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Analysis of Probabilistic Critical Thinking Skills of Students with High Mathematical Resilience

Arief Agoestanto[1]*, Puput Relitasari[1], Mashuri[1], Kholifatu Ulil Azmi[1], and Chitra Ayu Nevtianingsi[1]

[1]Universitas Negeri Semarang, Indonesia

Correspondence should be addressed to Arief Agoestanto: arief.mat@mail.unnes.ac.id

Abstract

Probabilistic critical thinking skills are essential for students to master. Previous studies have generally examined mathematical critical thinking based on cognitive abilities, resulting in a gap in the literature regarding how students' profiles of probabilistic critical thinking are viewed from an affective perspective, namely, mathematical resilience. The purpose of this study is to analyze the probabilistic critical thinking skills of students with high mathematical resilience. This study is a qualitative research conducted on students of the Mathematics Education Study Program, Faculty of Mathematics and Natural Sciences, Semarang State University, with the research subjects being students of the Mathematics Education Bachelor's Program, Faculty of Mathematics and Natural Sciences, Semarang State University, in the second semester of the 2024/2025 academic year. There were three research subjects with high mathematical resilience. Data collection was conducted through tests, interviews, and questionnaires. Data were analyzed using: (1) data reduction; (2) data display; and (3) conclusion drawing/verification, while data validity was determined through triangulation, namely by comparing test results with interview results, as well as comparing the results of the research subjects. The results of this study indicate that the probabilistic critical thinking ability of subjects with high resilience meets the indicators of focus, situation, inference, and overview. However, they are still unable to meet the indicators of reason and clarity. The suggestion is that students need reinforcement in giving reasons for each step in problem-solving, as well as in providing further explanations when concluding. Theoretically, these findings enrich the literature on probabilistic critical thinking by integrating the affective dimension of mathematical resilience. Practically, these results serve as a guide for educators in designing learning interventions explicitly aimed at training students to articulate their reasoning and clarify their conclusions.

Keywords: Critical thinking; probabilistic; resilience.

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Abstrak

Kemampuan berpikir kritis probabilistik merupakan kemampuan esensial yang harus dikuasai mahasiswa. Kajian terdahulu umumnya meneliti berpikir kritis matematis berdasarkan kemampuan kognitif, sehingga terdapat kesenjangan literatur mengenai bagaimana profil berpikir kritis probabilistik mahasiswa ditinjau dari aspek afektif, yaitu ketangguhan matematis. Tujuan dalam penelitian ini adalah menganalisis kemampuan berpikir kritis probabilistik mahasiswa dengan resiliensi matematis tinggi. Penelitian ini merupakan penelitian kualitatif yang dilaksanakan pada mahasiswa program studi Pendidikan Matematika FMIPA Universitas Negeri Semarang, dengan subjek penelitian mahasiswa Program Studi Sarjana Pendidikan Matematika Fakultas Matematika dan Ilmu pengetahuan Alam Universitas Negeri Semarang semester dua tahun perkuliahan 2024/2025. Subjek penelitian sebanyak tiga mahasiswa dengan resiliensi matematis tinggi. Pengambilan data melalui tes, wawancara, dan angket. Data dianalisis menggunakan: (1) data reduction; (2) data display; dan (3) conclusion drawing/verification, sedangkan keabsahan data dilakukan melalui triangulasi yaitu membandingkan hasil tes dengan hasil wawancara, serta membandingkan hasil subjek-subjek penelitian. Hasil penelitian ini menunjukkan kemampuan berpikir kritis probabilistik subjek dengan resilisensi tinggi mampu memenuhi indikator focus, situation, inference, overview. Sedangkan untuk indikator reason dan clarity masih belum mampu. Saran yang diberikan perlu adanya penguatan mahasiswa dalam memberi alasan dalam setiap langkah dalam memecahkan masalah, serta dalam memberi penjelasan lebih lanjut dalam membuat kesimpulan. Secara teoretis, temuan ini memperkaya literatur berpikir kritis probabilistik dengan mengintegrasikan dimensi afektif ketangguhan matematis. Secara praktis, hasil ini menjadi panduan bagi pendidik untuk merancang intervensi pembelajaran secara eksplisit untuk melatih mahasiswa dalam mengartikulasikan alasan dan memperjelas kesimpulan.

INTRODUCTION

The 4C competencies, Critical Thinking, Creativity, Collaboration, and Communication, are essential for students to master in the 21st century (Astuti, A. P. et al., 2019; Astuti, R. & Haryadi, 2023; Inganah et al., 2023). Therefore, critical thinking skills are an important skill that students must have. According to Ammade et al. (2021), critical thinking has become a focus of education worldwide. Meanwhile, Vincent-Lancrin et al. (2019) argues that critical thinking is a top priority in educational goals taught from an early age. Raslan (2023) states that critical thinking is not only important in an academic context, but also an essential skill for dealing with problems in everyday life.

Critical thinking also plays an important role in the mathematics learning process (Wang et al., 2022). Furthermore, Lugosi & Uribe (2022) states that mathematical critical thinking skills are essential for every student in solving various problems, especially mathematical problems. Mathematical critical thinking skills that students master greatly assist them in solving problems, even complex ones (Agoestanto et al., 2017; Setiana & Purwoko, 2020). Students with high critical thinking skills also have high mathematics learning outcomes (Hidayanti et al., 2020).

Given the importance of critical thinking skills, it is necessary to cultivate these skills in students from the outset. However, students have not yet fully mastered critical thinking skills. The study Lugosi & Uribe (2022) found that students' critical thinking skills are relatively low. These results are in line with studies (Dewanthikumala et al., 2021; Rochmad et al., 2018; Wardhani et al., 2021) that found that students' critical thinking skills remain low to moderate. This unsatisfactory critical thinking ability continues in college, especially in the early years. From student learning outcomes in the Introduction to Probability course, it was found that many students still lack critical thinking skills in solving probabilistic problems (Agoestanto et al., 2022).

Probabilistic critical thinking skills are the skills for solving probabilistic problems. In this study, the indicators of probabilistic critical thinking skills used

according to Ennis (1991) are Focus (identifying probabilistic problems), Reason (giving reasons based on relevant facts/evidence from the steps taken), Inference (making appropriate arguments), Situation (using all information relevant to the probabilistic problem), Clarity (providing further explanation of what is meant in the conclusions made), and Overview (rechecking and looking at everything as a whole). Ennis' indicators (1991) have been widely used by previous researchers, including Hidayanti et al. (2020), Mufida et al. (2023), and Aiyub et al. (2022).

In addition to cognitive aspects, affective aspects must also be considered in learning. According to (Nuryanti et al., 2018), a person's cognitive outcomes are also influenced by affective factors, including performance on various mathematical tasks. An effective aspect of learning is performance and perseverance in problem-solving. However, not all students have good performance and perseverance. From the researcher's observations in the Introduction to Probability learning, when students face complex probabilistic problems, some tend to give up easily and lack the perseverance to solve them. This impacts them when they are given new problems, as they cannot solve them immediately. Performance and perseverance in solving mathematical problems are important components of mathematical resilience.

Mathematical resilience is a positive attitude that includes hard work, self-confidence, fighting spirit, perseverance, persistence, and the refusal to give up when overcoming challenges and obstacles in solving mathematical problems (Batchelor et al., 2019; Muntazhimah & Ulfah, 2020). According to Lutfiyana et al. (2022), mathematical resilience is an important aspect that supports successful mathematics learning with its various problems, obstacles, and challenges. The importance of mathematical resilience in learning has been studied by several researchers, including Muntazhimah & Ulfah (2020), Inayah & Agoestanto (2023) who found that it has a significant effect on student success in mathematics. In this study, the indicators of mathematical resilience refer to Johnston-Wilder et al. (2015) and include (1) A positive attitude towards mathematics, (2) confidence in solving mathematical problems, (3) perseverance and persistence in facing mathematical difficulties, (4) self-control over negative emotions, (5) productive involvement in mathematical activities.

Many studies have examined critical thinking, but few have examined it in probabilistic problems and its relationship to resilience, especially high levels of mathematical resilience. Previous studies have generally examined mathematical critical thinking from cognitive and instructional intervention perspectives, thereby neglecting the role of affective factors such as mathematical resilience, particularly in the context of probabilistic uncertainty. This limitation has led to an incomplete understanding of how mental resilience influences students' ability to analyze, argue, and draw conclusions about probabilistic problems. This study addresses this gap by integrating affective and cognitive dimensions through an in-depth analysis of the probabilistic critical thinking profiles of students with high mathematical resilience. By mapping six indicators of critical thinking in detail, this study explicitly reveals that although these students demonstrate resilience in the areas of focus and inference, they still require targeted reinforcement in reasoning and clarity, thereby providing a more comprehensive theoretical and

practical foundation for future learning interventions. Therefore, research linking probabilistic critical thinking to mathematical resilience is an interesting and important topic for study.

METHOD

This study uses a qualitative research approach conducted in the Mathematics Education Undergraduate Program, Faculty of Mathematics and Natural Sciences, Semarang State University, with subjects being second-semester students in the 2024/2025 academic year. Three students were selected as subjects using purposive sampling. The specific characteristics of purposive sampling are (1) temporary; (2) snowballing; (3) tailored to needs; and (4) selected until saturation (Lincoln and Guba as cited by Sugiyono (2013)). The selection of subjects in this study took into account that the subjects were in the high mathematical resilience group, could communicate their ideas clearly, and were based on the uniqueness of the answers Given by students on questions of probabilistic critical thinking skills.

Data was collected through tests to measure probabilistic critical thinking skills and explored through interviews to obtain a description of students' probabilistic critical thinking skills for high mathematical resilience. The main instruments used by the researcher were guided by interview guidelines and written tests of probabilistic critical thinking skills, as well as a mathematical resilience questionnaire.

To ensure the quality and trustworthiness of the data collection, both the probabilistic critical thinking test and the mathematical resilience questionnaire underwent a systematic development and validation process. The probabilistic critical thinking test was developed as an essay instrument based on the indicators. Initially, a blueprint was constructed to ensure content alignment with the indicators. The draft test was then subjected to expert judgment by three experts in mathematics education and educational evaluation. They assessed the instrument's content and construct validity using a rating scale, which was subsequently analyzed using Aiken's coefficient to ensure the items adequately represented the theoretical framework. Following the experts' recommendations, several revisions were made to improve the clarity of the probabilistic context and the linguistic readability of the prompts. The revised test was then piloted on 30 undergraduate students who had completed the Introduction to Probability course but were not part of the research sample. This pilot test aimed to evaluate the readability and cognitive load of the problems, ensuring that subjects would not encounter linguistic ambiguities that could hinder the expression of their critical thinking.

This questionnaire uses a Likert scale that was validated through expert assessment to ensure face and content validity. In addition, pilot test data from 30 students were analyzed using Cronbach's Alpha to determine the questionnaire's internal consistency reliability. The analysis yielded a Cronbach's Alpha coefficient indicating that the instrument is highly reliable and consistent in measuring the mathematical resilience of the target population. The validated instrument was then used to screen and select research subjects.

Data analysis techniques used the model Miles & Huberman (1994), which consists of (1) data reduction, (2) data presentation, and (3) conclusion drawing. Data reduction involved grouping students into high-resilience groups,

correcting test results, and exploring subject test results in interviews. Data presentation consists of the results of the analysis of probabilistic critical thinking skills. Conclusions are drawn regarding the characteristics of probabilistic critical thinking abilities among students with high resilience. According to Moleong (2013), data validity requires examination techniques. The data validity examination in this study used triangulation, involving comparing test results with interviews and comparing each subject's work results.

RESULT AND DISCUSSION

Results

In this study, subjects were given the following probabilistic problem.

A class consists of 10 male students and 20 female students. Half of the male students and half of the female students wear glasses. A student is selected at random. Which is more likely to be selected: a male student or a student who wears glasses, compared to a female student or a student who wears glasses? Explain and give reasons!

The results of the written test for subject S-01, as shown in Figure 1.

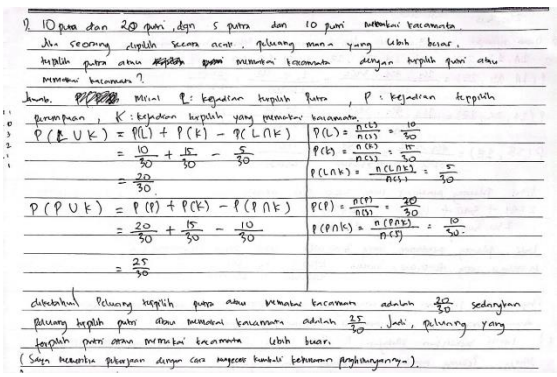


Figure 1. Subject S-01 Answer Results

The results of the interview with Subject S-01, as shown in Table 1. Based on the triangulation of test and interview results, the following results were obtained. On the indicator of identifying problems, S-01 correctly wrote down the information known and asked in the question. On the indicator of providing reasons based on relevant facts/evidence from the steps taken, S-01 provided reasons based on relevant facts/evidence from the steps taken, but was incomplete. On the indicator of using all information according to the problem, S-01 used all information correctly without any errors. On the indicator of making conclusions with the right reasons, S-01 made conclusions in accordance with the right reasons. On the indicator of providing further explanation of what is meant in the conclusion made, S-01 provides further explanation of what is meant in the conclusion made, but it is incomplete. On the indicator of double-checking and reviewing everything as a whole, S-01 checks the results of their work.

The results of the written test for subject S-02, as shown in Figure 2.

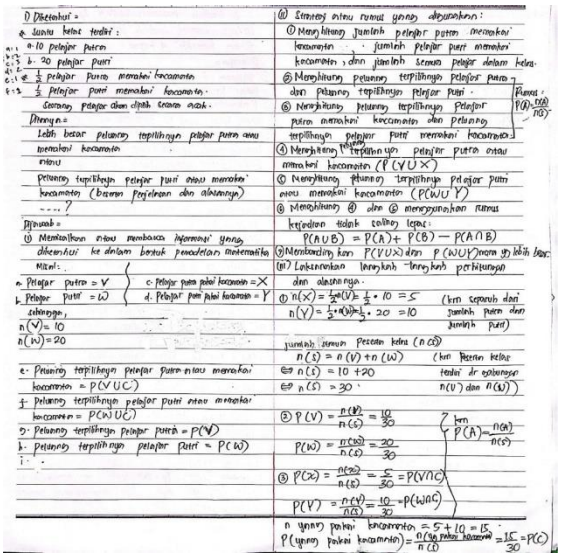


Figure 2. Subject S-02 Answer Result

The results of the interview with Subject S-02, as shown in Table 2. Based

on the triangulation of test results and the interview with S-02, the following findings were obtained. Regarding the indicator for identifying problems, S-02 correctly wrote down the information provided and the information requested in the question. Regarding the indicator for providing reasons based on relevant facts/evidence for the steps taken, S-02 provided reasons but was not entirely complete. For the indicator of using all relevant information, S-02 used all relevant information without errors. For the indicator of concluding with appropriate reasoning, S-02 concluded with appropriate reasoning. For the indicator of providing further explanation of what is meant in the conclusion drawn, S-02 provides further explanation of what is meant in the conclusion drawn, but it is incomplete. For the indicator of double-checking and reviewing everything as a whole, S-02 double-checks their work with the correct answers.

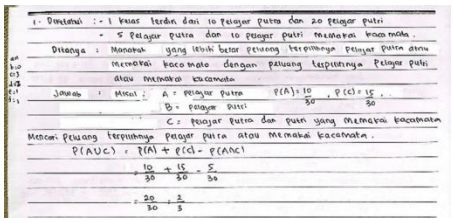
Table 1. Interview Result for Subject S-01

Indicators	Researcher's Question	Subject Answer S-01
Focus	1. Are you able to understand the problem in the question? Try to explain the meaning of the question in your own words! What is known, and what is being asked in the question? 2. Have you ever done a question like this before?	1. Given: A class consists of 10 male students and 20 female students. Half of the male students and half of the female students wear glasses. A student is selected at random. Question: Which is more likely to be selected, a male student or a student who wears glasses, compared to a female student or a student who wears glasses? Explain and give reasons! There is one question: which probability is greater? You must know the probability of selecting a male student who wears glasses, a female student who wears glasses, a male student who does not wear glasses, or a female student who does not wear glasses before you can compare them. 2. As far as I remember, I have never done a problem like this before.
Reason	1. What concepts will you use to solve this problem? Why? 2. How do you formulate the problem in symbolic form? Why?	1. The concept of combined probability, intersection. 2. Symbols: L for son, P for daughter, K for glasses, L combined with K: combined probability of selecting a son and glasses.
Situation	1. Is the information provided sufficient to solve the problem? Did you use all the information provided to solve the problem? 2. What formula or strategy did you use to solve the problem? 3. What were the steps you took to solve the problem based on the information provided?	1. The information is sufficient. 2. Strategy: calculate the probability of selecting a boy, then a girl, the probability of wearing glasses, the intersection of boys wearing glasses, the intersection of girls wearing glasses, then operate. 3. Steps: first, the probability of selecting a boy = 10/30 from the total number of boys, which is 10 out of 30 students; the probability of selecting a girl = 15/30 from the total number of girls, which is 5 out of 10 students; find the intersection of boys and girls = 5/30; the probability of boys or girls wearing glasses = boys = 20/30, find the probability of girls 20 out of a total of 30 = 20/30, the intersection of girls wearing glasses with girls wearing glasses 10 = 10/30, the combination of girls or glasses = girls + glasses - the intersection of girls and glasses = 25/30, compared.
Inference	What conclusion did you draw from the question? Are you sure about that conclusion? Give your reasons.	So the greater chance is a daughter or glasses.
Clarity	1. Explain the conclusion you have reached! 2. Why did you reach this conclusion? Explain!	1. The probability of selecting a boy or a girl with 20/30 vision is 25/30, so the probability of selecting a girl is greater. 2. Overall, there are more girls than boys who wear glasses, so the probability of selecting a girl is greater.
Overview	1. Do your answers address the problem? 2. How do you double-check the answers you have obtained?	1. It is correct in my opinion. 2. Steps to double-check: check the calculations, check whether they are correct or not.

Table 2. Interview Result for Subject S-02

Indicators	Researcher's Question	Subject Answer S-02
Focus	1. Are you able to understand the problem in the question? Try to explain the meaning of the question in your own words! What is known, and what is being asked in the question? 2. Have you ever done a question like this before?	1. Yes, it is possible, as follows: A class consists of 10 male students and 20 female students. Half of the male students and half of the female students wear glasses. That means 5 male students and 10 female students. A student is selected at random. The question is: Which has a higher probability of being selected—a male student or a student wearing glasses—compared to a female student or a student wearing glasses? Explain and give your reasoning! There are 3 questions: the probability of a male student with glasses, the probability of a female student with glasses, and which of the three is being compared. 2. Never.
Reason	1.What concepts will you use to solve this problem? Why? 2.How do you formulate the problem in symbolic form? Why?	1. Concepts: probability of an event, combined probability (combined probability = probability of event 1 + probability of event 2 – the intersection of events 1 and 2). 2. Symbols: Let V denote male students and W denote female students, such that the number of male students n(V) = 10 and the number of female students n(W) = 20. Suppose male students wear glasses X and female students wear glasses Y; the probability that a student wears glasses is P(V or W).
Situation	1.Is the information provided sufficient to solve the problem? Did you use all the information provided to solve the problem? 2.What formula or strategy did you use to solve the problem? 3.What were the steps you took to solve the problem based on the information provided?	1. Okay, that's enough. I'll use. 2. Strategy: convert to a mathematical problem, list the given and unknown variables, calculate the probability of a boy and a girl, the probability of a boy wearing glasses and a girl, the probability of a boy or a girl wearing glasses, and the probability of both a boy and a girl wearing glasses, then calculate the fourth using the formula for mutually exclusive events. 3. Solution process: calculate the number of boys and girls who wear glasses, find n(S) = 30, calculate the probability of a girl = $\frac{10}{30}$ (10 out of the total ($\frac{n(v)}{n(s)}$), but it should be for a boy.
Inference	What conclusion did you draw from the question? Are you sure about that conclusion? Give your reasons.	So, there are more female students than male students because $\frac{5}{6} > \frac{2}{3}$.
Clarity	1.Explain the conclusion you have reached! 2.Why did you reach this conclusion? Explain!	1. The probability of a boy or a girl wearing glasses is $\frac{2}{3}$, while that of a girl is $\frac{5}{6}$. Therefore, the probability for a girl is higher than that for a boy because $\frac{5}{6} > \frac{2}{3}$. 2. Logically, the probability is still higher for a girl because there are more girls; consequently, the probability of a girl wearing glasses is higher as well.
Overview	1.Do your answers address the problem? 2.How do you double-check the answers you have obtained?	1. Checking for errors, but lacking focus. 2. Steps: reread the text, check the calculations.

The results of the written test for subject S-03, as shown in Figure 3.



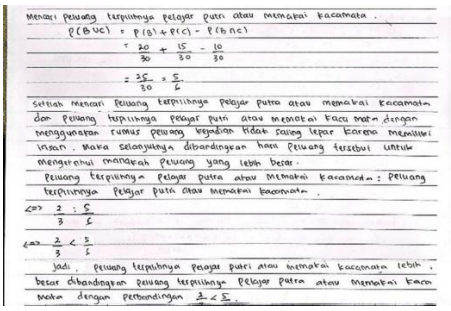


Figure 3. Subject S-03 Answer Result

The results of the interview with Subject S-03 are shown in Table 3. Based on triangulated results and interviews, the following findings were obtained. For the indicator on identifying problems, S-03 correctly wrote down the information provided and the information requested in the question. For the indicator of providing reasons based on relevant facts/evidence for the steps taken, S-03 provided some reasons based on relevant facts/evidence for the steps taken. For the indicator of using all relevant information, S-03 used all relevant information without errors. For the indicator of concluding with appropriate reasons, S-03 concluded with appropriate reasons. For the indicator of providing further explanation of what is

Table 3. Interview Result for Subject S-03

Indicators	Researcher's Question	Subject Answer S-03
Focus	1. Are you able to understand the problem in the question? Try to explain the meaning of the question in your own words! What is known, and what is being asked in the question? 2. Have you ever done a question like this before?	1. Yes, I can. 2. Given: A class consists of 10 male students and 20 female students. Half of the male students and half of the female students wear glasses. A student is selected at random. Question: Which has a higher probability of being selected, a male student or a student wearing glasses, compared to a female student or a student wearing glasses? Explain and give your reasoning! 3. Never.
Reason	1. What concepts will you use to solve this problem? Why? 2. How do you formulate the problem in symbolic form? Why?	1. Concepts: independent events, probability. Reason for using combinations: because there is an intersection. 2. Symbols: A = number of boys, B = number of girls, C = number of boys and girls who wear glasses, n(C) = 15 (half of the boys means 5, and half of the girls means 10). 3. Problem-solving process: list known and unknown quantities; the probability of a son or a student wearing glasses, and the probability of a daughter or a student wearing glasses. Let A be the number of sons with P(A) being the probability of a son in a class of 1, P(B) = $\frac{20}{30}$ (20 out of n(B) are female students), P(C) being the probability of a son or daughter wearing glasses = $\frac{15}{30}$, probability of a boy or a student wearing glasses (P(A) is the union of P(C) = P(A) + P(C) – the intersection) because we are looking for the probability of a boy or a student wearing glasses. In contrast, in C, the probability is the same for both boys and girls.
Situation	1. Is the information provided sufficient to solve the problem? Did you use all the information provided to solve the problem? 2. What formula or strategy did you use to solve the problem? 3. What were the steps you took to solve the problem based on the information provided?	1. Enough. 2. By calculating the probability. 3. Problem-solving process: write down the given information and the question, determine the probability of a boy or a girl wearing glasses, let A be the number of boys; what is the probability that a boy is in the class? P (B) = $\frac{20}{30}$, P(C) boys and girls wearing glasses = $\frac{15}{30}$, probability of a boy or a girl wearing glasses (P(A) combined with P(C) = P(A) + P(C) – their intersection.
Inference	What conclusion did you draw from the question? Are you sure about that conclusion? Give your reasons.	The odds are better for a girl with glasses. I'm sure.
Clarity	1. Explain the conclusion you have reached! 2. Why did you reach this conclusion? Explain!	1. Girls have a higher chance. 2. Without doing the math, it's easy to guess that since there are more girls than boys among the students, girls have a higher chance.
Overview	1. Do your answers address the problem? 2. How do you double-check the answers you have obtained?	1. Yes 2. Steps: After identifying the odds for a son or a daughter wearing glasses, compare them and check the numbers.

meant in the conclusion drawn, S-03 provides further explanation of what is meant in the conclusion drawn, but it is incomplete. For the indicator of double-checking and reviewing everything as a whole, S-03 double-checks their work with the correct answers.

Based on the triangulation of the findings and interviews with subjects S-01, S-02, and S-03, further triangulation was conducted among the subjects, as shown in Table 4.

Table 4. Triangulation Result for Subjects with High Relience

Indicators of Probabilistic Critical Thinking Skills	Subject S-01	Subject S-02	Subject S-03	Conclusion
Focus: Identifying the problem	Meet	Meet	Meet	Meet
Reason: Provide a rationale based on relevant facts or evidence regarding the action taken	Has not yet met	Has not yet met	Has not yet met	Has not yet met
Situation: Using all the information relevant to the issue	Meet	Meet	Meet	Meet
Inference: Drawing conclusions based on sound reasoning	Meet	Meet	Meet	Meet
Clarity: Provides further explanation of what is meant by the conclusion drawn	Has not yet met	Has not yet met	Has not yet met	Has not yet met
Overview: Reviewing and assessing the entire process and overall results	Meet	Meet	Meet	Meet

The triangulation results for Subjects S-01, S-02, and S-03 indicate that subjects with high resilience can identify problems (focus), but were not yet fully able to provide reasons based on relevant facts/evidence for the steps taken (reason), were able to use all information appropriate to the problem (situation), were able to conclude with appropriate reasoning (inference), were not yet able to provide further explanation of what was intended in the conclusions drawn (clarity), were able to review and view everything as a whole (overview), and can therefore be said to be capable of probabilistic critical thinking.

Discussion

Based on the triangulation of test results and interviews with subjects S-01, S-02, and S-03, it was found that students with high mathematical resilience demonstrated proficiency in probabilistic critical thinking, including the ability to identify problems, use information appropriately, draw logical conclusions, and verify their solutions. This indicates that subjects with high mathematical resilience are capable of probabilistic critical thinking. These findings also suggest that mathematical resilience plays a crucial role in supporting critical thinking, particularly in probability, which demands conceptual understanding, logical reasoning, and strategic decision-making.

The results of this study reinforce those of a previous study [19], which confirmed that metacognitive skills and resilience contribute to the development of critical thinking. In the context of probability learning, mathematical resilience enables students to persevere in the face of difficulties, reflect on mistakes, and refine their problem-solving

strategies. Thus, mathematical resilience not only influences the affective domain but also serves as a crucial supporting factor in the development of students' probabilistic critical thinking skills.

It is consistent with Wilder et al. (2021), who found that mathematical resilience serves as a protective factor when students face conceptual or procedural difficulties in mathematics learning. Students with high levels of resilience tend to persevere when facing obstacles, are willing to reevaluate the strategies they use, and reflect on the solutions they obtain. It is supported by Ju (2023), who found a very strong positive correlation between critical thinking disposition and academic resilience among students, and by Namaziandost et al. (2023), who demonstrated that critical thinking has a significant positive effect on academic resilience. Students with high resilience possess strong critical thinking skills.

Conceptually, mathematical resilience is understood as a psychological attribute that enables individuals to continue achieving optimal learning outcomes even when faced with challenging mathematical problems. According to Lee & Ward-Penny (2022), mathematical resilience is the ability to succeed in solving difficult mathematical tasks, characterized by self-confidence, perseverance, and a tendency to question and reflect on mathematical thinking processes. Furthermore, mathematical resilience also involves a strategic framework that enables students to overcome emotional barriers that arise during the problem-solving process.

Romano et al. (2021) found that resilience not only predicts academic achievement but also the quality of students' critical thinking processes. Students with high resilience demonstrated greater persistence in tackling challenging cognitive tasks and tended to use more effective metacognitive strategies. These findings are consistent with research showing that students with high resilience can apply appropriate strategies to solve probabilistic problems and provide logical justifications for each step of the solution. Batanero & Álvarez-Arroyo (2024) argue that in probability learning, tasks involving uncertainty require indicators of critical thinking, namely, testing assumptions, evaluating arguments, and drawing inferences, which learners more frequently achieve with a stronger disposition toward resilience.

The study found that the three subjects provided incomplete reasoning at each step of the problem-solving process and failed to provide a thorough explanation of what their conclusions meant. It indicates that students' mathematical justification skills tend to be limited to procedural justification, without accompanying in-depth conceptual explanations, so that their thinking processes stop at the algorithmic level and have not yet reached reflective reasoning, even though reflective reasoning is the core of probabilistic critical thinking. These findings reinforce the indication that a weak ability to provide logical reasoning and conceptual reflection is one of the main barriers to the development of students' probabilistic critical thinking. It aligns with the research by Simonovic et al. (2023), which explains that a lack of reflection and logical evaluation often hinders critical thinking ability. Although resilience helps students "persevere" in working on problems until the end, the ability to communicate logical reasoning is a higher-order skill that requires specific practice beyond affective factors.

Implication

Theoretically, this study enriches the literature on mathematics education by bridging the gap between the cognitive and affective domains, specifically in the context of probabilistic reasoning. These findings challenge the prevailing assumption that mathematical resilience automatically enhances all dimensions of critical thinking, demonstrating that affective strengths predominantly support inferential and focusing processes rather than argumentative justification. Furthermore, this research offers a more granular conceptual framework by specifically mapping which indicators of probabilistic critical thinking remain vulnerable even among highly resilient students. This theoretical contribution provides a novel foundation for future researchers to explore more complex cognitive-affective dynamics across various mathematical topics involving uncertainty.

Practically, these findings provide concrete guidance for curriculum developers and instructional designers to integrate explicit scaffolding that targets the reason and clarity indicators within probability units. The curriculum must not only focus on procedural and algorithmic mastery but also provide safe discursive spaces for students to practice arguing and reflecting on their conclusions. Furthermore, the results underscore the need to develop new assessment frameworks that separately evaluate the quality of mathematical justification rather than merely the correctness of final answers. Consequently, educational policies and adopted instructional models can be designed to balance both emotional resilience and rigorous mathematical communication skills.

For future research, subsequent studies are recommended to involve larger, more diverse samples, including students at various educational levels and across different categories of mathematical resilience. Further research could also adopt mixed-methods or quasi-experimental designs to investigate the causal relationships between targeted resilience interventions and specific improvements in the reason and clarity indicators. Additionally, longitudinal studies are warranted to explore how the interplay between mathematical resilience and probabilistic critical thinking evolves over time and across other mathematical domains. Finally, future research could focus on developing and validating instructional modules explicitly designed to strengthen the argumentative abilities of resilient students, followed by empirical testing of their effectiveness in diverse classroom settings.

Limitation

This study has several limitations, including a relatively small sample size of only three students, which limits the ability to generalize the findings. Additionally, as this study employed a qualitative approach, it did not provide quantitative evidence of a causal relationship between mathematical resilience and probabilistic critical thinking skills. Therefore, future research is recommended to include a larger sample and adopt a more comprehensive research approach.

CONCLUSION

Individuals with high resilience are capable of probabilistic critical thinking, meaning they can identify problems (focus), utilize all relevant information regarding the problem (situation), draw conclusions based on sound reasoning (inference), and review and consider the big picture (overview), however, there are weaknesses in the "reason" and "clarity" indicators, specifically: they do not fully

provide reasons based on relevant facts or evidence for the steps taken, and they do not fully explain the conclusions reached. This study confirms that mathematical resilience is an important affective foundation, but it is not an automatic guarantee of a comprehensive mastery of probabilistic critical thinking. Resilient students can "persevere" and "solve" probability problems, but they still require specific pedagogical support to "argue" and "clarify" the meaning of the solutions they produce. The significance of these findings lies in their key message for mathematics education: high quality probability instruction must balance building emotional resilience with fostering deep mathematical reflection, so that students become not only resilient problem solvers but also reflective and communicative critical thinkers.

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