



Explore Reflective and Impulsive Styles to Form Student Thinking Principles for Solving Mathematics Problems

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ARTICLE INFO

Article History:

Received: 14 August 2024

Received in revised form: 11 November 2024

Accepted: 30 January 2025

DOI: 10.14689/ejer.2024.114.02

Keywords

Exploration; reflective, impulsive, thinking mathematics; problems solving

ABSTRACT

Purpose. This research is essential to find the relationship between reflective and impulsive styles and students' understanding of mathematical problems. The reflective thinking process involves in-depth analysis, hypothesis testing, and searching for optimal solutions, resulting in more precise solutions. In contrast, impulsive forces tend to be quicker in taking action but are often less accurate. **Methodology.** Descriptive research is aimed at describing reflective and impulsive thinking profiles in solving mathematical problems. There were 25 students from the first secondary school as research subjects. The instruments used include MFFT (*Matching Familiar Figure Test*) test questions that have gone through the instrument development process and interview guidelines. Before the instrument is used, it has been validated by three validators. The data collection method used in this study is the test and interview method. Data collection begins by providing MFFT test questions. Three data analysis techniques are used in this study: instrument validity analysis, test

result data analysis, and interview data analysis. **Findings** The study results showed that students with an impulsive cognitive style met five indicators of mathematical thinking: generalization, abstraction, analytical thinking, dynamic thinking, and modeling. **Implications for research and practice.** Some students have an impulsive cognitive style and are seen as confused when understanding problems. They looked hesitant in answering questions, and there were still mistakes in writing the symbols.

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Introduction

Students' approaches to solving arithmetic problems are influenced by their reflective and impulsive tendencies. Reflective exercises are often used to address (in writing) themes, and focus group discussions and interviews are used to corroborate and triangulate the results (Khoza, 2023). In order to enhance students' professional capabilities and teach them practical skills for curricula, pedagogical research has shown a great deal of interest in the design and development of reflective and impulsive exercises involving several disciplines (Wei et al., 2023). When several disciplines are combined to address real-world issues, this is known as transdisciplinary integration (Zhou et al., 2023). Rethinking the nature of learning experiences is necessary to prepare our students for an increasingly complex and uncertain future. This includes creating more innovative and relevant problems that are difficult but manageable and, most importantly, support adaptive learning and problem solving, in-depth examination, hypothesis testing, and the pursuit of ideal answers (English, 2023), which are all components of the reflective thinking process.

In the current context, educational intervention planning is one of the most popular methods teachers employ to approach the reflective processes of practice (Cruz-Ramírez et al., 2022). Dimos et al. (2023) demonstrate that most educators employed computational thinking as a criterion for evaluation and reported no serious issues with it. Understanding the issue and selecting suitable approaches are part of the entry phase; this may entail specialized case trials (Stewart & Ball, 2023). Individual differences in reflexive and impulsive styles may have a lasting impact on information processing solutions (Idrizi et al., 2023). However, an impulse style can be quicker when taking action but often needs to be more precise. Impulsive forces tend to produce faster actions because decisions are taken spontaneously without much consideration. In addition to being unable to communicate effectively using speech, the impulsive individuals may appear inattentive, have difficulty sitting still, or engage in impulsive or self-injurious behaviors. These findings suggest that even the most impulsive individuals can acquire foundational literacy skills. An important consideration within any safer changes in behavior (Cheung, 2024; Houghton & Moss, 2024). However, this speed of action is often accompanied by a lack of accuracy because the decisions are not based on in-depth analysis or evaluation. As a result, impulsive actions may also result in suboptimal solutions, mistakes, or unintended consequences (Albaum et al., 2023).

At the university level, students are expected to be able to think independently, critically, and reflectively, especially in solving complex mathematical problems. It tells us that we need to know whether a person is impulsive or not to make the best prediction of their level of social fear (Wilson & Gullon-Scott, 2023). Especially when many emerging adults choose to move away from their parents and live independently (Cheung, 2024). However, no other case has the reference to other scientific disciplines, having been viewed so critically as in the case of biological and evolutionary approaches to human behavior and culture. Findings reveal that e-portfolios are beneficial in new knowledge creation, learning management, reflective learning, test anxiety elimination, and student performance assessment, particularly in the case of mathematical learning (Mei, 2022; Mpungose & Khoza, 2022). It is also asserted that children encounter mathematical and scientific concepts in their daily experiences (Altynbekov et al., 2023; Kay & Buxton, 2024).

This research was chosen because it can provide in-depth insights into how reflective and impulsive cognitive styles affect students' understanding and mathematical problem-solving processes. By exploring the relationship between these two thinking styles, this study aims to identify the strengths and limitations of each in developing mathematical understanding. In addition, the study features a shifting profile of student performance in problem-solving, which suggests that individualized guidance and classroom education may not be fully effective for all students. Therefore, the results of this study are expected to provide recommendations for more adaptive and effective learning strategies for improving students' mathematical problem-solving skills (English, 2023; Pals et al., 2023). Understanding this relationship is crucial for designing effective teaching strategies that accommodate diverse cognitive tendencies, enabling educators to foster deeper conceptual understanding and improve students' overall performance in mathematics (English, 2023; Yang et al., 2023). Additionally, the findings can contribute to developing interventions to enhance students' ability to adapt their thinking styles to various mathematical challenges.

This study advances our knowledge of how learning affects introspective, reflexive and impulsive cognitive styles, especially when resolving mathematical issues. The study offers important insights into how well teaching methods shape students' thought processes by assessing how different instructional strategies impact and influence these learning styles (Ho et al., 2023). The results can assist teachers in discovering strategies that foster the growth of balanced cognitive processes and their teaching styles, empowering pupils to tackle issues with thoughtful consideration and prompt decision-making (Stewart & Ball, 2023). Ultimately, this research provides a basis for developing learning environments that accommodate a range of cognitive inclinations, encouraging students to solve problems more effectively and comprehend concepts more deeply.

This study may offer helpful suggestions for enhancing instructional strategies that take into account students' impulsive and reflective cognitive processes. Teachers can create tactics that cater to the individual needs of each student by determining how different styles affect students' arithmetic comprehension and problem-solving techniques (Dimos et al., 2023). While teaching strategies for impulsive students may emphasize encouraging meticulous thinking and minimizing errors, those for reflective students may concentrate on improving efficiency and decision-making. The knowledge gathered from this study can help teachers provide differentiated instruction by allowing them to create learning activities that strike a balance between speed and accuracy, thereby helping all students improve their math performance.

Literature Review

Reflective and impulsive styles significantly affect students' effectiveness. They involve strengthening rational beliefs of learners as well as their reflective tasks to practice the skills learned. Reflective and impulsive cognitive styles significantly affect students' problem-solving, learning processes, and decision-making effectiveness. These styles influence how students approach tasks, process information, and respond to challenges in academic and real-world scenarios. Math problems are particularly challenging for students with introspective and impulsive cognitive processes. According to some research, spontaneous decision-making may result from an adaptation to the statistics of particular contexts when practicing the reflexive actions (Burk & Averbek, 2023). This demonstrates a learner's

qualities for cognitive activity and the willingness to comprehend several approaches to solving cognitive issues particularly in mathematics (Altynbekov et al., 2023; Sidekerskienė & Damaševičius, 2023). Naturally, teachers require their students to create a learning plan and to keep reflective diaries, which serve as the basis for resolving the mathematical problems (Mei, 2022). Help and service, personal efficacy, managerial skills, cognitive dimensions, are a few characteristics that are required in pre-service mathematics teachers to solve differential equations (Herrero et al., 2023; Liu & Alyoubi, 2022).

Teachers can gain insight into how students' progress throughout lessons of mathematics by observing the shift between the functional and optimal levels of understanding. This can also help students overcome obstacles and setbacks (Pals et al., 2023). The control group's stress mindset score does not significantly change. It is often found that individuals in "stress is enhancing" groups perform better at work in both soft and hard abilities, they also score lower on psychological symptoms. Problem-solving interventions that include time to struggle with problems improved students' problem-solving skills (Stewart & Ball, 2023). A balanced approach that nurtures adaptability can help both types of learners improve their mathematical problem-solving skills.

Integrating instructional tactics with the appropriate reflective and impulsive thinking style is challenging for teachers. College and university mathematics courses now face new opportunities and challenges due to the adoption of new media. Therefore, relevant lecturers should stay current in order to improve teaching outcomes and address learners' deficiencies (Walker et al., 2023). The adoption of the latest tools can play a leadership role for teachers and also reflect the subjectivity of students. Through empirical research, theoretical analysis, and literature evaluation, effective teaching strategies for mathematics education are investigated (Yang et al., 2023). Based on self-determination theory, the study examined the relationship between students' learning experiences, psychological needs, and professional development. It concluded that students' development in their profession skills is facilitated by their ability to adapt to learning (Guo, 2023). Research has repeatedly shown a connection between teachers' views and the methods they employ in the classroom; teachers who hold traditional ideas in mathematics are more likely to employ rule-based, teacher-directed methods (Hourigan & Leavy, 2023). A mix of diagnosis, adaptability, and metacognitive tactics can significantly facilitate integrating teaching methodologies to accommodate introspective and impulsive cognitive styles, even though doing so can be difficult. With targeted strategies, teachers can create an inclusive environment where all students thrive.

Many learners need help to solve mathematical issues and have misconceptions. In the modern environment, traditional ideas for addressing mathematical problems still need to be improved (English, 2023). Link prediction is viewed as a binary classification problem. This approach considers cognitive processes that support learning, problem-solving, decision-making, and the development of interdisciplinary concepts (English, 2023). Generally speaking, a tailored conversation can be beneficial since it can help identify why an inexperienced learner may not be able to connect the dots or why an experienced learner may be overwhelmed with information, reducing "the expertise reversal effect." (Pals et al., 2023). Additional advantages include cutting down on exam preparation time, expanding the scope and sources of knowledge beyond textbooks, encouraging a learner-centered approach to education, and lessening or doing away with exam cramming and the anxiety that goes along with it (Al Malki et al., 2023; Idrizi et al., 2023).

Stewart and Ball (2023) assert that learners need help with misconceptions and difficulties when addressing mathematical problems. When solving mathematical problems, students' capacity for reflective and spontaneous thought has yet to be fully utilized. The distinctive competency traits of all psychological instructors in health education colleges include a focus on student service, a drive for success, and the ability to influence and promote the growth of their students (Liu & Alyoubi, 2022). For instance, in order to develop reflexive control measures, it is crucial to investigate the events or environmental factors that trigger (Li & Huang, 2024; Liao et al., 2024), and how such environmental factors optimize the usefulness (Burk & Averbeck, 2023). To maximize the usefulness of explicit and tacit knowledge, this instructional approach heavily emphasizes utilizing each participant's theoretical knowledge and practical abilities (Yang et al., 2023). Although deriving lessons from reflexive and impulsive actions is directly related to mathematical models, it leads to the inference that impulsive choice methods are not effective in decision-making but relatively efficient adaptations to environments with significant uncertainty (Burk & Averbeck, 2023; Hameni Nkwayep et al., 2024).

Research Methods

Research design

This research adopted a descriptive research design with a qualitative approach to explore how reflective and impulsive cognitive styles shape the problem-solving principles of eighth-grade students in coastal areas. The study analyzes students' mathematical thinking based on these cognitive styles.

Sampling

The sample comprised 25 eighth-grade students aged 13-14 from coastal regions. Three research instruments are employed: a modified Matching Familiar Figure Test (MFFT) to categorize students into reflective or impulsive cognitive styles; a mathematics test on the Two-Variable System of Linear Equations (TVSYLE) to evaluate their problem-solving abilities; and interview guidelines to gain deeper insights into students' understanding and strategies. To ensure validity, the instruments were assessed by two mathematics education experts and one junior high school mathematics teacher. This study aims to provide a detailed description of the mathematical thinking profiles of eighth-grade students in coastal areas by examining their approaches to problem-solving through the lens of reflective and impulsive cognitive styles.

Instrument and data collection

The research procedure involved data collection through tests and interviews. Initially, students were given an MFFT (Matching Familiar Figure Test) consisting of 13 picture-based questions, for which they must select the image that matches the main image.

The responses were analyzed to classify students based on their cognitive style criteria (reflective or impulsive). Students were categorized as reflective if they provide more than seven correct answers ($f > 7$) and took more than 7.28 minutes ($t > 7.28$) to complete the test. Conversely, students were classified as impulsive if they provided fewer than seven correct answers ($f < 7$) and took 7.28 minutes or less ($t \leq 7.28$) to complete the test. The MFFT test results were analyzed using the following criteria: Reflective: Correct answers \geq

7 and processing time > 7.28 minutes; impulsive: Correct answers < 7 and processing time ≤ 7.28 minutes. Table 1 further details the classification of cognitive styles (reflective and impulsive) based on time and accuracy.

Table 1

MFFT Test Assessment

No	Cognitive Style	Time (t)	Correct answer (f)
1	Reflective	t > 7,28 minutes	f ≥ 7
2	Impulsive	t ≤ 7,28 minutes	f < 7

Data analysis

After completing the cognitive style classification, all students took the TVSYLE math test. Furthermore, a team of experts carried out a data analysis called Instrument Validity Analysis. Test Analysis included MFFT test results and math tests to see students' thinking profiles. Interview analysis was conducted on four students (two reflective and two impulsive) to confirm their written answers. The interview data was reduced, presented, and concluded. Then, in Data Triangulation, the researcher uses triangulation methods (tests and interviews) to increase the validity of the research results. In this study, researchers play a direct role in all stages, from planning and data collection to analysis of research results.

Results

This section summarizes the results of the work of students with reflective and impulsive cognitive styles who often face difficulties in solving mathematical problems, impacting their understanding of concepts and problem-solving strategies. In addition, teachers also experience challenges in integrating teaching strategies that are by these two styles of thinking, so the learning approach used is often less effective in accommodating the needs of students. Many students experience misconceptions and difficulties in understanding and applying mathematical concepts in depth. The results of the study show that students' reflective and impulsive thinking skills in solving problems are still not optimal, with a shallow understanding of solutions.

To ensure that the instruments used in this study can accurately measure understanding and problem-solving ability, validity tests were carried out on mathematics test questions and interview guidelines. The results of the validity test showed that the total average (Va) obtained was 2.8, which indicates that the instrument used has met the validity standard. The validity level of this instrument is presented in Table 2.

Table 2

Instrument validity level

Value V_a	Validity Level
$V_a = 3$	Highly Valid
$V_a = 2.5$ to 3	Valid
$V_a = 2.0$ to 2.5	Quite Valid
$V_a = 1.5$ to 2.0	Less valid
$V_a = 1.0$ to 1.5	Invalid

Note: Va (Validity) is measured based on the average score of the validated instrument or data.

This level of validity can be used to evaluate the quality or validity of a measuring tool, media, or research instrument.

Based on the instrument's validity level, the validity test placed it in the valid category, confirming its suitability for data collection. The research was conducted on 25 sampled students, and the data revealed variations in their cognitive styles. A total of 8 students were categorized as having a reflective cognitive style, while 6 students had an impulsive cognitive style. Additionally, 11 students were classified into the fast-accurate and slow-inaccurate categories. To gain a deeper understanding of the differences in thinking and problem-solving strategies, two students from each group were randomly selected for interviews. The interviews aimed to explore students' thinking processes, particularly when dealing with mathematical problems related to the Two-Variable Linear Equation System. Through these interviews, the researchers hoped to gather richer qualitative data on students' thought patterns, information management, and the strategies they employ to solve problems, both in writing and verbally. The interview results would complement the written data, providing a more comprehensive view of the differences and similarities between students with reflective and impulsive cognitive styles.

From the analysis of 8 students with a reflective cognitive style and 6 students with an impulsive cognitive style, it was evident that the ability to think mathematically in solving problems related to the Two-Variable Linear Equation System material varied. However, a similar tendency emerged among students with the same cognitive style. For example, two students with a reflective cognitive style demonstrated the ability to write correct answers and provide clear explanations of the problem's intent. Reflective students tended to present their answers in sequence, use appropriate mathematical symbols, and detail each step in solving the problem, resulting in more accurate final answers. Overall, students with a reflective cognitive style were more meticulous in their work, ensuring each step was laid out. This is reflected in the neat and systematic structure of their answers, as shown in Figure 1, where a student logically and clearly describes the solution to the TVSYLE problem. In contrast, students with impulsive cognitive styles exhibited different work patterns, which will be discussed further.

Figure 1 demonstrates a strong reflective ability of students, who is capable to use a cognitive style to model a given mathematical problem. They begin by accurately writing down the general form of the linear equation for two variables, starting with the formula for the circumference of a rectangle, $k = 2(x + y)$, and then clearly formulating the equation that describes the difference between the length and width of the garden, $x - y = 9$. In their problem-solving process, these students assign the variable x to represent the length of the garden and y to represent the width, an essential step for understanding and simplifying the problem. Additionally, they correctly rationalize rational variables and construct analogies to describe the situation in a clear and structured manner. The student also exhibits precision by clearly labelling the first and second equations in the problem, which facilitates the solving process. Such students with a reflective cognitive style met two critical indicators in mathematics: generalization and abstraction. Generalization is demonstrated by their ability to translate a real-world problem into a general mathematical equation, while abstraction is shown in their ability to simplify the problem into a symbolic form that is easier to process. This indicates that the student not only understands mathematical concepts but is also capable of applying them in broader contexts through logical and systematic steps.

$$\begin{aligned}
 K \square &= 2(p+l) \\
 k &= 30 \\
 2(p+l) &= 30 \\
 \frac{2(p+l)}{2} &= \frac{30}{2} \\
 (p+l) &= 15 \quad \textcircled{1} \\
 \frac{(p+l)}{x+y} &= 15 \\
 * \text{ Selisih panjang dan lebar} \\
 \frac{(p-l)}{x-y} &= 9 \quad \textcircled{2}
 \end{aligned}$$

Figure 1: Answers of students who have a reflective cognitive style

There is another example of an answer excerpt showing students' reflective cognitive style, which dynamically met the indicators of mathematical thinking, analytical thinking, and modelling, as shown in Figure 2.

$$\begin{aligned}
 * \text{ eliminasi per } \textcircled{1} \text{ dan } \textcircled{2} \\
 \begin{array}{r}
 x+y=15 \\
 p+l=15 \\
 p-l=9 \\
 \hline
 2l=6 \\
 l=3 \\
 x+l=15 \\
 x+3=15 \\
 x=15-3 \\
 x=12
 \end{array} \\
 * \text{ cari nilai } x, \text{ substitusi } y \\
 \begin{array}{l}
 x+y=15 \\
 x+3=15 \\
 x=15-3 \\
 x=12
 \end{array} \\
 \text{Jadi, Panjang kebun (x) adalah 12} \\
 \text{lebar kebun (y) adalah 3}
 \end{aligned}$$

Figure 2: Answers of students who have a reflective cognitive style

Figure 2 demonstrates that students with a reflective cognitive style showed good ability in making mathematical models and representing problems using mathematical forms of the information provided. In this case, students equate the width of the garden with the variable y . In addition, students with a reflective cognitive style also use elimination and substitution strategies to solve their problems. This can be seen from the ability of students to perform dynamic manipulation of mathematical objects, which is strengthened by written calculation steps such as " $x + y = 15, x + 3 = 15, x = 15 - 3$ ". The statement shows that students can determine the values of the x and y variables by substituting the values of known variables into the equation to get the desired result. Based on this analysis, it is evident that students can think dynamically and analytically and write and develop mathematical modelling per the given problem.

On the contrary, the answer sheet of students with an impulsive cognitive style in answering questions shows a lesser dynamism and lesser accuracy. Figure 3 shows that students with an impulsive cognitive style can only write down only the generalized form of a two-variable linear equation from the problem.

$$\begin{aligned}
 & k \square = 2(x + y) \\
 & k = 30 \\
 & 2(x + y) = 30 \\
 & x + y = \frac{30}{2} \\
 & x + y = 15 \quad \text{①} \\
 & * \text{ selesai panjang dan lebar:} \\
 & x - y = 9 \quad \dots \text{②}
 \end{aligned}$$

Figure 3: Answers of students who have impulsive cognitive styles

Figure 3 also shows that students can write down what is known from the problem using mathematical symbols. Students use x and y symbols to solve problems. Thus, students with an impulsive cognitive style are said to be able to think about math in generalization and abstraction. Figure 4 shows an excerpt of another answer sheet of students with an impulsive cognitive style who met the indicators of mathematical thinking dynamically and analytical thinking.

$$\begin{aligned}
 & * \text{ eliminasi? Perkag? ① dan ②} \\
 & \begin{array}{r}
 x + y = 15 \\
 x - y = 9 \\
 \hline
 2 = 6 \\
 y = \frac{6}{2} \\
 y = 3
 \end{array} \\
 & * \text{ cara lain? substitusi y} \\
 & \begin{array}{r}
 x + y = 15 \\
 x + 3 = 15 \\
 x = 15 - 3 \\
 x = 12
 \end{array} \\
 & \text{Jadi? Panjang kebun teh itu adalah 12.} \\
 & \text{Sedangkan lebar kebun teh adalah 3}
 \end{aligned}$$

Figure 4: Answers of students who have impulsive cognitive styles.

Figure 4 shows that students with an impulsive cognitive style are also capable of dynamically manipulating mathematical objects and solving equations to determine unknown values. However, several mathematical symbols are incorrectly written on their answer sheet, indicating that they are less thorough in their problem-solving approach.

The analysis of answer data from 14 students, including 8 with a reflective cognitive style and 6 with an impulsive cognitive style, revealed that both groups were able to determine the general form of the two-variable linear equation, thus meeting the indicator of generalization in mathematical thinking. Students from both cognitive styles could also write down the known information about the problem using symbols, with x and y representing the variables to rationalize the given situation. This demonstrated their ability to engage in analytical thinking, as both reflective and impulsive students were able to solve two equations and determine the values of the unknown variables through dynamic manipulation of the equations. Furthermore, both groups were able to model the problem and select the correct solution. However, neither group was able to describe the set of solutions on a Cartesian coordinate graph. As a result, both reflective and impulsive students met five mathematical thinking indicators: generalization, abstraction, analytical thinking, dynamic thinking, and modelling.

From the data analysis and interviews, the researchers identified differences between students with reflective and impulsive cognitive styles. During the interviews, students with a reflective cognitive style demonstrated a better understanding of the math problem. They answered questions confidently and provided clear explanations of the problem. When writing their answers, they used mathematical symbols accurately and understood the meaning of these symbols. On the other hand, students with an impulsive cognitive style struggled to fully comprehend the problem. They answered hesitantly and were unable to explain the problem in detail. During the interview, they also made mistakes when writing mathematical symbols on their answer sheets, highlighting the challenges they face in solving mathematical problems.

Discussion

Research on mathematical problem-solving and reasoning has decreased over the past 20 years, and more problems than answers are being raised (English, 2023). The current study revealed that students with impulsive and reflective cognitive styles face difficulty in solving mathematical problems, and require a tailored learning approach that meets their cognitive needs. Research also indicates that impulsive individuals tend to exhibit reduced novelty-seeking behaviours, affecting their decision-making processes (Burk & Averbek, 2023). In mathematics education, cognitive dimensions, personal efficacy, and management skills significantly influence students' problem-solving abilities. Studies highlight the importance of adaptive teaching strategies that align with students' cognitive styles, particularly in higher education settings focused on mental health education (Liu & Alyoubi, 2022; Mei, 2022; Mpungose & Khoza, 2022). These findings emphasize the necessity of structured interventions to improve students' learning outcomes.

To support impulsive students, structured exercises that emphasize precision, systematic double-checking, and gradual problem-solving can help slow their cognitive processes and enhance analytical depth. Meanwhile, reflective students can benefit from

time-restricted exercises to encourage efficiency without compromising analysis. Providing structured feedback tailored to students' cognitive styles can help them find a balance between speed and accuracy, fostering a more adaptive learning environment. By implementing these strategies, educators can enhance mathematical learning experiences, ultimately improving cognitive adaptability and student performance.

Overcoming teachers' difficulties in integrating teaching strategies that align with students' reflective and impulsive cognitive styles requires specialized training that deepens their understanding of cognitive diversity and equips them with diverse instructional techniques. Research suggests that individuals often rely on predetermined cognitive patterns when encountering novel and complex problems, which may hinder their ability to adapt to different learning needs (Idrizi et al., 2023; Tam & Lee, 2024). In mathematics education, many teachers adhere strictly to repetitive methods found in textbooks without fully considering their students' varying cognitive development levels, which can limit effective learning experiences (Pals et al., 2023). To address this issue, educators must be trained to recognize the different thinking styles of students and adopt more flexible approaches to instruction.

One effective strategy is implementing differentiated learning methods that allow teachers to design classroom activities suited to both cognitive styles. For instance, teachers can provide students with assignment choices, offering quick problem-solving exercises for impulsive learners while allowing reflective students to engage in deeper analysis (Li & Huang, 2024; Liao et al., 2024; Mpungose & Khoza, 2022). Additionally, integrating adaptive educational technology can help teachers tailor instructional strategies to better meet students' cognitive needs. Digital tools offering personalized feedback, real-time scaffolding, and adaptive problem-solving exercises can enhance learning outcomes for reflective and impulsive students. By adopting these targeted instructional methods, teachers can create a more inclusive and effective learning environment that accommodates diverse cognitive styles, ultimately improving students' mathematical problem-solving skills.

Implementing a concept-based learning approach is essential to address students' misconceptions and difficulties in solving mathematical problems. This method prioritizes deep understanding over rote memorization of formulas, allowing students to build a strong conceptual foundation. Many students struggle with mathematical problem-solving due to insufficient comprehension of fundamental operations and procedures, which can hinder their ability to apply mathematical concepts effectively (El Abbadi & Alaoui, 2023; Sidekerskienė & Damaševičius, 2023). These challenges stem from various factors, including cognitive barriers, instructional methods, and prior misconceptions. Therefore, educators must actively diagnose students' misunderstandings through continuous assessment and targeted interventions. Providing clear explanations, concrete examples, and real-life applications can help bridge gaps in understanding and facilitate meaningful learning experiences (Al Malki et al., 2023; Stewart & Ball, 2023).

In addition to direct instruction, collaborative learning techniques can be highly effective in reducing misconceptions and improving problem-solving abilities. Group discussions and structured problem-solving activities encourage students to share perspectives, clarify doubts, and correct errors in reasoning, leading to a more profound

comprehension of mathematical concepts (Mei, 2022; Sidekerskienė & Damaševičius, 2023). Furthermore, providing constructive feedback and incorporating iterative practice can reinforce students' conceptual mastery. Repeated exposure to mathematical principles through varied problem sets enables students to internalize key ideas and develop flexible problem-solving strategies. By integrating these approaches, educators can enhance students' mathematical reasoning skills, minimize learning obstacles, and foster a more robust understanding of mathematical concepts.

Maximizing students' reflective and impulsive thinking skills in solving mathematical problems requires a balanced learning approach that integrates critical thinking exercises and time management strategies. The socio-critical learning method has been identified as an effective approach to fostering active engagement and promoting cognitive flexibility among students (Cruz-Ramírez et al., 2022; Mpungose & Khoza, 2022). Educators can create a learning environment that supports reflective and impulsive thinkers by implementing interventions that encourage students to analyze problems while critically managing their cognitive processing speed. Studies utilizing multi-dimensional data collection and quantitative analysis through multi-case study techniques provide valuable insights into differentiated instructional approaches (Mpungose & Khoza, 2022). These findings highlight the importance of structuring learning activities to accommodate diverse cognitive styles while maintaining a collective and interactive learning experience.

For students with an impulsive cognitive style, structured exercises focusing on self-reflection and systematic double-checking can help slow down their decision-making process and improve accuracy. Meanwhile, reflective students, who take longer to analyze problems, can benefit from problem-solving tasks with time constraints to encourage quicker decision-making without compromising analytical depth (Sidekerskienė & Damaševičius, 2023; Tam & Lee, 2024). Implementing problem-based learning (PBL) strategies integrating both cognitive styles allows students to practice balancing speed and precision in problem-solving. Students develop cognitive adaptability by engaging in activities that require both rapid decision-making and in-depth analysis, ultimately enhancing their mathematical problem-solving abilities. This integrative approach ensures that reflective and impulsive thinkers optimize their potential while strengthening their mathematical competence.

Improving students' understanding of mathematical solutions requires a reasoning-based learning approach that emphasizes how to solve problems and why a particular solution is correct. Research on didactic sequences and learning trajectories using design-based research and content analysis has demonstrated the effectiveness of such an approach, particularly in engineering education (Cruz-Ramírez et al., 2022; Mei, 2022; Mpungose & Khoza, 2022). This method shifts the focus from rote memorization of formulas to a deeper exploration of the fundamental concepts and logical reasoning behind each problem-solving step. By fostering conceptual understanding, students are better equipped to apply their knowledge to various contexts rather than simply recalling procedures (Altynbekov et al., 2023; Dimos et al., 2023; Sidekerskienė & Damaševičius, 2023).

Interactive sessions and group discussions play a crucial role in this learning approach, as they encourage students to evaluate their responses and refine their reasoning critically.

By engaging in peer discussions, students gain exposure to different problem-solving perspectives, which enhances their cognitive flexibility and analytical thinking. Additionally, providing detailed feedback and assignments that require students to articulate their solution processes either orally or in writing can further reinforce their comprehension and retention of mathematical concepts. These strategies strengthen students' problem-solving abilities and cultivate their ability to justify and communicate mathematical reasoning effectively, leading to more meaningful and long-term learning outcomes.

Conclusion

The study concludes that there are significant differences in the mathematical thinking profiles of students, based on their cognitive styles (reflective and impulsive). Reflective students demonstrate more robust performance, meeting all five indicators of mathematical thinking generalization, abstraction, analytical thinking, dynamic thinking, and modelling. They are meticulous in understanding problems, systematically identifying steps, accurately solving problems, and minimizing symbolic errors through careful rechecking. Conversely, impulsive students face challenges in achieving these indicators. They respond quickly but often skip critical steps, leading to errors in symbolic representation and final results. Their conceptual understanding needs to be more thorough, and they need self-reflection and double-checking. While impulsive students can still meet the five indicators to some extent, they often appear hesitant and make more mistakes, highlighting the need for targeted learning strategies to improve precision and self-evaluation. This suggests reflective cognitive styles are more conducive to deep understanding and accuracy in solving mathematical problems, whereas impulsive styles require additional instructional support.

The findings of this study underscore the need for instructional strategies in mathematics that address different cognitive styles. Reflective students excel in mathematical thinking and benefit from structured problem-solving approaches, while impulsive students who struggle with accuracy and skipping steps need targeted interventions to enhance precision and understanding. Differentiated strategies, such as structured feedback, scaffolding, and reflective activities, can improve impulsive students' accuracy. Additionally, adaptive learning technologies and problem-based learning can bridge the gap between cognitive styles, ensuring all students develop mathematical proficiency tailored to their needs.

Future research should focus on developing cognitive-based learning models that address the differences in cognitive styles, helping reflective students improve efficiency and impulsive students enhance precision. Longitudinal studies could provide insights into how cognitive styles evolve and impact problem-solving skills. Additionally, exploring the integration of digital tools, such as AI tutoring and adaptive feedback, could help impulsive learners while enhancing reflective learners' strengths. Cross-disciplinary studies can also expand understanding of cognitive styles in STEM fields. Lastly, research should develop interventions, like scaffolding, metacognitive training, and time management, to improve impulsive students' accuracy and analytical depth, ultimately contributing to more effective teaching strategies.

References

- Al Malki, M., Al'Adawi, S., Al-Azzawi, N., & Al-Abri, K. (2023). Open-book-based Assessment during COVID-19: Challenges and Opportunities. *International Journal of Learning, Teaching and Educational Research*, 22(8), 146-168. <https://doi.org/10.26803/IJLTER.22.8.9>
- Albaum, C. S., Sellitto, T., Vashi, N., Bohr, Y., & Weiss, J. A. (2023). Treatment Engagement as a Predictor of Therapy Outcome Following Cognitive Behaviour Therapy for Autistic Children. *Journal of Autism and Developmental Disorders*, 3575-3586. <https://doi.org/10.1007/s10803-023-06083-7>
- Altynbekov, S., Ashirbayev, N., Torebek, Y., & Kerimbekov, T. (2023). Formation of Research Skills of Future Teachers of Mathematics in Solving Olympiad Problems. *Academic Journal of Interdisciplinary Studies*, 12(6), 335-346. <https://doi.org/10.36941/ajis-2023-0173>
- Burk, D. C., & Averbeck, B. B. (2023). Environmental uncertainty and the advantage of impulsive choice strategies. *PLoS Computational Biology*, 19(1). <https://doi.org/10.1371/journal.pcbi.1010873>
- Cheung, F. (2024). Career self-efficacy as a mediator between career-specific parental behaviors and school career support on career doubt. *BMC Psychology*, 12(1), 1-10. <https://doi.org/10.1186/s40359-024-01536-9>
- Cruz-Ramírez, S. R., García-Martínez, M., & Olais-Govea, J. M. (2022). NAO robots as context to teach numerical methods. *International Journal on Interactive Design and Manufacturing*, 16(4), 1337-1356. <https://doi.org/10.1007/s12008-022-01065-y>
- Dimos, I., Velaora, C., Louvaris, K., Kakarountas, A., & Antonarakou, A. (2023). How a Rubric Score Application Empowers Teachers' Attitudes over Computational Thinking Leverage. *Information (Switzerland)*, 14(2), 1-20. <https://doi.org/10.3390/info14020118>
- El Abbadi, S., & Alaoui, M. I. H. (2023). Distance Mathematics Teaching and Academic Performance in Morocco. *International Review of Research in Open and Distributed Learning*, 24(3), 234-249. <https://doi.org/10.19173/irrodl.v24i3.7150>
- English, L. D. (2023). Ways of thinking in STEM-based problem solving. *ZDM - Mathematics Education*, 55(7), 1219-1230. <https://doi.org/10.1007/s11858-023-01474-7>
- Guo, Q. (2023). Minimizing Emotional Labor through Artificial Intelligence for Effective Labor Management of English Teachers. *Journal of Combinatorial Mathematics and Combinatorial Computing*, 117, 37-46. <https://doi.org/10.61091/jcmcc117-04>
- Hameni Nkwayep, C., Glèlè Kakäi, R., & Bowong, S. (2024). Prediction and control of cholera outbreak: Study case of Cameroon. *Infectious Disease Modelling*, 9(3), 892-925. <https://doi.org/10.1016/j.idm.2024.04.009>
- Herrero, A. C., Recio, T., Tolmos, P., & Vélez, M. P. (2023). From the Steam Engine to STEAM Education: An Experience with Pre-Service Mathematics Teachers. *Mathematics*, 11(2), 1-18. <https://doi.org/10.3390/math11020473>
- Ho, Y. R., Chen, B. Y., & Li, C. M. (2023). Thinking more wisely: using the Socratic method to develop critical thinking skills amongst healthcare students. *BMC Medical Education*, 23(1), 1-16. <https://doi.org/10.1186/s12909-023-04134-2>
- Houghton, S., & Moss, M. (2024). Exploring the Impact of Safer Sports Betting Promotion on Social Media: An Experimental Study. *Journal of Gambling Studies*, 40(3), 1085-1102. <https://doi.org/10.1007/s10899-024-10280-z>

- Hourigan, M., & Leavy, A. M. (2023). Elementary teachers' experience of engaging with Teaching Through Problem Solving using Lesson Study. *Mathematics Education Research Journal*, 35(4), 901-927. <https://doi.org/10.1007/s13394-022-00418-w>
- Idrizi, E., Filiposka, S., & Trajkovikj, V. (2023). Gender impact on STEM online learning- a correlational study of gender, personality traits and learning styles in relation to different online teaching modalities. *Multimedia Tools and Applications*, 82(19), 30201-30219. <https://doi.org/10.1007/s11042-023-14908-x>
- Kay, L., & Buxton, A. (2024). Makerspaces and the Characteristics of Effective Learning in the early years. *Journal of Early Childhood Research*, 22(3), 343-358. <https://doi.org/10.1177/1476718X231210633>
- Khoza, S. B. (2023). Can Teachers' Identities Come to the Rescue in the Fourth Industrial Revolution? *Technology, Knowledge and Learning*, 28(2), 843-864. <https://doi.org/10.1007/s10758-021-09560-z>
- Li, B., & Huang, Q. (2024). Synchronization of time-delay systems with impulsive delay via an average impulsive estimation approach. *Mathematical Biosciences and Engineering*, 21(3), 4501-4520. <https://doi.org/10.3934/mbe.2024199>
- Liao, J., Wang, J., Li, J., & Jiang, X. (2024). The dynamics and control of a multi-lingual rumor propagation model with non-smooth inhibition mechanism. *Mathematical Biosciences and Engineering*, 21(4), 5068-5091. <https://doi.org/10.3934/mbe.2024224>
- Liu, S., & Alyoubi, K. H. (2022). Verifying the validity of the whole person model of mental health education activities in colleges based on differential equation. *Applied Mathematics and Nonlinear Sciences*, 7(2), 285-296. <https://doi.org/10.2478/amns.2021.2.00067>
- Mei, D. (2022). What does students' experience of e-portfolios suggest. *Applied Mathematics and Nonlinear Sciences*, 7(2), 15-20. <https://doi.org/10.2478/amns.2021.2.00166>
- Mpungose, C. B., & Khoza, S. B. (2022). Postgraduate Students' Experiences on the Use of Moodle and Canvas Learning Management System. *Technology, Knowledge and Learning*, 27(1), 1-16. <https://doi.org/10.1007/s10758-020-09475-1>
- Pals, F. F. B., Tolboom, J. L. J., & Suhre, C. J. M. (2023). Formative Assessment Strategies by Monitoring Science Students' Problem-Solving Skill Development. *Canadian Journal of Science, Mathematics and Technology Education*, 23(4), 644-663. <https://doi.org/10.1007/s42330-023-00296-9>
- Sidekierskienė, T., & Damaševičius, R. (2023). Out-of-the-Box Learning: Digital Escape Rooms as a Metaphor for Breaking Down Barriers in STEM Education. *Sustainability (Switzerland)*, 15(9). <https://doi.org/10.3390/su15097393>
- Stewart, E., & Ball, L. (2023). The Tension Between Allowing Student Struggle and Providing Support When Teaching Problem-Solving in Primary School Mathematics. *Canadian Journal of Science, Mathematics and Technology Education*, 23(4), 791-817. <https://doi.org/10.1007/s42330-024-00309-1>
- Tam, L., & Lee, H. (2024). *From Conspiracy Orientation to Conspiracy Attribution: The Effects of Institutional Trust and Demographic Differences* (Vol. 68). American Behavioral Scientist. <https://doi.org/10.1177/00027642231174330>
- Walker, B. J., Townsend, A. K., Chudasama, A. K., & Krause, A. L. (2023). VisualPDE: Rapid Interactive Simulations of Partial Differential Equations. *Bulletin of Mathematical Biology*, 85(11), 1-24. <https://doi.org/10.1007/s11538-023-01218-4>
- Wei, J. J., Lin, H. H., & Chen, S. L. (2023). Design of teaching aids in STEAM education and

- fuzzy hierarchical analysis of their educational effect. *Eurasia Journal of Mathematics, Science and Technology Education*, 19(11). <https://doi.org/10.29333/ejmste/13749>
- Wilson, A. C., & Gullon-Scott, F. (2023). Social Anxiety in Autistic People: Does the Clark and Wells Model fit? *Journal of Autism and Developmental Disorders*, 3908-3920. <https://doi.org/10.1007/s10803-023-06108-1>
- Yang, H., Zhu, H., Luo, W., & Peng, W. (2023). Design and practice of innovative practice workshop for new nurses based on creativity component theory and outcome based education(OBE) concept. *BMC Medical Education*, 23(1), 1-9. <https://doi.org/10.1186/s12909-023-04684-5>
- Zhou, D., Gomez, R., Davis, J., & Rittenbruch, M. (2023). Engaging solution-based design process for integrated STEM program development: an exploratory study through autoethnographic design practice. *International Journal of Technology and Design Education*, 33(2), 717-748. <https://doi.org/10.1007/s10798-022-09745-2>