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Metacognitive Disparities among Similar Learners: A Study on Learning Styles

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Abstract

Metacognitive ability plays a crucial role in the Combinatorics course, which requires a deep understanding of concepts and complex problem-solving strategies. This study aims to examine the relationship between the Felder-Silverman learning style model and students' metacognitive knowledge in the context of the Combinatorics course. The primary focus is on analyzing metacognitive gaps among students with similar learning styles. Using a qualitative descriptive approach, data were collected through learning style questionnaires, open-ended questions, semi-structured interviews, and participatory observations of four students with diverse academic backgrounds and learning styles. The findings indicate that although two students share the same learning style combination (active, sensing, visual, and sequential), their level of metacognitive knowledge differs significantly. One student demonstrated strong declarative, procedural, and conditional understanding, while the other could only theoretically identify strategies without concrete implementation. This difference suggests that learning styles are not always the sole predictor of metacognitive achievement. Factors such as self-reflection, emotional regulation, and active learning habits also influence the effectiveness of learning strategy implementation. These findings challenge conventional views on the linear correlation between learning styles and metacognition and offer new insights into the design of learning approaches that integrate learning styles and reflective abilities in a more adaptive and personalized manner.

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Introduction

Mathematics instruction at the higher education level presents unique challenges, particularly when it involves complex and abstract subjects such as combinatorics. Combinatorics is a branch of discrete mathematics that deals with counting, sorting, and the combination of discrete objects. This topic is essential in various scientific fields such as statistics, graph theory, and computer science, and it has practical applications in algorithm development and problem-solving. However, the complexity of combinatorics concepts often becomes a barrier for students in understanding the material.

One of the factors influencing students' comprehension of combinatorics is their learning style. Every student has different preferences and methods in receiving, processing, and understanding information. Several studies argue that learning style is an individual's tendency in absorbing, processing, and retaining new information or skills, reflecting personal characteristics and consistently applied learning strategies (Casinillo, 2023; Rashid et al., 2023; Xing, 2023). Moreover, learning style also includes one’s ability to recognize themselves, evaluate learning experiences, and draw lessons from those experiences (Tralisno, 2022). Learning style is not only about how someone learns but also involves self-reflection and personal development in the learning process. Studies show that students’ understanding of the subject matter can significantly improve when they adapt their learning style to match their preferences (Madhu & Bhattachryya, 2023). If students can find the most effective and comfortable way to learn—such as through visual, auditory, or kinesthetic approaches—they are more likely to comprehend and retain information effectively. This highlights the importance of recognizing and utilizing individual learning styles in education to enhance learning outcomes. The Felder-Silverman Learning Style Model is one of the most widely used frameworks for identifying students’ learning styles, as it classifies learners into four main dimensions: sensing vs. intuitive, visual vs. verbal, active vs. reflective, and sequential vs. global. By using this model, educators can better understand and accommodate students’ learning styles in a combinatorics course.

Another equally important aspect in learning combinatorics—besides learning style—is metacognition. Metacognition is an individual's ability to think about how they think and learn (Güner & Erbay, 2021; Mulyaningsih et al., 2023; Tabuyo, 2024; Wang et al., 2022), which is a crucial component of academic success. One key aspect of metacognition is metacognitive knowledge, which includes three major types: declarative, procedural, and conditional knowledge (Allo et al., 2019), along with metacognitive regulation components such as planning, monitoring, and evaluating (Teng, 2020). These components help keep learning on track and contribute significantly to understanding metacognition in academic settings.

Numerous studies have been conducted to analyze the role of learning styles in the academic success of students in both schools and universities, often in relation to metacognitive aspects (Firmanto et al., 2019; Irwansyah & Mahfudy, 2021; Rambe & Sinaga Asmin, 2019; Tralisno, 2022). Firmanto et al. (2019) explained that aligning teaching strategies with students’ learning styles has a significant impact on enhancing metacognitive abilities. These abilities develop through three main stages: learning awareness, learning planning, and monitoring and reflecting on the learning process. These findings underscore the importance of integrating learning style awareness with the development of metacognitive skills. A study by Irwansyah and Mahfudy (2021) showed that students' metacognitive abilities in solving mathematical problems—particularly non-routine problems—vary depending on their learning styles, namely visual, auditory, and kinesthetic. Similarly, Rambe and Sinaga Asmin (2019) found that students' levels of metacognitive ability in solving mathematical problems are influenced by their learning styles, which are categorized as activist, reflector, theorist, and pragmatist. Meanwhile, Tralisno (2022) revealed that students with a reflective learning style tend to fulfill all indicators of metacognitive knowledge in mathematical problem-solving, including developing action plans, monitoring and regulating those plans, and evaluating outcomes and learning strategies. Although various studies have examined the relationship between learning styles and metacognition, there remains a gap in research that specifically links the Felder-Silverman learning style model with metacognitive knowledge, particularly in the context of combinatorics courses. To deepen understanding of this relationship, a bibliometric analysis was conducted by collecting data related to the Felder-Silverman model and metacognitive knowledge within the 2015–2025 timeframe. The results of this analysis are presented in Figure 1.

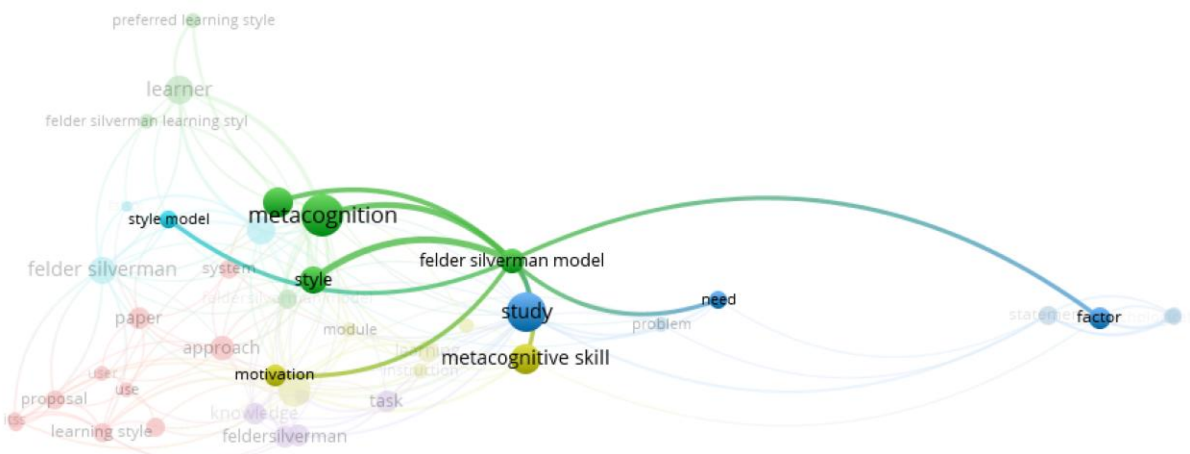

Figure 1. Visualization of the Relationship between Metacognition and the Felder-Silverman Model (2015–2025)

Based on Figure 1, several studies have explored the relationship between metacognition and the Felder-Silverman Learning Style Model (Irwansyah & Mahfudy, 2021; Randver, 2025; Rasyid, 2023). Randver (2025) found that instructional methods tailored to students' individual learning styles can help them regulate their thinking (metacognition) and learn more effectively. Students become more active, better at problem-solving, and more aware of how they process information. Rasyid (2023) also revealed a connection between learning styles and self-regulation (metacognitive) skills. Students whose learning styles align with the teacher's instructional methods tend to have stronger self-regulation skills, emphasizing the importance of understanding students' learning styles to foster more effective and independent learning. Meanwhile, Irwansyah and Mahfudy (2021) showed that learning approaches that consider students' learning styles can enhance their metacognitive skills in mathematics. Kinesthetic learners demonstrated the highest metacognitive abilities—they were able to plan, monitor, and evaluate problem-solving in a systematic and accurate manner. Visual learners had a moderate level of metacognition; they could understand and model problems well but were less thorough in writing final conclusions. Auditory learners, on the other hand, showed the lowest levels of metacognition, particularly in planning and evaluation, as they tended to omit detailed descriptions of problem information.

Although there has been considerable research on metacognition and learning styles, few studies have explicitly examined the relationship between learning styles and metacognitive knowledge in the context of Combinatorics—a specific subject in mathematics—particularly using the Felder-Silverman model. Prior studies have remained general and have not specifically investigated university students within the context of courses like Combinatorics. This gap presents an opportunity for further research to enrich the existing literature. Therefore, this article has the potential to contribute new insights into the development of studies on learning styles and metacognitive knowledge, especially in the context of higher education mathematics learning.

The urgency of this research lies in the need to specifically understand the relationship between the Felder-Silverman learning style model—which provides a clear framework for understanding students' learning preferences through four main dimensions: active-reflective, sensing-intuitive, visual-verbal, and sequential-global—and students' metacognitive knowledge, which includes declarative, procedural, and conditional knowledge (Abdelshiheed et al., 2023) in the context of the complex and abstract Combinatorics course. In this study, declarative knowledge refers to fundamental knowledge about facts or given information. Procedural knowledge refers to understanding the processes, steps, or strategies used to solve problems. Meanwhile, conditional knowledge refers to understanding which strategies should be used, when they should be applied, and why those strategies are relevant. This gap in the literature represents a critical area that needs to be addressed, especially given the importance of combinatorics in developing higher order thinking skills such as problem-solving, critical thinking, and strategic learning planning. Without a clear understanding of how students' learning styles affect their metacognitive knowledge in this course, the learning process risks being suboptimal and may hinder the achievement of learning outcomes. Therefore, this research is urgently needed to provide both theoretical and practical contributions to the development of adaptive learning strategies based on an understanding of students' learning characteristics and the strengthening of their metacognitive abilities.

Method

This study employs a qualitative descriptive method with the primary aim of understanding students' learning style patterns in the context of combinatorics lectures and identifying their connection to metacognitive aspects. In analyzing learning styles, the study refers to the Felder-Silverman model, which categorizes learning preferences into four main dimensions: active-reflective, sensing-intuitive, visual-verbal, and sequential-global. Additionally, this research seeks to identify the relationship between students' learning styles and metacognitive knowledge, which consists of three key components: declarative knowledge, procedural knowledge, and conditional knowledge.

Participants in this study were selected using purposive sampling, which allows researchers to choose participants based on specific criteria relevant to the research objectives. The selection criteria included students who were currently enrolled in the combinatorics course, had heterogeneous learning styles, and were willing to participate in the study, particularly those capable of providing necessary information through in-depth interviews. Based on these criteria, the study involved four male students: two with excellent academic performance and two with good academic performance, as determined by their previous Grade Point Average (GPA) and university admission pathway.

The instruments used in this study included open-ended questions designed to identify students' metacognitive concepts, semi-structured interviews to explore data obtained from the questionnaires and open-ended responses, participatory observation conducted over 12 weeks, and a learning style questionnaire based on Soloman & Felder (2012), which was modified by the researcher to align with the course content. The questionnaire included items that explored the four main learning style dimensions: active vs. reflective, sensing vs. intuitive, verbal vs. visual, and sequential vs. global. The characteristics of each dimension are described in Table 1.

Table 1. Dimensions of Felder & Silverman Learning Styles (ILS)

Learning Style Dimension	Learner Characteristics
Active	Learns by doing something, especially in groups.
Reflective	More comfortable learning alone; needs time to reflect before acting.
Sensing	Prefers facts, data, experiments, and pays close attention to detail
Intuitive	Enjoys ideas and theories; attracted to new and innovative things.
Verbal	Understands information through verbal explanations and discussions.
Visual	Understands information through pictures, symbols, diagrams, graphs, and reading.
Sequential	Prefers systematic steps and linear explanations.
Global	Tends to understand concepts holistically and intuitively.

To understand students' learning preferences based on the Index of Learning Styles (ILS), it is necessary to assess the four main dimensions that reflect how students process and absorb information. The ILS questionnaire consists of 44 statements, each requiring students, as respondents, to choose one of two options representing opposing sides of each dimension. Once the data is collected, the obtained scores need to be interpreted to make the results easier to understand. This interpretation is important because it can help educators or facilitators design teaching strategies that align with students' learning characteristics, making the learning process more effective and optimal. The interpretation of the scores is presented in Table 2 below.

Table 2. Interpretation Guide for ILS Scores

Score Difference	Interpretation	Description
$1-3$	Weak or balance	An individual with a score difference of 1 exhibits a very weak or undeveloped preference for either side of the dimension. Meanwhile, a score of 2–3 indicates flexibility in learning style and the ability to adapt to both sides of the dimension without a dominant preference.
$5-7$	Moderately strong	The individual shows a noticeable preference for one learning style, so learning methods that align with this preference are likely to be more effective.

Score Difference	Interpretation	Description
$9-11$	Very strong	The individual is highly dominant on one side of the dimension, making learning approaches that differ from this preference potentially less comfortable or harder to implement.

After determining the research instruments, the next step is data collection. The data collection process in this study was carried out in five stages, as shown in Figure 2. The first stage is participant identification, which involves selecting four students who are currently enrolled in a combinatorics course. The selection considered the diversity of learning styles, levels of academic performance, and willingness to actively participate throughout the research process. This selection aimed to ensure that the data obtained were rich and qualitatively representative. The second stage is the distribution of the learning style questionnaire using the Index of Learning Styles Questionnaire developed by Felder and Soloman. This questionnaire was used to identify students' learning preferences based on the four dimensions of the Felder-Silverman model: active-reflective, sensing-intuitive, visual-verbal, and sequential-global. The results of this questionnaire served as the basis for grouping participants and analyzing the relationship between learning styles and their metacognitive abilities.

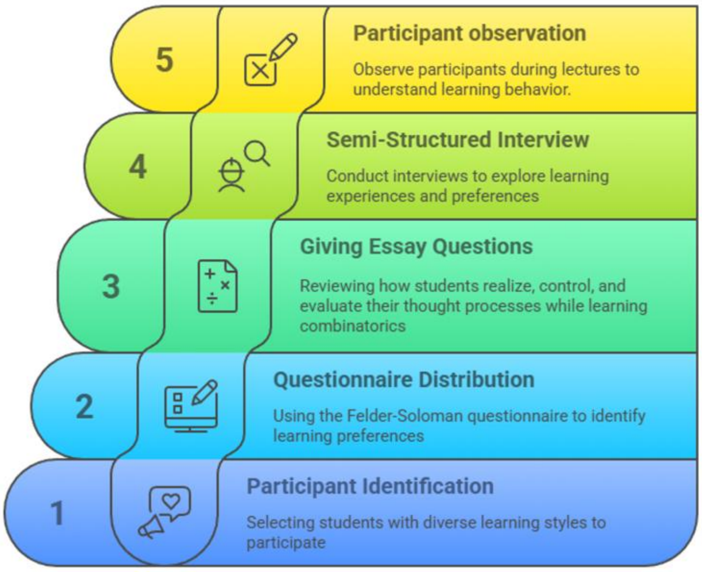

Figure 2. Research Data Collection Process

In the third stage, participants were given essay questions designed to stimulate higher-order thinking. These questions served as a tool to observe how students respond to combinatorics problems in written form, as well as to identify metacognitive elements such as problem-solving strategies, rationale for method selection, and their ability to reflect on their answers. The fourth stage is a semi-structured interview conducted after the participants completed the essay tasks. The purpose of this interview was to explore in greater depth the students' thinking processes and learning strategies, particularly to uncover metacognitive aspects such as declarative knowledge (what they know), procedural knowledge (how they do it), and conditional knowledge (when and why certain strategies are used). This interview also served as a means of clarification and reflection on their previous written responses. The fifth stage is participatory observation, which was conducted over 12 weeks of combinatorics lectures. The researcher directly observed the students' learning behaviors in their natural context—during group discussions, when answering questions, and in interactions with the lecturer and course materials. This observation enabled the researcher to assess the alignment between the questionnaire and interview results with actual classroom practices and to provide additional non-verbal and contextual data.

The collected data were analyzed using the Miles et al. (2014) model and visualized in Figure 3, which includes four main stages: data reduction, coding, pattern identification, and conclusion verification. The data reduction stage involved sorting, filtering, and organizing raw data obtained from questionnaires, open-ended questions, interviews, and observations. In this stage, irrelevant data were excluded, and the focus was directed toward information related to two main aspects: students' learning styles based on the Felder-Silverman model and metacognitive aspects based on Schraw's theory (declarative, procedural, and conditional knowledge). The reduced data were then labeled (thematic categorization). Each student response was coded according to the dimensions of learning styles and the types of metacognitive knowledge that emerged. For instance, the code "LS-R" was used for the reflective learning style, while "M-CON" referred to conditional metacognitive knowledge. This coding aimed to group the data within a consistent analytical framework and facilitate subsequent pattern identification. The third stage was pattern identification. In this stage, an analysis was conducted to examine the relationships between specific learning styles and the forms of metacognitive knowledge demonstrated by the students. The fourth stage was conclusion verification. This stage involved testing the validity of the initial interpretations. The process included tracing back to the raw data to ensure consistency between the identified patterns and the field evidence. Additionally, data triangulation was performed by comparing the results of the questionnaires, interviews, open-ended questions, and observations to strengthen the reliability of the conclusions drawn.

Figure 3. Qualitative Data Analysis Process of Miles and Huberman Model

Results and Discussion

Learning Style Preference Questionnaire

The learning style preference questionnaire was administered twice to each subject to test the reliability of the instrument. By administering the questionnaire on two separate occasions, the researcher could compare the consistency of the responses provided by the subjects. If the results of the two questionnaires indicate a similar learning style tendency, it can be concluded that the instrument has a good level of reliability. The summarized data from the first and second questionnaires are presented in Figure 4. The figure shows the analysis results of both questionnaires used to identify students' learning style preferences. The first questionnaire was administered in the 4th session, while the second was given in the 12th session. In the figure, red represents the learning preference of Subject 1, orange for Subject 2, green for Subject 3, and blue for Subject 4.

In the Active–Reflective dimension, Subjects 1 and 2 showed a balance with a slight tendency toward the reflective style (R). This means they prefer to think before acting and reflect on the material before applying it in practice. Subject 3 also demonstrated a reflective tendency (R), although to a lesser extent. In contrast, Subject 4 initially exhibited a stronger preference for the active learning style (A), meaning they engaged more directly in the learning process rather than reflecting first. However, after extended exposure to the material from the 4th to the 12th session, a shift occurred. Subjects 1 and 2, who initially leaned toward R, began to shift toward A, indicating that they were becoming more comfortable with a direct and participatory learning approach. Subject 3, who had shown a weak R tendency, also shifted toward an A preference. Meanwhile, Subject 4, who had consistently preferred the A style, maintained this preference without significant change.

In the Sensing–Intuitive dimension, there were some notable variations. Subject 1 preferred the intuitive style (I) in both questionnaires, but with a change in intensity. Initially, the I tendency was weak, then became more balanced in the second questionnaire, indicating a stronger understanding of abstract concepts. Subject 2, who initially had a low score in sensing (S), showed an increase from a score of 3 to 5, meaning they became more comfortable with fact-based and procedural learning. The most significant change was seen in Subject 3, who initially had a strong tendency toward S but shifted toward I in the second questionnaire, though not dominantly. This suggests that their learning style may be more adaptive or that there is some inconsistency in their perception of how they learn. Meanwhile, Subject 4 consistently showed a strong preference for the S style in both questionnaires, indicating that a fact- and procedure-based approach is their primary learning style.

In the Visual–Verbal dimension, Subject 1 had a very strong preference for the verbal style (Verb) in both questionnaires, meaning they felt more comfortable understanding material through text, discussion, and word-based concepts rather than through images or diagrams. Subject 2 experienced a change. Initially, they had a low preference for Verb, but in the second questionnaire, their preference became balanced between Verb and Visual (Vis). This indicates an adaptation in how they absorb and process information. Subject 3 showed a relatively consistent preference for Verb, although with weak intensity. This means that even though they remained more comfortable with text or discussion, their learning style was not heavily influenced by increased material exposure. Subject 4 initially had a very strong preference for Vis, but its intensity slightly decreased in the second questionnaire. Although Vis remained dominant, this change shows that they were becoming more open to non-visual aspects of learning, such as the use of text or verbal discussion.

In the Sequential–Global dimension, Subject 1 consistently showed a global preference (G), meaning they were more comfortable understanding the overall concept before delving into details in a systematic manner. However, the drawback was difficulty in following step-by-step instructions or understanding linearly organized information. Due to their holistic thinking style, learning methods that are too structured (sequential) are less effective for Subject 1. Meanwhile, Subject 2 tended to prefer the sequential style (S), although with weak intensity. This means they were more comfortable with structured learning and following steps in order, but not heavily reliant on sequential thinking patterns. This shows that although they were accustomed to a systematic approach, they still had some flexibility in understanding broader concepts. Subject 3, who initially showed a weak S tendency in the first questionnaire, developed to a more balanced preference in the second questionnaire.

This suggests that they were increasingly able to understand information step-by-step without significant difficulty in following a structured sequence. As for Subject 4, they experienced a shift in preference. Initially, they had a weak tendency toward G, but in the second questionnaire, they leaned more toward S, although still within a weak category. This indicates that they possess flexibility in information processing and can adjust their learning approach based on their experience and the material they are exposed to.

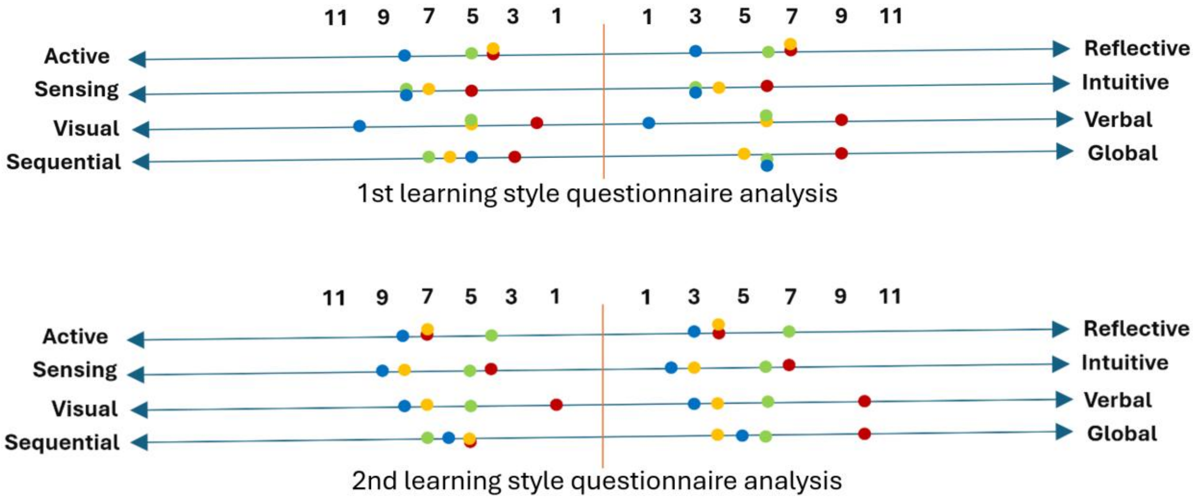

Figure 4. Data Analysis of Learning Preference (Style) Questionnaire Results

Many previous studies have used questionnaires administered on two separate occasions to test their reliability (Yousef, 2019). This approach is commonly employed in educational research to ensure the consistency of participants' responses. In the present study, administering the questionnaire twice enabled an analysis of the stability of students' learning style preferences. Additionally, in relation to learning styles, other research has noted that over time and with prolonged exposure to learning materials, students may experience shifts in their learning preferences (Alemdağ, 2020). The findings of this study support this notion, as some participants demonstrated a shift in their learning tendencies—for example, from LS-R to LS-A, or vice versa. One contributing factor to this change is the instructional method employed. From the first to the fourth sessions, students received material through a lecture-based approach. However, starting from the fifth to the twelfth sessions, the learning method was changed to problem-based learning, which allowed students to more actively construct their understanding through independent and collaborative problem-solving.

In the LS-S and LS-I dimensions, several studies have found that most students tend to prefer LS-S (Masegosa et al., 2024). The results of this study also indicate a similar trend, where Subject 2 and Subject 4 preferred fact-based and procedural learning. However, students with a LS-I preference became less engaged, as the method did not sufficiently emphasize abstract concepts and theoretical content, which they found more appealing. Furthermore, learners with a LS-G preference tend to understand concepts holistically before focusing on more detailed information (Madhu & Bhattachryya, 2023). This statement aligns with the findings of this study, in which Subject 1 consistently exhibited a LS-G processing style but struggled to comprehend information presented in a linear fashion.

Based on these findings, it can be concluded that learning styles are not static traits but rather can adapt in response to instructional methods or exposure to different types of material. The difference between the findings of this study and previous studies regarding learning styles lies in the observed shifts across dimensions. The study by Rijal et al. (2023) reported that LS-Vis was the dominant learning style among students and tended to remain constant. However, in this study, several participants demonstrated shifts from LS-Vis to LS-Verb and vice versa, indicating a greater level of adaptability in how they receive and process information. Similar patterns were observed across other dimensions, where changes in learning styles appeared to align with the shift in instructional methods. Initially, instruction was teacher-centered but was later transformed into problem-based learning, which is more student-centered. These findings provide valuable insight into how learning styles can evolve depending on the teaching methods employed.

Students' Metacognitive Knowledge

In this study, students' metacognitive knowledge was analyzed based on three main components: declarative knowledge, procedural knowledge, and conditional knowledge. These three components were used to examine the extent to which students understand, apply, and reflect on their thinking processes when solving problems in the Combinatorics Mathematics course. Data were obtained from students' responses to problem-solving tasks specifically designed to elicit metacognitive aspects in their answers. Each response was analyzed qualitatively using thematic coding techniques, with indicators tailored to each type of knowledge. The coding analysis results are presented in Table 3.

Table 3. Coding Analysis of Students' Metacognitive Knowledge

Student Code	Declarative Knowledge (D)	Procedural Knowledge (P)			Conditional Knowledge (C)		Special Notes
	Question a	Question b	Question c	Question d	Question e	Question g	
S1	√	√	√√	√√	√	√	There are shortcomings in the delivery of key points, the evaluation of answer accuracy, and the application of concrete alternative strategies
S2	√√	√√	√√		√√	√√	-
S3	–	–	√√	√	√	√	There are inaccuracies in presenting key points, selecting the correct formula, as well as in the evaluation and transition of strategies, which remain theoretical

Student Code	Declarative Knowledge (D)	Procedural Knowledge (P)			Conditional Knowledge (C)		Special Notes
	Question a	Question b	Question c	Question d	Question e	Question g	
S4	√	–	√	–	√	√	The connection between concepts and problems, the precision of steps, and the implementation of strategies are not clearly articulated, making the resulting solution less directed and difficult to verify for accuracy

The analysis of students' metacognitive knowledge across the three main aspects—declarative, procedural, and conditional—reveals considerable variation in mastery levels and the quality of individual reflections. Each student exhibited distinct characteristics in how they understand, manage, and evaluate their thinking strategies when engaging with problem-solving tasks, especially in the complex subject of Combinatorics. The analysis of four student subjects' metacognitive knowledge indicated inconsistency in the stability and depth of knowledge mastery. Even within a single individual, there could be significant disparities across the aspects.

Subject 1 demonstrated strong mastery in procedural knowledge (M-PROC) but showed weaknesses in declarative (M-DEC) or conditional knowledge (M-CON), such as in understanding basic information or evaluating when and why certain strategies should be used in problem-solving. Moreover, there was a clear gap between the awareness of strategies and their actual application. Subjects 1, 3, and 4 were able to mention possible evaluation methods or alternative strategies, but they did not follow through with concrete implementation in their answers, making it impossible to assess the accuracy of the alternatives offered. This phenomenon suggests that, for some students, their metacognitive abilities remain at a discourse or passive knowledge level and have not yet become active skills that are automatically applied during thinking and problem-solving processes.

Furthermore, the relationship between conceptual understanding, strategy selection, and final solutions still showed gaps in self-regulation across the four subjects. A particularly striking example is seen in Subject 3, who demonstrated a mismatch between the solution procedure and the nature of the given problem. The question required students to calculate the number of ways to divide 9 projects into three categories—junior, intermediate, and senior—with the condition that each category must receive at least one project. This is not a simple partitioning task but one that specifically involves the distribution of positive integers—dividing objects into groups with a fixed total and the requirement that each group receives at least one item. Mathematically, such problems are solved using the restricted repetition combination approach. The first step is to allocate one project to each category to fulfill the minimum requirement. After this initial allocation, the remaining projects are then counted using the formula for combinations with limited repetition:

$$\binom{n+r-1}{r-1}$$

where n is the number of remaining projects, and r is the number of categories.

However, Subject 3 made an error in applying the problem-solving strategy. Instead of using the combination with repetition approach, the subject answered the question using the standard combination formula, as shown in Figure 5, which illustrates that Subject 3 chose 3 out of 9 objects without considering the order. In fact, the context of the question was not merely selecting objects but rather distributing projects into categories with certain constraints.

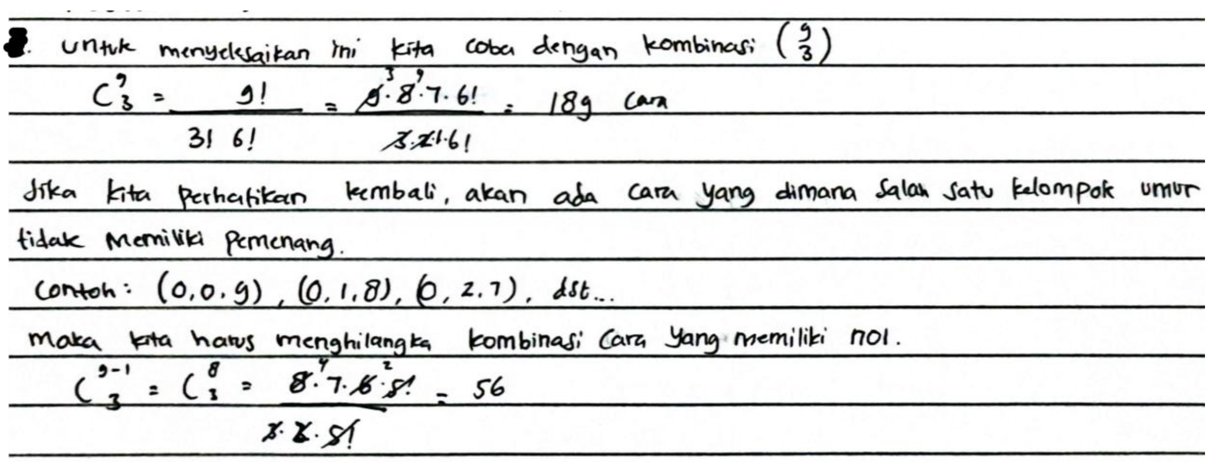

Figure 5. Subject 3's Work

The mistake becomes more evident when Subject 3 wrote the result of the calculation as 189 ways. The appropriate strategy for this problem is to first allocate a minimum of one project to each category, so the number of projects that actually need to be distributed becomes 9 – 3 = 6. Only after that should the distribution be calculated using the combination with repetition formula:

$$\binom{6+3-1}{3-1} = \binom{8}{2} = 28$$

Interview results with Subject 3 revealed that the error in calculating the factorial occurred because they felt rushed to finish the problem quickly due to discomfort in the exam room and psychological pressure (stress). In such a condition, their brain tended to operate in survival mode rather than engaging in deep reflective thinking. This explains why they made a mistake in the factorial calculation and did not take the time to recheck their answer.

In addition to Subject 3, a lack of self-regulation was also evident in Subject 4. Unlike Subject 3, who misapplied the formula, Subject 4 did not implement any strategy at all. They merely mentioned the proposed strategy without working through the problem, making it impossible to assess the accuracy of the final solution. The interview results indicated that Subject 4 had a fairly good conceptual understanding but failed to explicitly connect it to the type of problem presented. This limitation led to the use of an inappropriate problem-solving strategy, as they focused more on general concepts without considering the specific context of the question. Furthermore, they experienced uncertainty in selecting a solution method, which resulted in listing procedural steps without verifying their correctness.

During the problem-solving process, Subject 4 did not carry out any calculations, believing that simply stating the strategy was sufficient. Their thinking pattern was more theoretical than practical, and as a result, they did not apply the concrete steps necessary to test the accuracy of their answer. This was further compounded by low self-regulation in problem-solving, which hindered evaluation and decision-making. Because they were unsure about the chosen strategy, they opted not to perform any calculations, even though reflection and verification are essential to ensure a correct solution.

Based on the analysis that has been conducted, it can be concluded that conditional knowledge (M-CON) is the most difficult aspect for students to master. This indicates that although students possess relatively strong declarative and procedural understanding, they still struggle to apply this knowledge contextually and flexibly in various situations. Like the findings of Mbato (2019), this difficulty arises due to the inherently more complex nature of conditional knowledge compared to declarative and procedural knowledge. While declarative knowledge focuses on understanding concepts and procedural knowledge concerns how a particular strategy is implemented, conditional knowledge requires students to understand when and why a certain strategy should be used in an appropriate context. This ability, of course, demands higher-order evaluative skills as well as a deeper understanding of the variables that influence the effectiveness of a strategy.

Moreover, there is a significant gap between theoretical knowledge and practical application in implementing problem-solving strategies. Subject 3 demonstrated that even when students have a solid conceptual grasp of a strategy, they may still encounter difficulties when applying it in real-life situations. This gap reflects a pattern previously identified by Mevarech & Kramarski (2003), who emphasized that theoretical understanding alone is insufficient to ensure successful problem solving. Students need hands-on experience in applying the strategies they have learned, along with constructive feedback to help them correct mistakes and improve the effectiveness of their approaches.

The method used in this study differs from previous research, which often relied on Likert-scale questionnaires or single reflection tests. This study employed a distributed item-by-item analysis method based on written responses and process observations, to provide a more contextual and dynamic depiction of students' fluctuating understanding, allowing for a deeper evaluation. Furthermore, this research specifically focuses on Combinatorics, in contrast to earlier studies that predominantly explored metacognition in general problem-solving or basic algebra contexts. Combinatorics requires more complex strategy selection, information verification, and in-depth decision-making processes.

One interesting finding from this study is the inconsistency of strategies among students, even when they are presented with the same type of problem. This variation indicates that the application of learning strategies is not entirely fixed but can change depending on the situation, students' confidence levels, and individual characteristics. This finding offers a new perspective rarely highlighted in previous studies, which often evaluate metacognitive abilities as something static. By understanding this variation, the study opens opportunities to design more adaptive learning approaches that help students identify strategies most suited to their learning styles and academic challenges.

The Relationship Between Learning Styles and Metacognitive Knowledge

The relationship between Felder-Silverman learning styles and metacognitive knowledge plays a crucial role in how students understand and process information during learning. The analysis of the relationship between the Felder-Silverman learning style model and metacognitive knowledge is presented in Figure 6. The analysis revealed several interesting findings that deviate from common theoretical expectations regarding the connection between learning styles and metacognitive knowledge. While some studies suggest that certain learning styles tend to support better metacognitive development (Cayetano & Ibarra, 2024), the empirical results of this study indicate anomalies that may offer new contributions to the field of education and instruction. These findings show that the relationship between the two is not always aligned. These differences suggest that individual factors in learning may play a more complex role than previously anticipated.

Subject 1 exhibits a reflective, intuitive, verbal, and global learning style. Reflective learners typically possess strong abilities to think deeply and evaluate information thoroughly (Yadav & Bhatia, 2024), while intuitive and global styles indicate a tendency to grasp concepts holistically rather than in parts (Sobkow et al., 2018). However, the analysis shows that Subject 1's metacognitive knowledge remains at a basic level. Their declarative and procedural knowledge only covers general information, and their conditional knowledge lacks concrete implementation. Interview results reveal that Subject 1 tends to study independently with minimal interaction with others, prefers repeated reading of material for understanding, and often neglects reflection on their learning strategies. This explains why their metacognitive knowledge is still basic—despite having a learning style that theoretically supports strong conceptual understanding, the lack of awareness and control over their learning process hinders the development of declarative, procedural, and especially conditional knowledge.

Subject 2 demonstrates an active, sensing, visual, and sequential learning style. These characteristics indicate a preference for practical, systematic, and experience-based approaches. This learning style aligns with the development of strong metacognitive knowledge (Hu et al., 2021), where individuals with such a combination tend to exhibit high self-regulation, heightened awareness of their thought processes, and the ability to choose and apply appropriate learning strategies based on learning situations. The analysis confirms that Subject 2 possesses a high level of declarative, procedural, and conditional knowledge and can relate strategies to problem contexts in depth. This suggests that their active and sequential learning style directly supports the effective application of metacognitive strategies.

Subject 3 exhibits a reflective, sensing, verbal, and sequential learning style. This combination should ideally support deep and systematic thinking. However, the results indicate otherwise. Subject 3’s declarative and procedural knowledge is lacking, with some errors in choosing problem-solving steps. Their conditional knowledge is also limited to theory without practical application. This indicates a mismatch between learning style potential and metacognitive performance. Classroom observations and interview data reveal that Subject 3 is generally passive during learning and rarely reflects on mistakes or strategies used in solving problems. Although they possess reflective and sequential tendencies that should ideally support structured information processing, they report feeling uncertain about understanding concepts, lack confidence in evaluating solutions, and rely more on memorization than conceptual understanding. The inability to connect theory to practice shows that their conditional knowledge is underdeveloped. Thus, the main barrier is not their learning style potential, but rather the lack of self-reflection and active learning strategies.

Subject 4 shares an active, sensing, visual, and sequential learning style like Subject 2. However, Subject 4's metacognitive mastery is not as strong as expected. While their declarative knowledge is adequate, their procedural and conditional knowledge remains weak, especially in connecting strategies to problem types and applying solutions. Interview data suggest that Subject 4 is not yet accustomed to reflecting on their thinking processes during problem-solving. Although they are actively engaged in learning and show interest in visually presented materials, they still rely on mechanical approaches without deeply considering the rationale behind their chosen steps.

The relationship between learning styles and metacognitive knowledge is a frequently discussed topic in educational research. In general, previous studies have noted that certain learning styles are more likely to support metacognitive development (Cayetano & Ibarra, 2024). One example is the active, sensing, visual, and sequential style, which is known to foster self-regulation, awareness of cognitive processes, and effective learning strategies. This aligns with the findings related to Subject 2, who demonstrates high mastery of declarative, procedural, and conditional knowledge. With a practical, systematic, and experience-based learning style, Subject 2 can select and adapt learning strategies optimally to suit different learning conditions.

However, this study also found several findings that deviate from common theoretical expectations. Subjects 1 and 3, for example, possess a reflective learning style that is theoretically linked to deep and evaluative thinking. Nonetheless, both subjects showed low levels of metacognitive mastery. Subject 1 tends to study independently and focuses on repetitive reading while neglecting strategy reflection. Subject 3 shows a passive learning pattern and relies on memorization rather than conceptual understanding. Despite having reflective and sequential learning styles that should support systematic thinking, Subject 3 struggles to apply knowledge conditionally, such as linking theory to practice. This highlights that the potential of learning styles is not always realized if not accompanied by effective reflection and learning strategies.

One of the key findings of this study is that two subjects with nearly identical learning styles can demonstrate significantly different levels of metacognitive mastery. Both Subject 2 and Subject 4 share the active, sensing, visual, and sequential learning style. However, Subject 4 displays a much lower level of metacognitive knowledge, particularly in procedural and conditional aspects.

Overall, this study shows that the relationship between learning styles and metacognitive knowledge is neither linear nor absolute. While learning styles may provide an initial indication of an individual's approach to information processing, the actual development of metacognitive knowledge is strongly influenced by other internal factors. Factors such as active participation in learning, habitual reflection, confidence in evaluating problem-solving steps, and the strategies used all play significant roles in shaping metacognitive ability. These findings contribute to educational research by emphasizing the importance of considering individual factors comprehensively—not solely based on learning styles—when designing more effective and personalized learning strategies.

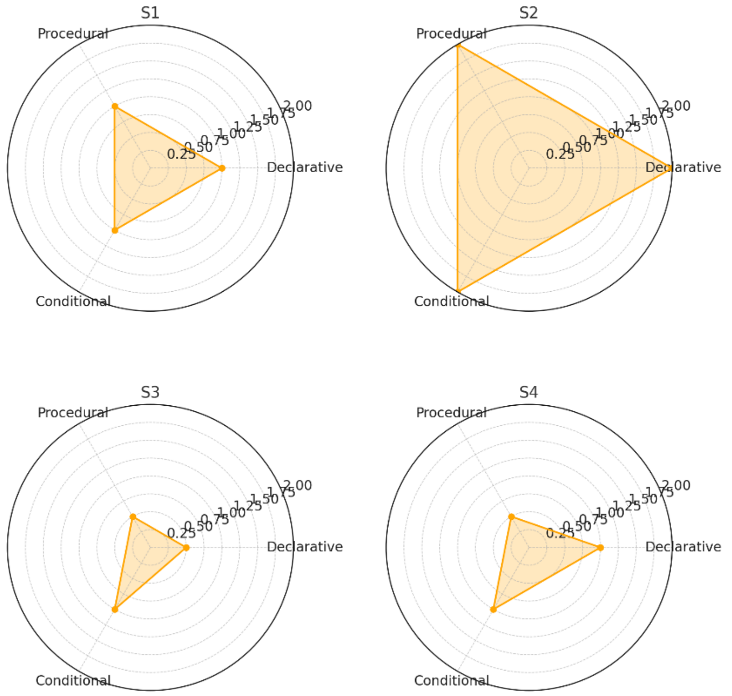

Figure 6. Relationship between Learning Style and Metacognitive Knowledge

Conclusion

This study found that although two students shared an identical combination of learning styles according to the Felder-Silverman model (active, sensing, visual, and sequential), their levels of metacognitive knowledge mastery differed significantly. Some participants demonstrated a solid understanding of declarative, procedural, and conditional knowledge, while others were only able to mention learning strategies theoretically without actual implementation. These findings indicate that learning style is not the sole predictor of metacognitive achievement; rather, it is also influenced by self-reflection, emotional regulation, and active learning habits.

The findings of this study provide a solid foundation for educators in designing more holistic and effective learning strategies. It is essential not only to consider students' learning style preferences but also to consider internal factors that contribute to the success of the learning process, such as reflective awareness and self-regulation abilities. By understanding these dimensions, educators can develop more personalized and responsive approaches to meet students' needs, thereby fostering deeper engagement in learning. Moreover, the curriculum and teaching methods should be designed adaptively to comprehensively support the development of students' metacognitive knowledge. A more flexible and needs-oriented approach can enhance the effectiveness of learning, especially in complex subjects such as combinatorics. Consequently, students will not only gain a strong conceptual understanding but also develop more reflective and independent thinking strategies to solve challenging mathematical problems.

This study is limited by the small number of participants—only four students—and its focus on a single course context. These limitations may restrict the generalizability of the findings to broader contexts. In addition, the measurement of metacognition was conducted through qualitative analysis, which, despite being in-depth, still involves elements of subjectivity.

For future research, it is recommended to involve a larger number of participants and include various course contexts to obtain more representative results and enhance the validity of the findings. By expanding the scope of the study in terms of both participant numbers and the diversity of academic settings, the results are expected to better reflect general patterns in students' learning styles and metacognition dynamics. In addition, the development of supplementary quantitative instruments can be a crucial step in increasing objectivity in measuring metacognitive aspects. This approach allows for a more in-depth analysis of the relationship between self-regulation, reflective awareness, and the effectiveness of students' learning strategies. A more comprehensive instrument can also aid in identifying patterns of interaction among these variables, thereby providing deeper insights for educators and researchers.

Overall, this study makes a significant contribution to expanding the understanding of the relationship between learning styles and metacognitive knowledge. By revealing how individual learning preferences interact with reflective and self-regulatory abilities, the findings highlight the need for a more comprehensive learning approach. An approach that focuses solely on learning style types without considering students' internal aspects may limit the effectiveness of the learning process. Therefore, educational strategies should be designed to include the development of reflective awareness and self-regulation as integral parts of the learning process. This is not only intended to enhance students' conceptual understanding but also to encourage them to develop critical and independent thinking skills in facing academic challenges.

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