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Using Reflective Thinking to Find the Best Solutions to Combinatorics Problems

Buhaerah Mappanyompa[1]*, Muhammad Ahsan[1], Abdullah Ibrahim[2]
[1] Department of Mathematics Education, Institut Agama Islam Negeri Parepare, South Sulawesi, Indonesia
[2] Fakulti Pengajian Umum dan Pendidikan Lanjutan, Universiti Sultan Zainal Abidin, Terengganu, Malaysia
E-mail: buhaerah@iainpare.ac.id
* Corresponding Author

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ABSTRACT

Penelitian ini bertujuan mengeksplorasi proses berpikir reflektif dalam memecahkan masalah kombinatorial untuk mendapatkan solusi optimal. Sebanyak tujuh puluh mahasiswa yang telah atau sedang mengambil mata kuliah kombinatorial dan berpartisipasi dalam penelitian ini. Prosedur penelitian meliputi pemilihan partisipan yang sesuai, penyebaran pertanyaan kombinatorial yang telah diuji kualitasnya untuk memastikan validitas dan reliabilitas, dan pelaksanaan tes. Setelah tes, wawancara dilakukan dengan beberapa mahasiswa yang dipilih secara acak. Data dari tes dan wawancara dianalisis berdasarkan indikator berpikir reflektif. Penelitian ini menggunakan beberapa instrumen, seperti Myers-Briggs Type Indicator dan Matching Familiar Figures Test, untuk mengidentifikasi karakteristik dan kecenderungan berpikir reflektif mahasiswa. Analisis data meliputi analisis hasil, perbandingan hasil antara mahasiswa reflektif untuk setiap instrumen, dan perumusan kesimpulan. Hasil penelitian menunjukkan bahwa berpikir reflektif membantu mahasiswa mengevaluasi strategi mereka, mengidentifikasi kesalahan lebih cepat, dan menyesuaikan pendekatan berdasarkan pemahaman baru yang diperoleh dari refleksi. Pendekatan ini terbukti efektif dalam mendukung pemecahan masalah yang lebih kreatif dan sistematis serta membantu mencapai solusi optimal sesuai dengan tujuan penelitian.

This research explores the reflective thinking process in solving combinatorial problems to achieve optimal solutions. Seventy students who have taken or are taking combinatorial courses participated in this study. The research procedure includes selecting suitable participants, distributing combinatorial questions that have been tested for quality to ensure validity and reliability, and conducting tests. After the test, interviews were conducted with several randomly selected students. Data from tests and interviews were analyzed based on reflective thinking indicators. This study uses several instruments, such as the Myers-Briggs Type Indicator and the Matching Familiar Figures Test, to identify students' reflective thinking characteristics and tendencies. Data analysis includes analyzing the results, comparing the results between reflective students for each instrument, and formulating conclusions. The results showed that reflective thinking helped students evaluate their strategies, identify mistakes faster, and adjust approaches based on new understandings gained from reflection. This approach has proven effective in supporting more creative and systematic problem-solving and helping achieve optimal solutions according to research objectives.

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INTRODUCTION

Reflective thinking plays a role in solving problems and increasing the accuracy of optimal solutions. The variance in parental education levels in communities is also reflected in our sample (Gotlieb, Yang, and Immordino-Yang 2024). Reflective capacity is the ability to reconsider past experiences (Khoshgoftar and Barkhordari-Sharifabad 2023). It is especially appropriate for guidelines focusing on population and system-level treatments (Movsisyan et al. 2024). The optimal solutions, which considered both objective functions, varied very little (Karthik et al. 2024). An advanced class of mathematical problems is solving optimization issues in scientific research and mathematics teaching (Wang, Zhang, and Jin 2024). Algorithms based on modeling techniques may help tackle issues with certain features but may only apply to a few optimization problems (Subburaj et al. 2024). Incorporating a chaotic self-adaptive mechanism into the optimization procedure enhances optimal solutions and performance attributes (Karthik et al. 2024). Resources are used effectively, promoting a more methodical approach to finding the best answers (Cuevas et al. 2024). Many presumptions are made to solve the system (Alinezhad, Khatibi, and Ashrafizadeh 2024).

Reflective thinking contributes to identifying patterns and structures in combinatorics problems. One element of ongoing assessment in education now includes reflective writing (Ismail et al. 2024). This thoughtful story reinforces the need for regular mental models and methods of operation to be checked for (Neville 2023). Numerous studies indicate that these networks facilitate effortful, concentrated, contemplative thinking (Gotlieb et al. 2024). Important stakeholders provided input informing the study's objectives (Scheidell et al. 2024). These investigations assume that some underlying mechanism is at work, and they debate the existence of self-replication (Corominas-Murtra, Seoane, and Solé 2018). The model's predictive performance may be further enhanced by combining these regularization strategies with dimensionality reduction approaches (Oshternian et al. 2024). This optimization problem is because a comprehensive analysis of every combination of core genes is not practicable in practice due to the situation's combinatorics (Garnier et al. 2018).

Combinatorics problem solving can be optimized by using algorithms, which include defining the problem, planning a solution, choosing a solution, implementing the Solution, and reviewing the results. The instruction emphasized the significance of excellent and clear communication (Kwon et al. 2024). Teaching mathematics using picture books, consider broadening the narrative to include other media, like movie clips and short films (Russo, Russo, and Roche 2021). There are significant scientific questions for which no analytical solutions exist; however, in two dimensions, they can be integrated (Lavaei 2024). Therefore, choosing an approach based on a trial and error method takes time to solve a given optimization problem (Subburaj et al. 2024). The data is represented in the activation states and network connectivity (Mininni and Zanutto 2024). Studies have shown that creativity may be naturally cultivated in all people via thoughtful preparation and application of materials to support the Process (Mahlaba 2020).

They maximize the opportunity to find a more optimal solution in combinatorics problem solving, both in effectiveness and efficiency. Support good communication and work toward mutually beneficial settlements by being able to recognize and interpret signals (Ismail et al. 2024). A problem can lead to solutions that divert or preserve attention from the real issue (Plamondon et al. 2023). More than any other country, I have learned to use personal initiative to achieve fundamental objectives and ideals (Khoshgoftar and Barkhordari-Sharifabad 2023). The findings demonstrated that these kinds of problems interest and encourage experimentation and the development of several approaches to problem-solving (Rizos and Gkrekas 2023). The learning process was followed by the written exam, which covered the markers of problem-solving abilities (Putri, Zulkardi, and Riskanita 2022). Students should be able to solve problems by utilizing a variety of tactics as crucial tools in resolving this kind of circumstance and addressing all types of mathematics problems (Barbosa and Vale 2021). Numerous research has demonstrated that when addressing issues and individual reasoning (Chrismawaty et al. 2023),

Optimal solutions to combinatorics problems are about getting the right results and finding solutions most efficiently and effectively. It is crucial to remember that their technique is heuristic and based on the k-walk theory. Thus, it might only sometimes yield the best answers (Someya, Akutsu, and Nacher 2024). The requirement is to thoroughly sample the search space with limited information to locate interesting locations (Cuevas et al. 2024). Space mathematics issues are typically complicated

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and nonlinear (Karthik et al. 2024). Algorithms manipulate one or more possible solutions to arrive at the best or most advantageous option to tackle highly complicated optimization problems (Wang et al. 2024). Most courses emphasize problem-solving, professional skills, and illness treatment rather than developing critical thinking and metacognitive abilities (Ho, Chen, and Li 2023). Students work in groups to complete the research assignment, thoroughly examining the issue and pinpointing important answers (Yang et al. 2023). Students are involved in interactive exercises that enable them to use their newly acquired information to solve challenging challenges with their peers (Lu et al. 2023). During the next in-person class period, students are involved in interactive exercises that enable them to use their newly acquired information to solve challenging challenges with their peers (Wijeakumar et al. 2023).

The ability to think reflectively benefits finding optimal solutions in combinatorics problem solving, namely the Development of Alternative Strategies and Better Decision Making. Reinforcement learning uses interactions between agents and their surroundings to maximize cumulative rewards to choose the best course of action (Shixin et al. 2024). The requirement is to thoroughly sample the search space with limited information to locate interesting locations (Cuevas et al. 2024). Reflective capacity predicts the inclination toward critical thinking (Khoshgoftar and Barkhordari-Sharifabad 2023). These constraint signal separation problems need more estimation strength for subject-wise analysis (Khalid et al. 2024). Scholars have posited that reflective practice is crucial for achieving professionalism and humanism in medicine (Ho et al. 2023).

In contrast to studies on learning-by-teaching from other areas (Kuhn et al. 2023). The following optional methods can be applied to modify any formulation (Becker, Araújo, and Buriol 2022). Here, we concentrate on the combinatorial setting; no probability distribution is applied to any particular item (Bui et al. 2022).

However, there are still reflective thinking processes that could be more optimal in contributing. Reinforcement learning uses interactions between agents and their surroundings to maximize cumulative rewards to choose the best course of action (Sweeney et al. 2024). Guiding a learner involves both critical thinking and reflective practice, which are interwoven processes (Khoshgoftar and Barkhordari-Sharifabad 2023). There were embedded chances for small-group interactive, experiential learning, reflective practice, critical thinking, and application (Jaramillo-Restrepo et al. 2024). Instructors are urged to highlight various problem-solving methods, assist students in making connections between multiple answers, and accept mistakes as valuable learning experiences (Soto, Siy, and Harel 2022). Working with the analytical formulations for these models requires much combinatorial analysis (Arpin, Popa, and Turner 2022). We consider the mathematical formalization offered by combinatorics to examine the variety of patterns seen in Temari balls and their potential musical representation (Mannone and Yoshino 2022).

Reflective thinking needs more space in the problem-solving Process. The new research has significant practical ramifications for educational initiatives that increase students' reflective capacity and foster critical thinking (Khoshgoftar and Barkhordari-Sharifabad 2023). The Process of changing one's thoughts and actions on the inside through introspection is known as reflective practice (Ide and Beddoe 2024). Students were required to write a reflection on their performance and the lecturer's criticism following the small group discussion to complete the reflective writing analysis (Ismail et al. 2024). it can quickly and efficiently solve simple differential equations (Agraz 2024). This method reduces the range of usage by using an offline statistical method even though it enhances positioning precision. to address the issues mentioned previously (Hou et al. 2024).

Supervision and control of the reflective thinking process are necessary for practical evaluation and identification of optimal solutions. This thoughtful story reinforces the need for constant self-reflection to ensure that harmful and racially incorrect presumptions, mental models, and methods of operation are examined (Neville 2023). As a result, this study used topic modeling to assess students' reflective thinking. It proved that game-based learning activities are essential for encouraging learners' reflective thinking and professional development (Kwon et al. 2024). Another research investigates collective responsibilities and issues of solidarity in global governance throughout time through an active process of critically reflective discussion with a varied audience of people with knowledge and interest in the policy implications of vaccine nationalism (Plamondon et al. 2023). However, these coefficients lacked a direct combinatorial explanation (Gan, Ouvry, and Polychronakos 2022). A minimal way to write a word's syndrome as a linear combination of the columns of a particular parity check matrix is one-to-one with the cost of that word (Blokhuis, Pellikaan, and Szőnyi 2022).

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No involvement in identifying patterns and structures in combinatorics problems for optimal solutions. The results showed that the cylindrical shape of the soft layer had an ideal charge value at low electrolyte concentrations (Alinezhad et al. 2024). Depending on the size of the search space, the perfect number of neurons in the hidden layer must be carefully balanced (Cuevas et al. 2024). The new research has significant practical ramifications for educational initiatives that increase students' reflective capacity and foster critical thinking (Khoshgoftar and Barkhordari-Sharifabad 2023). The adhesion and storage issues in the mathematics problem application of ice particle air jet technology were resolved by the quick manufacture and use of ice particles (Man, Zehua, and Liu 2024). They suggested a novel iterative method for resolving issues with nonlinear mathematics (Ganie et al. 2024). gives values to the network firing states connected to every node in the graph and solves linear separation problems to determine the synaptic weight matrices (Mininni and Zanutto 2024).

Difficulty in integrating different information in the Process of developing optimal solutions. Fundamentally, optimization determines the best variables or conditions to meet specific constraints to maximize or minimize a goal function (Cuevas et al. 2024). Around some steady states, we find an optimal function space that guarantees the local existence of solutions to the linearized model (Bachmann et al. 2023). Combinatorics can be used to study the variety of their geometries and tessellations both computationally and formally (Mannone and Yoshino 2022). The critical component of these simulations is the formulations for the coefficients, which involve a large amount of combinatorics (Arpin et al. 2022). In this case study, we examine a teacher's application of based combinatorics curriculum in a high school discrete mathematics class (Soto et al. 2022).

Reflective thinking in solving combinatorics problems follows a structured process that includes reviewing solution steps, evaluating errors, and developing more effective alternative strategies. This type of thinking begins with a state of confusion and involves repeated evaluation until a solution is reached (Pamungkas et al. 2025; Sa'dijah et al. 2020). By engaging in reflection, individuals can analyze the appropriateness of their steps, identify and correct mistakes, and refine their strategies for future problem-solving situations (Kusmaryono imam 2023; Pamungkas et al. 2025; Setiyani*;S. B. Waluya;Y.L. Sukestiyarno;Adi Nur Cahyono 2022). The stages involve first recalling and reviewing the solution steps, then monitoring and assessing the correctness of those steps, and finally conceptualizing new approaches that may yield better results (Alfayez, Aladwan, and Shaheen 2022; Braund 2021). These stages are supported by key aspects of reflective thinking such as technique, monitoring, insight, and conceptualization, which together guide learners in systematically addressing complex problems.

In the context of combinatorics, reflective thinking is especially valuable as it enables students to compare different methods, evaluate their efficiency, and select the most effective one. This cyclical process of reviewing, evaluating, and revising not only leads to accurate solutions in the immediate problem but also strengthens students' long-term problem-solving skills (Geiger and Schmid 2024; Rosana et al. 2021; Setiyani*;S. B. Waluya;Y.L. Sukestiyarno;Adi Nur Cahyono 2022) Ultimately, reflective thinking equips learners with the ability to adapt their strategies, avoid recurring errors, and approach future combinatorics challenges with greater confidence and efficiency.

This research is vital because reflective thinking can help identify patterns and structures underlying combinatorics problems, alternatively, by organizations that actively seek to change the system in which they find themselves engaged. They employ systems thinking and critically reflective discourse in their local contexts to examine how equality is operationalized (Plamondon et al. 2023). Extensive research indicates that these networks facilitate introspective, self-reflective, and unstructured thinking and deliberate, concentrated thinking, respectively (Gotlieb et al. 2024). It is acknowledged that reflective practice is a crucial instrument for decolonizing work and a tactic to undermine white power (Neville 2023). Neglecting childhood issues and providing inadequate guidance during childhood growth is the primary cause of the majority of physical and mental diseases that manifest in adulthood (Faghani et al. 2024).

In addition, reflective thinking can encourage individuals to consider various alternative solutions and evaluate the effectiveness of each. Critical thinking is closely related to what has been learned or is being gained (Khoshgoftar and Barkhordari-Sharifabad 2023). Reflective learning and its pedagogy and assessment have drawn attention in the last ten years (Fakhri et al. 2023). Our primary finding creates an ideal function space for smooth solutions local in time (Bachmann et al. 2023). Rethinking viewpoints on issue-solving and how various modes of thinking can help or impede solutions is one such

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consequence (English 2023). To improve assessment accuracy and efficiency, they also consider how steps are observed in the Solution of a problem (Brancaccio, de Chiusole, and Stefanutti 2023).

In the context of combinatorial problem-solving, effective feedback plays a crucial role in enhancing student performance. For instance, groups that received sufficient feedback through simple tools such as sticky notes demonstrated significantly greater progress compared to those that did not (Pals, Tolboom, and Suhre 2023). Beyond direct problem-solving, training also emphasized essential complementary skills, including stress management, communication, and time management, which are all vital in navigating complex problem scenarios (Nguyen et al. 2023). The strategies proposed in this area often stem from two central challenges, leading to distinct approaches designed to overcome them (Schaller et al. 2023). These approaches require comprehensive analysis of the problem space and the identification of pivotal solutions that can optimize outcomes (Yang et al. 2023). Furthermore, combinatorial problem-solving is deeply connected to the development of higher-order skills, such as critical thinking, evidence-based reasoning, and effective decision-making, which together strengthen students' ability to address both mathematical and real-world challenges (Ho et al. 2023).

This research explores the reflective thinking process in solving combinatorics problems for optimal solutions. Metaheuristics do not rely on as stringent mathematical features as classical approaches, which frequently demand constraints like convexity and differentiability to guarantee finding an optimal solution (Cuevas et al. 2024). One element of ongoing assessment in mathematics education education now includes reflective writing. Examining a student's past performance is a practice that has grown to be important to the idea of learning from experience (Ismail et al. 2024). Our goals are to demonstrate the Process of adopting the integrated framework in guideline creation and to offer thoughtful observations about the benefits, difficulties, and lessons learned (Movsisyan et al. 2024). The Tent map yielded a more accurate solution than other maps regarding generating chaotic variables. The Tent map, Logistic map, and Gaussian map are all considered and applied to all the issues in this study

Reflective thinking contributes significantly to combinatorics problem solving because it allows students to review the steps taken, identify patterns, and evaluate the strategies used more critically. Through this process, students not only pay attention to the final result but also examine the consistency and accuracy of the procedures carried out, so that errors or inconsistencies can be identified early and immediately corrected. Reflection also encourages creativity by opening up opportunities for students to develop alternative strategies that are more effective and adaptive in dealing with complex problems. Thus, this research is important because it provides a deeper understanding of how reflective thinking serves as a foundation for building critical, systematic, and flexible thinking skills, ultimately strengthening the achievement of optimal solutions in combinatorics problem solving and supporting the broader goals of mathematics education .

METHOD

This research methodology is structured in a logical sequence, beginning with participant selection, followed by testing, interviews, and data analysis. Each stage is designed to transition smoothly into the next to ensure a systematic and consistent research process.

Research Procedure. The procedure begins with the selection of participants who meet predetermined criteria. Participants are then given combinatorics problems that were designed based on reflective thinking indicators to optimize solutions in problem-solving. The quality of the test items was examined in advance to ensure validity and reliability. Students completed the test within the allocated time limit, after which several participants were randomly selected for semi-structured interviews. These interviews provided deeper insights into their thought processes and were conducted after the test sessions. Test and interview data were later analyzed separately according to reflective thinking indicators, with the results offering an overview of the diverse ways students approach combinatorics problem-solving.

Instruments. Three main instruments were used in this study: Myers-Briggs Type Indicator (MBTI) – Matching Familiar Figures Test (MFFT). This instrument identified student characteristics and reflective thinking tendencies, offering insights into how they gather and process information and make decisions. Combinatorics Mathematics Problem Test. This instrument measured students' ability

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to solve combinatorics problems. The test items covered a range of combinatorial concepts and provided an overview of both conceptual understanding and the application of knowledge in problem-solving contexts. Semi-structured Interview Sheet. The interview instrument supported test results by deepening the understanding of students' reflective processes. Questions explored problem-solving strategies, steps taken, and reflections on the solutions produced.

Data Analysis. Data analysis was carried out in several stages: Analysis of MFFT results. Groups of students were identified based on their tendency toward reflective or impulsive thinking, with attention given to patterns or distinctive characteristics within each group. Analysis of combinatorics test results. Student performance was evaluated by examining the strategies used in solving problems, particularly among reflective students. Analysis of interview results. Responses were reviewed to identify how students understood the steps and strategies applied in problem-solving, and whether reflective or impulsive tendencies were evident in their reasoning. The findings from these analyses were then compared across groups to identify significant differences in performance, strategy use, and reflective tendencies. Observations focused on how student characteristics influenced both the process and the outcomes of solving combinatorics problems. Conclusions and Implications. Based on the comparative analysis, conclusions were drawn regarding how reflective students approach combinatorics problem-solving and whether specific patterns indicated a relationship between their characteristics and performance. Finally, the study discusses the implications of these findings for the teaching and learning of combinatorics and provides recommendations for developing instructional methods that support diverse student characteristics.

RESULTS

This chapter describes and analyzes research data to understand students' reflective thinking processes and how both processes are internalized in solving combinatorics problems. The research was conducted on students of the Mathematics Education study program. A total of 17 students participated in this study. The research began by distributing question sheets to students to be worked on independently under strict supervision. After completion, the supervisor collected the answer sheets and submitted them to the researcher. After collecting the answers, the researcher interviewed randomly selected students to learn more about solving combinatorics problems. The research and interview results and the thinking process analysis are described as follows.

Table 1. Percentage and Number of Students Based on Problem-Solving Stages

Question Number	Number and Percentage of Students at Each Stage of Problem Solving			
	Understanding the Problem	Planning a Solution	Finding Solutions	Reviewing Solutions
1	17 (100%)	16 (94%)	16 (94%)	12 (71%)
2	17 (100%)	16 (94%)	16 (94%)	15 (88%)
3	16 (94%)	15 (88%)	14 (82%)	13 (76%)
4	16 (94%)	15 (88%)	13 (76%)	12 (71%)
5	17 (100%)	15 (88%)	14 (82%)	13 (76%)
Average	16,6 (97,6%)	15,4 (90,6%)	14,6 (85,9%)	13 (76,0%)

Based on the table, the percentage and number of students based on the problem-solving stages will be converted into the following problem-solving ability category table.

Table 2. Categories of Problem-Solving Abilities

No	percentace	Classification
1	85,00 < n < 100,00	Very good
2	70,00 < n < 85,00	Good
3	55,00 < n < 70,00	Pretty good
4	00,01 < n < 55,00	Not good

Based on the table of percentage and number of students based on problem-solving stages, the average student showed excellent performance in several stages. At the stage of understanding the

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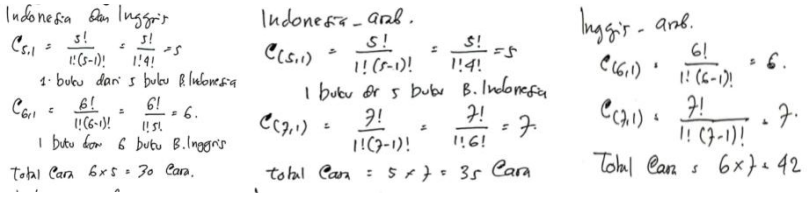
problem, the average percentage reached 97.6% with an average value of 16.6, which is in the outstanding category. At the stage of planning a solution, the average percentage also reached 97.6%, with an average value of 15.4, which is in the outstanding category. When finding a solution, the average percentage was 85.9%, with an average value of 14.6, also in the exceptional category. While at the stage of reviewing solutions, the average percentage reached 76% with an average value of 13, which is in the excellent category.

Problem

There are five books in Indonesian, six in English, and seven in Arabic. Calculate the possible outcomes if two books from 2 different languages are chosen.

Answer

Before students do the assignments given, students are asked to read and understand the questions. After reading the questions carefully, students write $C_{(3,2)} = \frac{3!}{2!(3-2)!} = \frac{3!}{2!\cdot 2!} = 3.$ as a form of student understanding of the problems presented, and this is the student's initial plan in writing the answer. Next, the student continues his writing by writing.



This answer proves that the student has found a solution to the given problem. Then, the student continues his answer by writing $30 + 35 + 42 = 107$ Cara. as a form of student confirmation of the answers they have obtained.

Based on the workflow above, the students' thinking process in solving combinatorics problems is as follows: Students need to clearly understand what the question asks, as a Step, Understand the situation, and plan the Solution. Then, they have to choose two books from 2 different languages; we have to determine which language pairs can be selected. With three different languages (Indonesian, English, Arabic), we can choose two languages from the three languages. The possible combinations are Indonesian and English, Indonesian and Arabic, and English and Arabic. The potential language combinations can be calculated using the combination formula: $(3 \mid 2) = 3$. So, there are three ways to choose two languages from the three languages. Now, we need to calculate the possibilities for each language combination as a step-finding solution. Finally, add up all the options that we have calculated for each language combination: 30 (Indonesian and English) + 35 (Indonesian and Arabic) + 42 (English and Arabic) = 107. Finally, they review the Solution as the last stage in solving combinatorics problems.

Based on the table and the results of the data analysis above, students' problem-solving abilities have met the minimum criteria of good. This shows that the students' reflective thinking process in solving combinatorics problems has gone as expected.

Internalization of Students' Reflective Thinking Process in Solving Combinatoric Problems. Internalizing reflective thinking processes in solving combinatoric problems requires a continuous and repetitive approach. Students must be guided through various stages so that this thinking process becomes part of their habits. The following describes the internalization of students' reflective thinking processes in solving combinatorics problems.

Table 3. Internalization of Reflective Thinking Processes in Combinatorics Problems

Internalization of Process		Reflective thinking on combinatorics problems
Initial understanding	Introduction to Concepts	It is an essential process in solving combinatorics problems because it allows students to consciously consider each step, evaluate alternatives, and ensure the accuracy of decisions. This approach helps avoid errors arising from hasty decision-making, thus allowing for accurate and precise mathematical results, which demands precision and patience.

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Internalization of Process		Reflective thinking on combinatorics problems
	Case Studies and Examples	Students use real-world examples, employ reflective thinking to successfully solve combinatorial problems, and discuss their results and processes.
Repeated Practice and Habituation	Structured Training	They are presenting combinatorial problems that require reflective thinking. Start with simple problems and increase their complexity over time.
	Reflection journal	a. Ask students to write a reflection journal after each exercise. Students should record their thinking process, decisions, and their reasons. b. Please e c. please encourage students to evaluate the effectiveness of their approach and consider alternatives.
Use of Tools and Technology	Digital Aids	a. I use Mathematica, MATLAB, or online combinatorics applications to visualize and explore problems. b. Conducting simulations and interactive games to practice reflective thinking in a controlled environment.
Collaborative Learning	Group Discussion	Debates and Presentations: Hold debate and presentation sessions in which students defend their solutions and receive feedback from their classmates.
Metacognition and Self-Awareness	Metacognitive Exercises	a. Teach students to be aware of their thinking processes. They should be able to recognize when they are using reflective thinking. b. Train students in strategies such as planning, monitoring, and evaluating their thinking processes.
Assessment and Feedback	Formative Assessment	a. Use quizzes and short assignments to monitor student understanding periodically. Provide constructive feedback. b. Conduct observations during class sessions and provide direct feedback on their thinking processes.
	Summative Assessment	Design a final project requiring reflective thinking to solve a combinatorics problem. Include elements that require quick decisions to assess their thinking skills.
Soft Skills Development	Communication Skills	Train good communication skills so students can articulate their thought processes and receive feedback from others.
	Time Management	They are helping students develop time management skills to avoid decisions caused by time pressure.
Integration in Curriculum	Inclusion in Lecture Materials	a. Integrate the concept of reflective thinking into every lecture material. Make students familiar with this approach in every learning. b. Conduct periodic evaluations to ensure students continue developing and internalizing this thinking process.

By implementing these strategies, students can internalize the reflective thinking process in solving combinatorics problems. This approach will help them become more effective in analysis and decision-making in academic and professional contexts.

The results of this study revealed that students tend to use a reflective thinking approach when facing more complex combinatorics problems. This finding highlights the importance of reflective thinking in the learning process, particularly in subjects that require higher-order cognitive skills. Reflective thinking encourages students to engage deeply with the material, allowing them to analyze and evaluate their understanding of the concepts at hand. As students encounter intricate problems, such as those involving the calculation of combinations, they are prompted to think critically about the methods and strategies they employ.

For example, when students face issues involving calculating combinations of several elements, those who adopt a reflective approach are more likely to formulate strategies carefully. This careful

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formulation is essential in combinatorics, where the relationships between elements can be complex and multifaceted. Students who take the time to reflect on their problem-solving process are better equipped to identify potential pitfalls and misconceptions. By considering various strategies and approaches, they can select the most effective method for tackling the problem, which ultimately leads to a more robust understanding of the material. Moreover, reflective thinkers are inclined to check each step before reaching the final solution. This practice of verification not only enhances accuracy but also reinforces learning by allowing students to recognize and correct errors in their reasoning. By systematically reviewing their work, students develop a habit of diligence and attention to detail, which is crucial in mathematics. This approach not only aids in solving combinatorics problems but also fosters a deeper appreciation for the problem-solving process itself, encouraging a mindset that values thoroughness and critical evaluation in all areas of study.

The data obtained from this study significantly strengthens the existing findings regarding the effectiveness of reflective thinking in problem-solving. Specifically, it reveals that 70% of students who adopt a reflective approach are able to successfully solve combinatorics problems correctly. This statistic underscores the positive correlation between reflective thinking and academic performance in mathematics, particularly in areas that require intricate reasoning and strategic planning. By emphasizing the role of reflection in learning, the study provides valuable insights into how students can enhance their problem-solving skills. These findings highlight the importance of a reflective thinking approach when tackling complex mathematical problems. Reflective thinking encourages students to engage in thorough analysis and careful consideration of the problem at hand. This method not only aids in understanding the underlying principles of combinatorics but also fosters a deeper comprehension of mathematical concepts overall. As students reflect on their thought processes and the strategies they employ, they become more adept at identifying potential pitfalls and developing effective solutions, which is crucial in a subject that often presents challenges. In conclusion, the study's results advocate for the integration of reflective practices into mathematics education, particularly in the realm of combinatorics. By promoting a reflective approach, educators can equip students with the necessary tools to navigate complex problems with confidence and accuracy. As the data suggests, fostering an environment that values reflection can lead to improved problem-solving abilities, ultimately enhancing students' overall mathematical proficiency. This approach not only benefits individual learners but also contributes to a more robust understanding of mathematics as a discipline.

Furthermore, these results indicate that an approach may have limitations in the context of problems requiring strategic planning and attention to detail. While an approach may be helpful in more straightforward situations or when time is of the essence, in the case of complex combinatorics problems, this approach is less practical than more deliberate and systematic reflective thinking.

The findings of this study emphasize the importance of developing reflective thinking skills among students, particularly in mathematics education. Teaching strategies to facilitate and encourage reflective thinking are essential in improving students' ability to solve complex problems and achieve better mathematics studies.

In contrast, when faced with problems that are considered more straightforward, for example, in a situation that asks them to count the number of ways to choose two out of five objects, many students immediately give their answer without going through the Process of planning or considering the steps required. They rely on instinct and previous experience to provide answers quickly.

When students answer directly without double-checking or considering other alternatives, the risk of errors increases. In some cases, the resulting answer may be correct, but there are also situations where the results could be more accurate due to the lack of evaluation of the procedures. These findings underscore the importance of teaching students to balance reflective thinking depending on the complexity of their problems. Especially when dealing with issues that require attention to detail and deeper analysis, this will improve their ability to solve different types of issues and help them make better and more informed decisions in other contexts.

These findings are consistent with previous research, which stated that individuals with a tendency toward reflective thinking can produce better decisions, especially in complex situations requiring in-depth analysis. In addition, the analysis of this study also revealed that students with more experience in solving combinatorial problems tend to use the reflective approach more often. These findings suggest a significant relationship between knowledge and critical thinking skills. Students familiar with different combinatorial problems can better identify when they need to take more careful

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steps and consider multiple possibilities before reaching a final solution. This experience provides them with a strong foundation for applying reflective thinking and improving the quality and accuracy of the solutions they get.

This link between experience and reflective thinking highlights the importance of providing opportunities for students to engage in challenging and varied exercises in mathematics education. By increasing the frequency and complexity of the problems that students encounter, they can build confidence and better critical thinking skills. This also means that effective mathematics instruction should include a variety of strategies that not only foster understanding of basic concepts but teach reflective thinking through practical experiences.

These findings confirm that experience and reflection are essential to developing students' critical thinking skills. By better understanding how these two factors interact, educators can design more comprehensive and practical teaching approaches focusing on the results and the underlying thinking processes.

DISCUSSION

Make time for introspection at every stage of the problem-solving procedure. Subsequently, the issue can be divided into manageable chunks, with a thoughtful assessment following each segment. Reflection at every stage of the problem-solving Process is necessary to ensure that the strategy employed is effective. Collaboration prioritizes student-centered learning, reflective thinking, effective communication, and a framework for understanding the relevance of phrases (Ismail et al. 2024; Kwon et al. 2024). An instantaneously prepared and used ice pellet jet surface treatment technology is suggested to address the issues with ice pellet bonding and clogging in conventional ice pellet jet paint removal technology (Man et al. 2024). The results of this study highlight the value as an effective tool for resolving fractional partial differential equations, offering a reliable and efficient substitute for the conventional approach (Ganie et al. 2024; Ide and Beddoe 2024). The following thoughtful narrative remembers this white researcher's continuous battle with the methodological, ethical, and epistemological challenges they encountered while continuing their decolonization path (Neville 2023). This reduces the possibility of errors and helps find and fix problems early on, enhancing the quality of the Solution. Frequent reflection also allows individuals or teams to learn and adapt, making them more capable of overcoming obstacles and finding the best answers.

Research on combinatorics tasks highlights their effectiveness in training individuals to identify patterns and structures, with findings showing that systematic approaches such as segmenting problems into smaller components significantly enhance problem-solving and pattern recognition (Cherop et al. 2024; Setiyani*;S. B. Waluya;Y.L. Sukestiyarno;Adi Nur Cahyono 2022). Combinatorial models, like classifying jigsaw puzzles, also improve learners' ability to organize data and detect relationships (Dash, Seker, and Shahpasand 2025; Tobin et al. 2025), while logical combinatorial approaches have been successfully applied in broader fields such as medicine to accommodate both quantitative and qualitative variables (Setiyani*;S. B. Waluya;Y.L. Sukestiyarno;Adi Nur Cahyono 2022). These strategies are effective because breaking down complex problems aligns with cognitive processes like decoding and adapting, which are central to analogical transfer and problem-solving (Kusmaryono imam 2023; Pamungkas et al. 2025; Setiyani*;S. B. Waluya;Y.L. Sukestiyarno;Adi Nur Cahyono 2022). Moreover, the tangible and relatable nature of combinatorial models fosters deeper understanding, enabling learners to classify and interpret information more accurately (Setiyani*;S. B. Waluya;Y.L. Sukestiyarno;Adi Nur Cahyono 2022). Overall, training through combinatorics tasks not only enhances accuracy but also cultivates systematic thinking and reflective problem-solving, making it a promising method for improving learning outcomes and supporting applications across diverse domains.

Establish a transparent, encouraging atmosphere where input is valued as a helpful component of the development process. Acknowledging that everyone makes mistakes and that modification and reevaluation are necessary for success is also crucial. This planned proposal also included the application of the integrated framework during the guideline formulation process (Movsisyan et al. 2024). Rather than acknowledging that my whiteness, as opposed to my racialized Irishness, was more predictive for my pupils in this particular circumstance, I loaded the deck in favor of exoneration. Flexible, inquisitive, and creative problem solvers have acquired the abilities to take on new challenges that will be required in the workforce of the future Flexible, inquisitive, and creative problem solvers have acquired the

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ability to take on new challenges that will be required in the workforce of the future. By implementing organized procedures for gathering and debating feedback and encouraging ongoing education, teams and individuals can be more productive and adaptive when taking on new tasks.

Research indicates that giving people or organizations official instruction in reflective thinking can improve their efficacy. Reflective journaling, for instance, has been shown to enhance critical thinking and problem-solving skills among nursing students, suggesting that structured reflective practices can lead to better professional competence and satisfaction (Kusmaryono imam 2023; Pamungkas et al. 2025; Setiyani*;S. B. Waluya;Y.L. Sukestiyarno;Adi Nur Cahyono 2022). Additionally, strategies such as open-ended questioning have been found to significantly improve solution quality in problem-solving tasks, demonstrating the effectiveness of reflective questioning techniques in fostering deeper cognitive engagement (Pamungkas et al. 2025; Sa'dijah et al. 2020; Salas-Pilco, Xiao, and Hu 2023). Reflective practices, including journaling and peer feedback, have also been linked to increased reflective thinking levels and deeper learning among students, although the design and implementation of these strategies need careful consideration to avoid potential negative effects (Duville et al. 2023). Furthermore, the lesson study approach, which involves collaborative reflection among teachers, has been shown to significantly enhance reflective thinking and teacher efficacy, highlighting the benefits of collective reflective practices in educational settings (Kusmaryono imam 2023; Salas-Pilco et al. 2023; Setiyani*;S. B. Waluya;Y.L. Sukestiyarno;Adi Nur Cahyono 2022). However, it is important to note that while reflective practices can promote individual growth and critical examination, they must be implemented thoughtfully to avoid homogenized thinking that can stifle innovation (Kusmaryono imam 2023; Setiyani*;S. B. Waluya;Y.L. Sukestiyarno;Adi Nur Cahyono 2022). In conclusion, employing structured reflective strategies such as journaling and open-ended questioning can inspire deeper reflection and improve efficacy in both individuals and organizations.

Establish a systematic monitoring mechanism to evaluate reflective thinking procedures regularly. Next, cultivate a culture within the team that recognizes reflection as a critical component of problem-solving. I was confident that this methodological choice would not further solidify or reinforce power disparities between the research and the research after going through this cycle of reflection (Plamondon et al. 2023). I was confident that this methodological choice would not further solidify or reinforce power disparities between the research and the research after going through this cycle of reflection (Russo et al. 2021; Sweeney et al. 2024; Vale et al. 2022). The sine and cosine formulas are combined with the opposition-based learning approach to provide a solution that is the opposite of the newly generated Solution (Karthik et al. 2024). At the same time, a structured monitoring mechanism ensures that reflection is carried out regularly and impartially. Teams can enhance their problem-solving techniques, improve the efficacy of reflection, and produce better outcomes by combining these two elements.

Integrating data from many viewpoints can be facilitated by fostering excellent team collaboration. Use systematic thinking frameworks like flow charts, mind maps, or structured problem-solving models to arrange and integrate diverse data. To evaluate a worldview, one must consider how relationships are discursively produced in the world, including how certain viewpoints or approaches to equity issues are justified and lead to specific solutions (Caballero-Carrasco et al. 2021; Mahlaba 2020; Plamondon et al. 2023). Students must be inclined to handle STEM-based problem-solving from the beginning of their education (English 2023). The framework consists of three types of thinking: systems thinking, design-based thinking, and critical thinking (which includes crucial mathematical modeling and philosophical investigation) (English 2023). Combined team decision-making and problem-solving can be more successful when these two components are combined.

CONCLUSION

This study confirms that reflective thinking plays a crucial role in solving combinatorics problems by guiding students through stages such as identifying patterns, organizing information effectively, and evaluating alternative solutions. Integrating reflection into each step of problem-solving fosters systematic, adaptive, and creative thinking, allowing students to detect errors early and refine their strategies based on new insights. These findings highlight not only the effectiveness of reflective thinking in achieving more optimal solutions but also its contribution to the development of critical and flexible problem-solving skills. The results provide valuable implications for educational practice,

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suggesting that incorporating reflective approaches into mathematics instruction can enhance students' analytical abilities, while also offering a foundation for future research to further explore reflective processes in diverse learning contexts.

Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflict of Interest

The authors declare that there is no conflict of interest.

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