Research Questions

1. How do metacognitive strategies help students to overcome challenges or barriers when they struggle in learning Mathematics (e.g., misconceptions, cognitive overload)?
2. How Metacognition is helpful in bridging the gap between theoretical understanding (thinking) and practical application (doing)?
3. How can digital tools or apps promote metacognitive practices in Mathematics Achievement?
4. What are the challenges and opportunities in implementing Metacognitive Practices in Mathematics Education?
5. How can Metacognitive Strategies be integrated into existing Mathematics Curriculum according to NEP 2020?

The Role of Metacognitive Strategies in Mathematics Achievement

Mathematics achievement, the successful acquisition of mathematical knowledge and problem-solving skills, is a critical academic outcome for student's at all educational levels. However, many students face challenges such as cognitive overload, misconceptions, and difficulty in applying learned concepts to novel problems. These types of challenges often hamper their performance, leading to frustration and disengagement. When students engaged in metacognitive practices during mathematical problem solving, their ability to generate alternative strategies and evaluate their own solutions led to improved problem-solving skills and higher achievement

(Zohar & David, 2008). Students who received metacognitive feedback (e.g., guidance on adjusting their thinking or strategies) were more likely to improve their mathematical performance (Hattie & Timperley, 2007).

Students who were taught to use metacognitive strategies, such as self-monitoring and error correction, performed better in solving mathematical problems compared to students who were not experienced in these strategies (Veenman et al. 2006). These type of students were capable to identify misconceptions in their understanding and take corrective actions, leading to improved performance. Metacognitive regulation, such as task chunking and strategic pacing, helps reduce cognitive overload in problem-solving tasks. Their study highlights that students who employ metacognitive strategies to regulate their teaching - learning experience less mental fatigue and perform better on complex mathematical tasks, especially those that require multi-step reasoning (Sweller et al. 2011). Further, studies on self-regulated learning, such as those by Schraw (1998), advocated that students who grab in metacognitive practices, such as self-reflection and strategic problem solving, achieve higher scores on mathematics tests. These practices help students to develop deeper understandings of mathematical concepts, leading to improved long-term retention and performance.

Metacognition and the "Thinking to Doing" Journey

The metaphor of **"thinking to doing"** encapsulates the progression from conceptualizing a mathematical problem (thinking) to executing a solution (doing). This transformation needs not only cognitive knowledge but also metacognitive awareness to ensure that the knowledge is applied appropriately. Metacognition facilitates this progressive journey in several ways. Firstly, Metacognitive processes assist students to become active participants in their study, ensuring that they are not merely passively executing procedures but are actively thinking about and refining their approach. When faced with difficulties, metacognitive students are more probably to adapt their problem – solving approach, choosing alternative strategies if their initial attempts do not succeed. It enables students to adjust strategies in real-time when confronted with unfamiliar or difficult problems and hence it is helpful in improve problem-solving flexibility.

It caters and enhances perseverance and self-regulation. Students who identify their thinking patterns are more probably to persist through difficulties, using metacognitive strategies to navigate obstacles. Metacognitive regulation involves reflection, which helps students learn from errors and avoid repeating them, contributing to long-term mastery. When students grab in metacognitive practices, become more aware of their strengths and weaknesses. This leads to greater motivation in their capability to solve mathematical problems and a more positive attitude toward the subject. Hence, self- efficacy is extremely increased. Self-regulated learning (SRL), which is heavily influenced by metacognitive skills and has been strong positively correlated with Mathematics Achievement, particularly in problem-solving contexts where strategic thinking is so essential.

For instance, when a student encounters a difficult word problem, metacognitive strategies can help them break it down into manageable parts (planning), track their progress step by step (monitoring), and verify their solution to ensure it is correct (evaluating). In contrast, students who has lack of metacognitive skills may find it challenging to transition from thinking to doing. They might become stuck when their initial strategy does not work, leading to frustration or disengagement, or they might fail to recognize and correct mistakes.

How Digital Tools and Apps Foster Metacognitive Practices?

One of the key components of metacognition is self-monitoring, which involves assessing one's progress and understanding Digital tools can provide immediate feedback to students, allowing them to quickly evaluate their performance. For instance, interactive math platforms like Khan Academy**,** Desmos**,** or GeoGebra offer instant feedback on problem-solving tasks. Reflective thinking is an essential aspect of metacognition, as it involves evaluating one's thinking after completing a task to improve future performance. Many digital tools are designed to motivate students to reflect on their problem-solving process. Such as, platforms like Desmos, Socrative and Quizizz**.** Metacognitive regulation includes selecting and adapting strategies to solve problems effectively. For example, some math learning platforms present multiple methods for solving a problem, such as graphical, numerical, and algebraic approaches. In platforms like Wolfram Alpha or Mathway**.** Many digital tools use adaptive learning algorithms to personalize the learning experience for each student. These systems adjust the difficulty level and types of problems presented based on a student's progress, providing a customized learning path. For example; DreamBox Learning and Knewton**.** Another one is goal setting, an important metacognitive practice because it helps students set clear objectives and observe their progress towards achieving them. Many math-learning apps allow students to set personalized goals (e.g., mastering a particular concept or completing a set of exercises) and track their progress over time. Brilliant.org allows students to set learning goals and track their progress, facilitating them with visual indicators of their performance.

Challenges in Implementing Metacognitive Practices in Mathematics Education

One of the major primary challenge in implementing metacognitive strategies in Mathematics Education is the crisis of teacher training and familiarity with metacognitive techniques. In our country, several teachers are not trained to explicitly teach students how to be metacognitive in their approach to learning. Teachers may have a strong mathematical background but may not be equipped with the pedagogical skills necessary to guide students in developing metacognitive awareness. Mathematics curricula are often packed with content that needs to be covered within a limited time frame Metacognitive practices require time for self-reflection, strategy exploration, and monitoring, which may be seen as an additional burden on an already crowded syllabus. Students may not initially see the value of metacognitive strategies, especially if they are accustomed to passive learning or rote memorization. The shift towards self-regulated learning can be so difficult for students who are used to being given step-by-step instructions without actively engaging in the thinking process.

Traditional assessments often focus on measuring students' ability to recall facts or apply procedures, rather than assessing their ability to regulate their thinking or reflect on their learning. The lack of metacognitive assessments can hinder the full integration of metacognitive practices into the grasping process and this is especially challenging in Mathematics. In many educational settings, especially in traditional or more rigid systems, there may be institutional or cultural barriers to adopting new teaching practices. Metacognition often calls for a shift in both teacher and student mindset—from focusing on completing tasks correctly to emphasizing learning and self-regulation

Opportunities in Implementing Metacognitive Practices in Mathematics Education

One of the major key opportunities of implementing metacognitive practices in mathematics education is the promotion of students' autonomy and self-regulation. By teaching students how to monitor their thinking and adjust their strategies when encountering difficulties, teachers help students take proprietorship of their study and learning. Metacognitive practices can significantly enhance students' problem-solving abilities. Mathematics often requires students to work through multiple steps, identify patterns, and choose the most successful approach. The integration of technology in mathematics education provides an excellent opportunity to support metacognitive practices. Online platforms, interactive apps, and mathematical software can facilitate self-regulated learning by allowing students to track their progress and receive real-time feedback. Metacognitive strategies align well with personalized learning approaches. By guiding students to reflect on their individual learning preferences, strengths, and areas for improvement, teachers can transform their instruction to better meet the necessity of each student. When students learn to introduce their thinking and recognize that errors are a natural division of the learning process, they become more resilient and willing to engage with difficult tasks.

Integration of Metacognitive Practices in Mathematics Curriculum according to NEP 2020

The National Education Policy (NEP) 2020 marks a transformative shift in India's educational framework by emphasizing holistic, student-centered learning and the upgradation of critical skills, including metacognition.. NEP 2020 advocates for a reflection on the upgradation of higher-order thinking skills, such as critical thinking, creativity, and problem-solving, all of which are aligned with metacognitive practices. By integrating metacognitive practices into the mathematics curriculum, NEP 2020 aims to foster deeper understanding, problem – solving tasks and self-regulated learning among students. The integration of metacognitive practices into the mathematics curriculum, as outlined in NEP 2020, fascilitate great promise for increasing students' learning experiences. By incorporating self-reflection, goal-setting, strategy planning, error correction, and the use of technology, educators may become able to develop critical metacognitive skills that promote independent learning, problem-solving, and deeper mathematical understanding. Despite challenges such as teacher training and curriculum constraints, the opportunities presented by NEP 2020 such as interdisciplinary learning, collaborative problem solving, and the use of technology make it possible to provide a conducive environment that supports the upgradation of metacognitive skills in mathematics education. By aligning these practices with the recommendations of NEP 2020, educators can foster a generation of students who not only conceptualize Mathematics but also possess the different types of skills.

Conclusion

The uncharted role of metacognition and its practices in Mathematics Achievement is decisive for understanding the journey from thinking to doing. Metacognition serves as the uncharted bridge between conceptual understanding and effective action. Metacognitive skills such as planning, monitoring, and evaluating allow students to navigate complex mathematical problems more effectively and adapt their strategies to overcome challenges. By unveiling the power of metacognition, we empower students to become not only better problem-solvers but also more reflective and self-regulated learners . Research signifies that explicitly teaching metacognitive strategies or practices and creating conducive learning environment where students can reflect on and adjust their thinking can significantly improve their mathematical achievement. Thus, metacognition serves not only as a cognitive tool but also as a bridge to deeper learning and better academic performance in mathematics.

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