Volume 17 Number 2 (2025)
July-December 2025
Page: 1379-1390

E-ISSN: 2656-9779
P-ISSN: 1907-6355
DOI: 10.37680/qalamuna.v17i2.8113

QALAMUNA
JURNAL PENDIDIKAN, SOSIAL, DAN AGAMA

Analysis of the Refractive Thinking of Students in Decision Making on Open Problems in Mathematics

Ardiana [1]

[1] Universitas Khairun, Indonesia; ardiana@unkhair.ac.id

Received: 15/08/2025 Revised: 03/10/2025 Accepted: 03/12/2025

Abstract

This study aims to describe students' decision-making processes in solving open mathematical problems based on refractive thinking. The research employed a qualitative approach with a descriptive design. The participants were undergraduate students of the Mathematics Education Study Program at the State University of Malang, selected purposively based on decision-making style, domicile, and understanding of the problem context. Research instruments included validated open-ended problem sets based on graph theory and semi-structured interview guides. Data were collected through problem-solving tasks and in-depth interviews, and then analyzed using Miles and Huberman's interactive model, which consists of data reduction, data display, and conclusion drawing. The findings reveal that students experienced five stages of reflective thinking—perplexity, investigation, construction, evaluation, and decision—throughout the decision-making process. Students with a rational style demonstrated more systematic and consistent reasoning, while intuitive, dependent, and avoidant students tended to perform incomplete evaluations. These results highlight that refractive thinking plays a crucial role in forming logical and adaptive decisions. The study implies that open-ended, context-based mathematics learning can effectively enhance students' higher-order thinking through reflective and evaluative reasoning. Future research should explore the development of instructional models and digital-based learning environments that systematically foster reflective thinking and decision-making skills across diverse cognitive styles and educational levels.

Keywords Decision Making Styles; Decision Making; Math Education; Open-ended Problems; Refractive Thinking

Corresponding Author
Ardiana
Universitas Khairun, Indonesia; ardiana@unkhair.ac.id

1. INTRODUCTION

Mathematics is one of the disciplines that is studied from an early age because it plays an important role in daily life. In mathematics learning, students often encounter various types of problems that require high-level thinking skills (Fauzan et al., 2024; Suharna et al., 2020). Classify mathematical problems into two categories, namely closed types and open-ended types. Closed problems usually have a definite method of resolution as well as a single correct answer. In contrast, open problems are characterized by the absence of a definitive method of resolution, the possibility of multiple answers, and a variety of alternative strategies. Open-ended problems enable students to develop their creativity

Published by Institut Agama Islam Sunan Giri (INSURI) Ponorogo; Indonesia
Accredited Sinta 2

and explore various mathematical approaches to problem-solving. Thus, open-ended problems offer students opportunities to make decisions based on logical considerations. Therefore, learning mathematics through open-ended problems is considered relevant to developing students' critical and reflective thinking skills.

Open issues have several characteristics that distinguish them from closed issues. First, there is no one definitive solution method used to find a solution. Second, many possible answers can be considered correct based on logical arguments. Third, open problems can be accessed by students with diverse levels of abilities (accessible to mixed abilities). Fourth, open-ended problems provide students with the opportunity to make decisions and think mathematically naturally. Fifth, this issue encourages the development of reasoning and communication skills. Sixth, open problems provide space for creativity and imagination in facing real problems. Presmeg (2016) States that open-ended problems can help students relate mathematical concepts to everyday life situations. Thus, open problems serve as an important forum for training students in decision-making within a mathematical context.

Decision-making is one of the important cognitive skills in open problem-solving. Syazwani & Voutama (2025) Explains that decision-making and problem-solving are two interconnected cognitive processes. Problem-solving is a general coping strategy used to overcome obstacles that arise in a situation. Meanwhile, decision-making is the process of selecting among various alternative solutions that result from problem-solving. This process requires students to identify information, select alternatives, and determine the most appropriate strategy (Dwi Prastika & Nugroho, 2025a). Defines decision-making as the process of choosing a single decision from several available alternatives to achieve a goal. Therefore, decision-making in the context of open issues demands the involvement of a high-level thought process. In such a situation, students' ability to think reflexively and critically becomes indispensable.

Decision-making is essentially a rational, logical, and principle-based process. Decision-making is a complex process that involves a wide range of cognitive abilities (Johnson et al., 2021; Román-González et al., 2017). The stages of decision-making have been extensively researched by experts using various frameworks. For example, the stages of decision-making include generating ideas, clarifying these ideas, and assessing their reasonableness (Weintrop et al., 2021). The stages begin with defining the problem, determining needs, setting goals, and evaluating alternatives (Ansari et al., 2020; Cansoy & Turkoglu, 2017), and emphasizing the importance of validating solutions to problem statements. Simatupang et al. (2022) outline five stages: problem identification, selection of key information, creation of alternative solutions, evaluation of alternatives, and selection of strategies. Thus, the decision-making process involves the interaction between critical, reflective, creative, and logical thinking skills.

In the context of mathematics education, refractive thinking emerged as a combination of reflective and critical thinking. Refractive thinking occurs when a person faces complex problems and must go through the stages of perplexity, investigation, construct, evaluation, and conclusion (Boonjeam et al., 2017; Dwyer et al., 2017; Widiya & Radia, 2023). The perplexity stage is characterized by initial confusion in understanding the problem. Investigation involves efforts to gather relevant information related to the given problem. Construct is the process of building possible strategies or solutions. Evaluation is conducted to select the most suitable alternative. The last stage, conclusion, results in a final decision as a form of problem-solving. Thus, refractive thinking plays an important role in decision-making for open problem-solving.

The relationship between decision-making and reflective thinking is evident in open problem-solving. When students encounter open-ended problems, they usually experience initial confusion or perplexity. The next step is an investigation to gather and understand the available information. From the results of this investigation, students can build (construct) various possible completion strategies. The alternatives are then evaluated to find the best solution that fits the purpose. In the end, students make a decision (conclusion) from the chosen alternative. This refractive thought flow is a cyclic process that supports mathematical problem-solving solving (Khaesarani & Ananda, 2022; Rusdiana et al., 2023; Zayyadi et al., 2019). Therefore, in student decision-making, reflective thinking acts as a bridge between problem-solving and choosing solutions.

Preliminary research conducted among students of Khairun University, Ternate, reveals that they employ various strategies in solving open-ended problems. Students experience confusion in the early stages, then write down the information obtained from the questions. After that, they built a settlement strategy in different ways. Interestingly, although their strategies varied, the final decision was the same: to arrange 70 flower pots in the cupboard by making five piles of 12 pots and one pile of 10 pots. This shows that they evaluate and draw conclusions about various possibilities. This process shows the involvement of refractive thinking in decision-making. Thus, students can find the optimal solution even though the strategies used are different.

Research on *decision-making* in mathematical problem solving emphasizes the importance of high-level thinking processes in determining strategies and solutions. Recent studies have shown that students' success in solving open-ended problems is influenced by their ability to identify relevant information, evaluate alternatives, and make logical decisions (Allsop, 2019; Atikah et al., 2025; Attallah et al., 2019). However, most students are still accustomed to closed problems that have only one correct answer, so their thinking flexibility skills are less developed (Christia et al., 2024). This condition necessitates more in-depth research into the cognitive processes underlying decision-making on open issues.

Several studies (Simatupang et al., 2022; Widiya & Radia, 2023) have elaborated that the decision-making process consists of the stages of problem identification, information search, preparation and evaluation of alternatives, and finally, the decision. This process requires a combination of reflection, critical evaluation, and creative thinking. In this context, *refractive thinking* emerges as an important concept that bridges reflective and critical thinking through the stages of *perplexity, investigation, construct, evaluation,* and *decision* (Dwyer et al., 2017; Widiya & Radia, 2023). However, empirical research that specifically links *refractive thinking* with students' decision-making styles in mathematics is still very limited.

Most previous studies have examined reflective or critical thinking in isolation (Trimawati et al., 2020; Rusdiana et al., 2023), have not highlighted how *reflective thinking* plays a role in the decision-making process in various styles, such as rational, intuitive, dependent, avoidant, and spontaneous (Pratama et al., 2025). Therefore, this research situates itself at the intersection of open problem solving, *refractive thinking,* and decision-making theory. This study is expected to make a theoretical contribution to enriching high-level thinking models and provide practical implications for the development of mathematics learning strategies that train students' reflective and critical abilities.

Based on the description above, it is clear that decision-making is an essential skill that warrants further study in the context of solving open problems in mathematics. Refractive thinking, as a combination of reflective and critical thinking, plays a major role in this process. Research has examined students' reflective thinking, but there has been no research that specifically examines the relationship with decision-making (Syamsudin, 2020). Therefore, this research is important to fill this gap. Based on this description, this study aims to analyze the form and stages of students' reflective thinking in the decision-making process when solving open mathematics problems**.** In particular, this research focuses on how each style of rational, intuitive, dependent, avoidant, and spontaneous decision-making is reflected in the stages of *perplexity, investigation, construct, evaluation,* and *decision* in the context of graph theory-based problems.

2. METHODS

Types of Research

This study employed a qualitative approach with a descriptive design. A qualitative descriptive design aims to understand and describe a phenomenon from participants' perspectives, rather than measuring variables as in quantitative research. This approach is suitable for examining students' experiences and thought processes in depth, particularly their reflective thinking during the decision-making process in solving open mathematical problems. The study focuses on capturing the meaning, process, and variations in students' reasoning patterns as they identify problems, construct strategies, and make final decisions.

This study employed a qualitative approach with a descriptive design to explore students' reflective thinking in decision-making when solving open-ended mathematical problems. The formal object of the study is the decision-making process involving reflective thinking. In contrast, the material object is the thinking activity of undergraduate students in the Mathematics Education Study Program at the State University of Malang. Research subjects were selected using purposive sampling based on specific criteria, including decision-making style, domicile, and contextual understanding of graph theory problems. This design enables the researcher to describe the students' cognitive processes systematically and in context.

Data were collected through open-ended problem-solving tasks, semi-structured interviews, and field notes to obtain a comprehensive understanding of the students' reflective thinking stages—*perplexity, investigation, construct, evaluation,* and *decision*. The research instruments included validated open-ended problem sets and interview guides. Data were analyzed using the interactive model of Miles and Huberman, which involves data reduction, data display, and conclusion drawing. To ensure data validity, triangulation of sources and methods was applied. This methodological combination enables the study to capture the dynamics of students' decision-making and the manifestation of refractive thinking in mathematical problem-solving.

Data Analysis Techniques

The data analysis in this study uses an interactive model which includes three stages, namely data reduction, data presentation, and conclusion/verification (Widiya & Radia, 2023; Siregar et al., 2020). First, data from student work, interviews, and field notes are transcribed and then reduced to select information relevant to the research focus. Second, data is presented in the form of tables, thought flow diagrams, and descriptive narratives to facilitate the identification of patterns and relationships between stages of decision-making. Third, the researcher concludes by interpreting the data in light of decision-making theory and reflective thinking.

To maintain **the validity of the data**, this study uses **triangulation of sources and methods**. Triangulation is a technique used to verify the validity of data by employing multiple sources, methods, and theories to assess the consistency of findings. In this case, data from test results, interviews, and field records are compared to ensure the validity of the findings. In addition, research is conducted over a long period of time (prolonged engagement) to increase credibility. With this step, the research results are expected to accurately describe the student's decision-making process, which involves reflective thinking in solving open-ended problems.

3. FINDINGS AND DISCUSSIONS

Findings

The findings of this study reveal that students demonstrated various methods for identifying information when solving open-ended mathematical problems. Students from Khairun Ternate

University tended to write down detailed information before determining a strategy, showing a systematic approach to understanding the problem. In contrast, most students from the State University of Malang preferred rereading the problem without explicitly identifying information, indicating limited initial analysis. This difference shows variation in how students begin the stage of understanding open problems.

At the investigation stage, Khairun Ternate University students explored several possible strategies to solve the problem, resulting in different methods but similar final answers. Meanwhile, students from the State University of Malang tended to use the same combination formula repeatedly, producing different results. This suggests that students who explored multiple alternatives achieved more consistent solutions, while those using a single strategy showed less flexibility.

In the construct stage, Khairun Ternate University students developed their own creative strategies, such as visualizing pot arrangements or estimating quantities through patterns. On the other hand, students from the State University of Malang generally relied on symbolic calculations and standard formulas. This difference suggests that Khairun students were more diverse and exploratory in developing solutions, whereas Malang students tended to follow procedural approaches.

At the evaluation stage, rational-style students showed more thoroughness by checking and comparing several alternatives before making a decision. In contrast, intuitive-style students tended to make decisions quickly after obtaining the first result without reevaluating their options. Dependent-style students tended to follow examples or peer input, while avoidant students skipped checking their answers. These tendencies indicate that decision-making styles have a direct impact on how students evaluate solutions. In the decision stage, students from Khairun Ternate University, despite using different strategies, arrived at the same final decision, indicating internal consistency. Meanwhile, students from the State University of Malang, who used similar strategies, produced different answers. Rational-type students generally maintained consistent reasoning across stages, while intuitive and avoidant students produced more varied outcomes.

Another finding shows that students who were familiar with the problem context, such as understanding the Malang City map, solved problems more efficiently and accurately. Conversely, students with limited contextual understanding took longer and often changed strategies. This indicates that contextual familiarity supports more effective decision-making. Overall, the data indicate that students' decision-making in open problem-solving is influenced by the completeness of reflective thinking stages and by individual decision-making styles. Rational students tend to complete all stages systematically, while intuitive and dependent students are less structured. These findings demonstrate that refractive thinking manifests differently across decision-making styles and contributes to the diversity of student reasoning in solving open-ended mathematical problems.

Discussion

The findings of this study reveal that students' biased thinking in solving open mathematical problems follows the stages proposed by Dewey's reflective inquiry and Schön's concept of reflection-in-action. The confusion experienced at the beginning of the assignment triggers students to investigate and construct alternative solutions, in line with Dewey's idea that confusion stimulates reflective reasoning (Rodgers, 2018). Rational-style students exhibit a more complete cycle—from investigation to evaluation and decision-making—that demonstrates internal coherence between reflection and action. Instead, intuitive and evasive students exhibit fragmented processes, making premature decisions without a thorough evaluation. Systematic reflection leads to higher-quality decisions (Özsoy-Güneş et al., 2015; Reinholz, 2016; Yildiz & Baltaci, 2016). Thus, this study confirms that refractive thinking serves as a bridge between reflective understanding and critical evaluation in decision-making.

Compared to previous research on open problem-solving (Trimawati et al., 2020; Widiya & Radia, 2023; Fauzan et al., 2024), these findings broaden the discussion by highlighting the interaction between *decision-making styles* and *biased thinking* (Prastika & Nugroho, 2025). Previous research has mostly explored reflective or critical thinking separately, whereas this study integrates the two within a refractive framework. This suggests that rational-style students consistently apply evaluation and verification. In contrast, intuitive or dependent students exhibit a cycle of partial reflection, demonstrating cognitive diversity in their approach to open problems. These findings refine previous models by emphasizing that biased thinking does not occur uniformly but is mediated by personal decision-making tendencies and contextual familiarity. Therefore, this study enriches theoretical understanding by providing an empirical model of the stages of refractive thinking that are manifested in real problem-solving behavior.

Theoretically, this research contributes to the development of decision-making theory in mathematics education by positioning biased thinking as an integrated cognitive process that combines reflection, analysis, and transformation (Benakli et al., 2017; Bulent et al., 2016; Imaniyati et al. 2024, 2024). In practical terms, this study provides evidence that open-ended context-based math problems can foster students' reflective and evaluative habits, which are essential for higher-level thinking. These insights suggest that lecturers should design a learning environment that encourages students to continually question, evaluate, and revise their reasoning. For future research, the refractive thinking models presented here can serve as a framework for examining how decision-making develops across different cognitive styles, academic levels, or digital learning contexts (Bull et al., 2020; Nouri et al., 2020). In this way, this research advances theory and practice by linking cognitive processes with effective pedagogical design in mathematics education.

The findings of this study reveal that students' reflective thinking in solving open mathematical problems follows the stages proposed by Dewey's reflective inquiry and Schön's concept of *reflection-in-action*. The perplexity experienced at the beginning of the task triggered students to investigate and construct alternative solutions, aligning with Dewey's idea that confusion stimulates reflective reasoning. Rational-style students demonstrated a more complete cycle—from investigation to evaluation and decision—showing internal coherence between reflection and action. In contrast, intuitive and avoidant students exhibited fragmented decision-making processes, making decisions prematurely without a thorough evaluation. This supports Dwyer et al. (2017), who stated that systematic reflection leads to higher decision quality. Thus, the study confirms that refractive thinking functions as a bridge between reflective understanding and critical evaluation in decision-making.

Compared to previous studies on open-ended problem solving (Trimawati et al., 2020; Widiya & Radia, 2023; Fauzan et al., 2024), the present findings extend the discussion by highlighting the interaction between *decision-making styles* and *refractive thinking*. Prior research has mostly explored reflective or critical thinking separately, whereas this study integrates both within a refractive framework. It shows that rational-style students consistently apply evaluation and verification, while intuitive or dependent students exhibit partial cycles of reflection, indicating cognitive diversity in their approach to open problems. These findings refine earlier models by emphasizing that refractive thinking does not occur uniformly but is mediated by personal decision-making tendencies and contextual familiarity. Therefore, this study enriches theoretical understanding by providing an empirical model of refractive thinking stages manifested in real problem-solving behavior.

The study's results show that students employ various methods to identify information on open problems, reflecting their respective decision-making styles. Students with a rational style are more systematic in writing information, while intuitive students tend to interpret problems directly. Understanding the problem is a crucial foundation for strategizing (Kholid et al., 2021). In this process, indicators of refractive thinking, such as perplexity and investigation, emerge. The initial confusion triggers students to investigate further information. Reflection often arises from the uncertainty experienced by a person (Istichomah, 2021). Therefore, the problem identification stage plays a crucial role in determining the quality of student decisions. These findings show that thinking styles affect the completeness of the early stages of reflective thinking.

The investigation process shows that students with rational and intuitive styles show different strategies in finding solutions. Rational students write down several alternatives, while intuitives are quicker to choose strategies, even though they are less in-depth. Decision-making styles affect the depth of information processing. At this stage, refractive thinking works by connecting reflection and criticism to generate alternative solutions. Divergent thinking so that individuals can develop many possible solutions. The results of the study support this theory, because flexible students are better able to explore strategies (Dumas, 2018). On the other hand, students who tend to be procedural experience limitations at the investigation stage. Thus, flexibility of thinking is an important key in decision-making.

The construct stage shows a variety of creativity in building solutions. Students of Khairun Ternate University develop different strategies, ranging from visualization to combination calculations. Meanwhile, students at the State University of Malang tend to use a standard formula with little variation. Learning that emphasizes procedures makes students less creative in dealing with open problems (Agbo et al., 2023). Solution construction involves interpretation and conjecture as part of refractive thinking. These findings suggest that the diversity of strategies is an important indicator of higher-level thinking skills. In other words, the ability to construct solutions shows differences in the quality of student decision-making. Therefore, the construct stage is a critical point in measuring reflective thinking.

Solution evaluation is a stage that distinguishes students with high and low reflective thinking skills. Rational students conduct a thorough evaluation of all alternatives before reaching a final decision. Evaluation is at the core of critical thinking. Conversely, intuitive or dependent students tend to make decisions more quickly without thorough evaluation. This condition makes them susceptible to conceptual errors. Evaluation requires analysis, interpretation, and self-regulation skills (Stufflebeam & Zhang, 2017). The findings of this study indicate that evaluation is both a reflective and a critical stage in the reflective thinking process. Therefore, learning needs to emphasize the importance of evaluation before decision-making. That way, students can minimize bias in their strategy choices.

Final decision-making shows different levels of consistency among students. Rational students tend to make the same decisions despite different strategies, while intuitive students produce different decisions with the same strategies. This supports the theory of decision-making styles, which categorizes styles into rational, intuitive, dependent, avoidant, and spontaneous. Decision consistency reflects mature reflective thinking skills. Refractive thinking produces transformative knowledge by considering multiple alternatives (Rusdin, 2023). The findings of this study demonstrate that refractive thinking is a key factor in making logical decisions. Thus, decision-making styles are closely related to the quality of students' final results. This condition shows a relationship between cognitive preferences and success in open problems.

Students' habits in dealing with closed problems affect their ability to solve open problems. Some students only give one strategy and one answer, as well as solve routine problems. Open problems demand higher thinking flexibility than closed problems. A lack of exposure to open-ended problems makes it challenging for students to develop alternative solutions. The results of the study showed that UM students were more familiar with procedural patterns, while UMM students were more varied. The importance of experience in shaping thinking skills (Suharna et al., 2020). Therefore, learning mathematics should provide more exposure to open-ended problems. In this way, students' reflective thinking skills can be sharpened.

The relationship between decision-making style and refractive thinking is clearly seen in this study. Students with a rational style are more likely to pass all stages of reflective thinking than those with other styles. In contrast, avoidant students often avoid in-depth processes and immediately give answers without clear reasoning. Decision-making styles represent an individual's cognitive preferences. These findings reinforce the theory by showing a stark difference in the quality of decision-making. Reflection-in-action helps individuals improve decisions on an ongoing basis (Reinholz, 2016). Thus, the rational style encourages reflection and evaluation better than other styles. This suggests that decision-making styles have implications for the depth and completeness of reflective thinking.

The process of refractive thinking also helps students correct the mistakes they make with their strategies. Students who re-evaluate are quicker to find alternative solutions than those who do not. This is in accordance with the view that Reflection functions to correct errors in thinking (Lestari et al., 2022). Reflection in actions helps direct strategy adjustments. In this study, rational and dependent students did more strategy revisions. Conversely, intuitive and avoidant students tend to stop at the first answer that comes to mind. These findings suggest that refractive thinking increases flexibility in decision-making. Therefore, continuous reflection needs to become a habit in mathematics learning. That way, students are more adaptive to mistakes.

Contextual knowledge has been shown to influence the quality of student decision-making. Students who understand the map of Malang City can find solutions to the given graph problems faster. Social and contextual experiences play an important role in cognitive development. This is proven when students with better contextual knowledge can build efficient strategies. Conversely, students who are less familiar with the context take longer. This condition shows the importance of presenting open issues that are relevant to students' daily experiences. Meaningful learning occurs when material is connected to real-life experiences. Thus, the mastery of context supports the development of refractive thinking (Alvinaria et al., 2022). Therefore, contextual problems are worth approaching in mathematics learning.

The findings of this study also support the view that Trimawati et al. (2020) Critical and reflective thinking are essential prerequisites for making informed, quality decisions. The evaluation and decision stage shows how students weigh reasons logically. Rational students conduct thorough analysis, while intuitive students rely more on intuition. This condition underscores the importance of integrating reflection and critical analysis in the reflective thinking process to foster transformative knowledge. Thus, refractive thinking is not just a reflection but also an evaluation that leads to informed decisions. This suggests that mathematics learning should train both reflective and critical thinking skills simultaneously. That way, the quality of student decision-making can be improved.

When compared to previous research, the results of this study show a new contribution. Students think refractively in solving mathematical problems, but have not emphasized the decision-making aspect. This study fills this gap by emphasizing the involvement of refractive thinking in decision-making. The results of this study illustrate the stages of perplexity, investigation, construction, evaluation, and decision in practical terms. This enriches the study of the relationship between refractive thinking and decision-making processes. Thus, this research expands our understanding of how students approach open-ended problems. These findings also make a practical contribution to learning strategies. Therefore, this research can be a reference for future studies.

Overall, this discussion highlights that refractive thinking is a crucial foundation for students' decision-making on open mathematics problems. This process involves critical reflection and evaluation, leading to informed and logical decisions. Differences in decision-making styles have a significant effect on the completeness of the refractive thinking stages. Rational students are more consistent, while intuitive and avoidant students tend to be less systematic. These findings support Dewey, Schön, Scott & Bruce, as well as Pagano & Roselle's theories about the importance of reflection and evaluation. Thus, this study emphasizes the need for open-ended, problem-based learning to train students in reflective thinking. This also provides practical implications for mathematics lecturers in designing learning strategies.

4. CONCLUSION

This study concludes that student decision-making in solving open mathematical problems occurs through the stages of refractive thinking, which include perplexity, investigation, construction, evaluation, and decision. Students with a rational decision-making style tend to be more systematic and consistent in their approach to all stages than those with other styles. On the other hand, students with intuitive, dependent, and avoidant styles tend to be less thorough in conducting investigations and evaluations. The study's findings show that students at Khairun Ternate University employ different strategies yet arrive at the same decisions. In contrast, students at the State University of Malang use similar strategies but reach different conclusions. This indicates that decision-making styles and learning experiences have a significant impact on the quality of students' reflective thinking. Contextual knowledge has also been proven to support the smooth process of reflective thinking in solving open problems. Thus, open-ended problem-based mathematics learning is essential for training students' reflective and critical thinking abilities. This research contributes theoretically to strengthening the study of the relationship between refractive thinking and decision-making, and practically serves as a reference for lecturers in designing mathematics learning strategies that emphasize higher-level thinking-based decision-making.

REFERENCES

Agbo, F. J., Olaleye, S. A., Bower, M., & Oyelere, S. S. (2023). Examining the relationships between students' perceptions of technology, pedagogy, and cognition: The case of immersive virtual reality mini games to foster computational thinking in higher education. *Smart Learning Environments*, *10*(1), 16. https://doi.org/10.1186/s40561-023-00233-1

Allsop, Y. (2019). Assessing the computational thinking process using a multiple evaluation approach. *International Journal of Child-Computer Interaction*, *19*, 30–55. https://doi.org/10.1016/j.ijcci.2018.10.004

Alvinaria, A., Lukito, A., & Wijayanti, P. (2022). Identifikasi Berpikir Aljabar Siswa Field Independent dan Field Dependent Menggunakan Taksonomi SOLO. *Jurnal Riset Pendidikan Dan Inovasi Pembelajaran Matematika*, *5*(2), 142–165. https://doi.org/10.26740/jrpipm.v5n2.p142-165

Ansari, B., Taufiq, T., & Saminan, S. (2020). The use of the creative problem-solving model to develop students' adaptive reasoning ability: Inductive, deductive, and intuitive. *International Journal on …, Query date: 2023-09-06 09:20:59*. https://scholar.archive.org/work/ep52usovzbbohbcbytvtav4i3y/access/wayback/http://ejournal.uin-malang.ac.id/index.php/ijtlm/article/download/9439/pdf

Atikah, Fitroh Adhilla, & Zunan Setiawan. (2025). Pengaruh Iklan Media Sosial, Electronic Word of Mouth dan Citra Merek Terhadap Keputusan Pembelian Smartphone Oppo: Studi Kasus pada Pengguna Smartphone OPPO di Yogyakarta. *Economic Reviews Journal*, *4*(2). https://doi.org/10.56709/mrj.v4i2.698

Attallah, B., Change, Y.-K., & Il-Agure, Z. (2019). Developing IoT Competencies in Non-Computer Science Students in Higher Education. *2019 Sixth HCT Information Technology Trends (ITT)*, 240–246. https://doi.org/10.1109/itt48889.2019.9075075

Benakli, N., Kostadinov, B., Satyanarayana, A., & Singh, S. (2017). Introducing computational thinking through hands-on projects using R with applications to calculus, probability, and data analysis. *International Journal of Mathematical Education in Science and Technology*, *48*(3), 393–427. https://doi.org/10.1080/0020739X.2016.1254296

Boonjeam, W., Tesaputa, K., & Sri-ampai, A. (2017). Program Development for Primary School Teachers' Critical Thinking. *International Education Studies*, *10*(2), 131–138. https://doi.org/10.5539/ies.v10n2p131

Bulent, D., Erdal, B., Ceyda, A., Betul, T., Nurgul, C., & Cevahir, D. (2016). An analysis of teachers' questioning strategies. *Educational Research and Reviews*, *11*(22), 2065–2078. https://doi.org/10.5897/ERR2016.3014

Bull, G., Garofalo, J., & Hguyen, N. R. (2020). Thinking about computational thinking: Origins of computational thinking in educational computing. *Journal of Digital Learning in Teacher Education*, *36*(1), 6–18. https://doi.org/10.1080/21532974.2019.1694381

Cansoy, R., & Turkoglu, M. E. (2017). Examining the Relationship between Pre-Service Teachers' Critical Thinking Disposition, Problem-Solving Skills, and Teacher Self-Efficacy. *International Education Studies*, *10*(6), 23. https://doi.org/10.5539/ies.v10n6p23

Dumas, D. (2018). Relational reasoning and divergent thinking: An examination of the threshold hypothesis with quantile regression. *Contemporary Educational Psychology*, *53*(January), 1–14. https://doi.org/10.1016/j.cedpsych.2018.01.003

Dwi Prastika, A., & Nugroho, Y. S. (2025a). Klasifikasi Efektivitas Iklan di E-Commerce dan Media Sosial terhadap Minat Beli Mahasiswa UMS dengan Decision Tree. *Jurnal Pendidikan Dan Teknologi Indonesia*, *5*(4), 919–933. https://doi.org/10.52436/1.jpti.727

Dwi Prastika, A., & Nugroho, Y. S. (2025b). Klasifikasi Efektivitas Iklan di E-Commerce dan Media Sosial terhadap Minat Beli Mahasiswa UMS dengan Decision Tree. *Jurnal Pendidikan Dan Teknologi Indonesia*, *5*(4), 919–933. https://doi.org/10.52436/1.jpti.727

Dwyer, C. P., Hogan, M. J., Harney, O. M., & Kavanagh, C. (2017). Facilitating a student-educator conceptual model of dispositions towards critical thinking through interactive management. *Education Technology Research*, *65*, 47–73. https://doi.org/10.1007/s11423-016-9460-7

Fauzan, H. R., Hidayanto, E., & Chandra, T. D. (2024). Reversible thinking in solving mathematics problems in terms of cognitive style. *Al-Jabar : Jurnal Pendidikan Matematika*, *15*(2), 559–576. https://doi.org/10.24042/ajpm.v15i2.24527

Imaniyati, N., Ramdhany, M. A., Rasto, R., Nurjanah, S., Solihah, P. A., & Susilawati, A. (2024). Neuroscience Intervention for Implementing Digital Transformation and Organizational Health Completed with Literature Review, Bibliometrics, and Experiments. *Indonesian Journal of Science & Technology*, *9*(2). https://doi.org/10.17509/ijost.v9i2.67763

Istichomah, N. (2021). *Pengembangan lembar kerja siswa berbasis learning trajectory menggunakan motif anyaman pada materi transformasi refleksi*.

Johnson, C. A. N., Bin Daud, M. F., Bin Arsat, M., Hussin, W. N. Bt. W., & Egba, E. I. (2021). The Effect of Computer Software Interaction on Students' Cognitive Abilities Enhancement: The Case of Engineering Educators' Perspective. *International Journal of Emerging Technologies in Learning (iJET)*, *16*(18), 228–241. https://doi.org/10.3991/ijet.v16i18.24379

Khaesarani, I. R., & Ananda, R. (2022). Students' mathematical literacy skills in solving higher-order thinking skills problems. *Al-Jabar : Jurnal Pendidikan Matematika*, *13*(1), 81–99. https://doi.org/10.24042/ajpm.v13i1.11499

Kholid, M. N., Imawati, A., Swastika, A., Maharani, S., & Pradana, L. N. (2021). How is Students' Conceptual Understanding for Solving Mathematical Problems? *Journal of Physics: Conference Series*, *1776*(1). https://doi.org/10.1088/1742-6596/1776/1/012018

Lestari, K. I., Arcana, I. N., Susetyo, A. E., & Kuncoro, K. S. (2022). Development of Online Learning Quiz and Educational Game Using Word Walls in Mathematics for Grade 10. *INSANIA : Jurnal Pemikiran Alternatif Kependidikan*, *27*(2), 145–159. https://doi.org/10.24090/insania.v27i2.6924

Nouri, J., Zhang, L., Mannila, L., & Norén, E. (2020). Development of computational thinking, digital competence, and 21st-century skills when learning programming in K-12. *Education Inquiry*, *11*(1), 1–17. https://doi.org/10.1080/20004508.2019.1627844

Özsoy-Güneş, Z., Güneş, İ., Derelioğlu, Y., & Kırbaşlar, F. G. (2015). The Reflection of Critical Thinking Dispositions on Operational Chemistry and Physics Problems Solving of Engineering Faculty Students. *Procedia - Social and Behavioral Sciences*, *174*(February), 448–456. https://doi.org/10.1016/j.sbspro.2015.01.688

Presmeg, N. (2016). Semiotics as a Tool for Learning Mathematics: How to Describe the Construction, Visualisation, and Communication of Mathematical Concepts by Adalira Sáenz-Ludlow & Gert Kadunz (Eds.). *Mathematical Thinking and Learning*, *18*(3), 233–238. https://doi.org/10.1080/10986065.2016.1184953

Reinholz, D. L. (2016). Developing mathematical practices through reflection cycles. *Mathematics Education Research Journal*, *28*(3), 441–455. https://doi.org/10.1007/s13394-016-0175-1

Rodgers, C. (2002). Defining Reflection: Another Look at John Dewey and Reflective Thinking. *Teachers College Record,104*, *104*(4), 842–866.

Román-González, M., Pérez-González, J. C., & Jiménez-Fernández, C. (2017). Which cognitive abilities underlie computational thinking? Criterion validity of the Computational Thinking Test. *Computers in Human Behavior*, *72*, 678–691. https://doi.org/10.1016/j.chb.2016.08.047

Rusdiana, R., Samsuddin, A. F., Muhtadin, A., & Fendiyanto, P. (2023). Development of Mathematical Literacy Problems in the Context of East Kalimantan. *Jurnal Cendekia : Jurnal Pendidikan Matematika*, *7*(1), 197–210. https://doi.org/10.31004/cendekia.v7i1.1885

Rusdin, R. (2023). Transformasi Pendidikan Islam di Banten Melalui Program Unggulan. *An-Nuha: Jurnal Sosial & Humaniora*, *1*(1), 31–43. https://doi.org/10.63005/annuha.v1i1.1

Simatupang, H. W., Riskiana, R. R., Widowati, S., & Alitu, A. F. (2022). Evaluasi Usability Website dengan Website Usability Evaluation tool dan Importance-Performance Analysis. *Techno.Com*, *21*(1), 103–114. https://doi.org/10.33633/tc.v21i1.5584

Siregar, S. M., Utomo, B., & Marlina, L. (2020). Perancangan Buku Interaktif untuk Memperkenalkan Ragam Profesi Sebagai Sarana Pengembangan Minat Pelajar Usia Dini. *Prosiding Konferensi Nasional Pengabdian Kepada Masyarakat dan Corporate Social Responsibility (PKM-CSR)*, *3*, 828–834. https://doi.org/10.37695/pkmcsr.v3i0.881

Stufflebeam, D. L., & Zhang, G. (2017). *The CIPP Evaluation Model: How to Evaluate for Improvement and Accountability*. Guilford Publications.

Suharna, H., Hairun, Y., Abdullah, I. H., Alhaddad, I., Afandi, A., Ardiana, & Sari, D. P. (2020). The Reflective Thinking Elementary Student in Solving Problems Based on Mathematic Ability. *International Journal of Advanced Science and Technology*, *29*(6), 3880–3891.

Syamsudin, S. (2020). Problem Based Learning dalam Mengembangkan Kemampuan Berpikir Kritis dan Keterampilan Sosial. *ELSE (Elementary School Education Journal) : Jurnal Pendidikan dan Pembelajaran Sekolah Dasar*, *4*(2), 81. https://doi.org/10.30651/else.v4i2.4610

Syazwani, S. A. H., & Voutama, A. (2025). ANALISIS PENGGUNAAN SISTEM INFORMASI DALAM PENGAMBILAN KEPUTUSAN PEMASARAN PADA TOKO ONLINE DI SHOPEE (STUDI KASUS: TOKO LINAZENSHOP OFFICIAL). *Jurnal Informatika Dan Teknik Elektro Terapan*, *13*(2). https://doi.org/10.23960/jitet.v13i2.6358

Trimawati, K., Kirana, T., & Raharjo, R. (2020). Pengembangan Instrumen Penilaian IPA Terpadu dalam Pembelajaran Model Project Based Learning (PjBL) untuk Meningkatkan Kemampuan Berpikir Kritis dan Kreatif Siswa SMP. *Quantum: Jurnal Inovasi Pendidikan Sains*, *11*(1), 36. https://doi.org/10.20527/quantum.v11i1.7606

Weintrop, D., Rutstein, D. W., Bienkowski, M., Mcgee, S., Weintrop, D., Rutstein, D. W., Bienkowski, M., & Mcgee, S. (2021). Assessing computational thinking: An overview of the field. *Computer Science Education*, *31*(2), 113–116. https://doi.org/10.1080/08993408.2021.1918380

Widiya, A. W., & Radia, E. H. (2023). Pengaruh Model Pembelajaran Inkuiri Terbimbing Terhadap Kemampuan Berpikir Kritis dan Hasil Belajar IPS. *Aulad: Journal on Early Childhood*, *6*(2), 127–136. https://doi.org/10.31004/aulad.v6i2.477

Yildiz, A., & Baltaci, S. (2016). Reflections From the Analytic Geometry Courses Based on Contextual Teaching and Learning. *The Online Journal of New Horizons in Education*, *6*(4), 155–166.

Zayyadi, M., Nusantara, T., Subanji, Hidayanto, E., & Sulandra, I. M. (2019). A Cognitive Framework: The Process of Solving Mathematical Problems for Middle School Students. *International Journal of Learning, Teaching and Educational Research*, *18*(2), 89–102. https://doi.org/10.26803/ijlter.18.2.7