

An analysis of Indonesian and Malaysian postgraduate students' mathematical problem-solving behavior using research skill development framework

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Abstract

Problem-solving behavior is a crucial skill for postgraduate students. However, research employing the Research Skill Development (RSD) framework to improve the skill across different cultural contexts and genders is limited. This study aims to analyze the problem-solving behavior of postgraduate students in Indonesia and Malaysia using the RSD framework, taking into account the perspectives of learning culture and gender. It employed the qualitative method with a case study design. Data were collected by testing and interviewing postgraduate students they are five students in Indonesia and four students from Malaysia. The results revealed that students with high levels of RSD do not always show high mathematical problem-solving behavior. However, those with low mathematical problem-solving behavior tend to have low levels of RSD. The categorization of problem-solving behavior is not determined by learning culture or gender. However, differences in cognitive strategies and approaches were observed across groups, suggesting that culture and gender may influence problem-solving style rather than behavioral level. Female students in Indonesia are more likely to use an analytical approach, while male students in Malaysia are more likely to use a creative approach. In addition, a collaborative and inclusive learning culture can improve students' problem-solving abilities. The results of this study can serve as a reference for improving the quality of postgraduate education in both countries.

Keywords:

Gender, Learning culture, Postgraduate student, Problem-solving behavior, RSD framework

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1. INTRODUCTION

Behavior is an individual's response to a given stimulus. The stimulus given in the form of test questions should align with the ability indicators to be achieved (Gunawan et al., 2019). Students' solutions to mathematical problems reflect their mathematical problem-solving behavior (Hafizatunnisa et al., 2024; Harisman, Asra, Hafizatunnisa, et al., 2025; Harisman & Khairani, 2021; Harisman et al., 2020, 2021; Mairing, 2020; Muir et al., 2008; Vermeer et al., 2000). Individuals' mathematical problem-solving behavior can be seen through their verbal or written responses (Adhimah et al., 2020; Harisman et al., 2020, 2021; Jögi & Kikas, 2016). Problem-solving behavior includes cognitive, affective, psychomotor, and metacognitive aspects (Hafizatunnisa et al., 2024; Harisman et al., 2020, 2021).

Mathematical problem solving is essential for postgraduate students in research methodology courses, as it indicates how students understand and resolve problems (Adhimah et al., 2020; Apino et al., 2024; Hidayat et al., 2025; Méndez-Parra et al., 2022; Pawar & Ahirwal, 2023; Suparman et al., 2025). Krulik and Rudnick (1989) stated that mathematical problem solving is a process in which an individual uses previously acquired knowledge, skills, and understanding to meet the demands of an unfamiliar situation. In addition, mathematical problem solvers also use new strategies to solve problems. Previous research recommended problem-solving strategies usually use come from Polya (Hafizatunnisa et al., 2024; Muir et al., 2008; Özcan, 2016). According to Polya (1973), a person is said to have good problem-solving skills if they can understand the problem, plan a solution strategy, implement the strategy, and re-evaluate the process that has been carried out. This has implications for the learning of postgraduate students in research methodology courses when solving a research problem (Zhang et al., 2021).

It is expected that lecturers will pay attention to the problem-solving behavior of postgraduate students in research methodology courses (Khaerudin et al., 2023). Muir et al. (2008) suggest that rather than focusing on whether or not certain strategies are taught and how, it is more beneficial to examine what successful problem solvers do and then develop individual problem-solving behavior to achieve goals. However, existing research concentrates only on the correctness of the final results in solving mathematical problems, without paying attention to the process (Jitendra et al., 2017; Pawar & Ahirwal, 2023). Consequently, when faced with a problem, students often feel confused about how to solve it (Jitendra et al., 2017; Oswald et al., 2016). In research, the process how postgraduate students conduct research can be developed through the Research Skill Development (RSD) framework (Gyuris, 2018).

RSD framework is an effective approach to developing students' research skills. The RSD framework can help students develop better research skills by facilitating a deeper understanding and application of research concepts (Willison & O'Regan, 2007). By using the RSD framework, students can develop more comprehensive research skills that can be applied in various research contexts (Castillo & Ho, 2021; Gyuris, 2018; Mataniari et al., 2020; Parange & Marks, 2016; Pérez-Reveles et al., 2021; van der Merwe et al., 2022; Willison & O'Regan, 2007). Then, the RSD framework can be an effective tool for improving postgraduate students' research skills (Gyuris, 2018).

Previous studies have discussed the application of the Research Skill Development (RSD) framework in various scientific fields described how the critical thinking skills of biology students were developed in solving problems by using the RSD framework (Mataniari et al., 2020). Additionally, research by Castillo and Ho (2021) revealed that the RSD framework can help improve the research skills of students in interdisciplinary programs. Parange and Marks (2016) also demonstrated that the use of the RSD framework can enhance the clinical diagnostic reasoning and research skills of medical students in obstetric and gynecological sonography.

However, its application in mathematics, especially at the postgraduate level, is still relatively new and requires further emphasis as a significant research gap. In the existing literature, most studies focus primarily on the validity of the final results of mathematical problem-solving without adequately emphasizing the behavioral processes used by students while solving problems (Harisman et al., 2021). For example, many studies in Western countries focus on assessing the accuracy of the final answer, but few examine how problem-solving strategies or processes are applied during problem-solving (Hao et al., 2025; Jiang et al., 2021). This indicates a significant research gap regarding the importance of understanding the problem-solving process, not just the final results (Hafizatunnisa et al., 2024; Muir et al., 2008). Furthermore, most studies tend to focus on limited educational contexts, without providing comparative insights into how students in developing countries, such as Indonesia and Malaysia, face challenges in mathematical problem-solving. Cultural differences in learning approaches need to be further explored to gain a deeper understanding.

The discussion on developing research skills and problem-solving behaviors among postgraduate students is relevant globally. However, the use of the framework in this study focuses solely on the context of Indonesia and Malaysia. This is because Indonesia and Malaysia have unique educational systems and cultures (Jaedun et al., 2024; Laub, 1999). In addition to the educational and cultural factors of the two countries, this study also considers gender in examining how the RSD framework is applied in the context of mathematics. This indicates the need for a deeper exploration of how the RSD framework and problem-solving behaviors can be applied in broader and more diverse contexts.

Despite the extensive application of the RSD framework across disciplines, its integration with mathematical problem-solving behavior, particularly in postgraduate research contexts, remains underexplored (Harisman, Asra, Suherman, et al., 2025). Existing studies focus predominantly on outcome correctness rather than behavioral processes, and there is limited evidence on how research-oriented frameworks such as RSD shape students' cognitive, metacognitive, and affective engagement when solving mathematical research problems. Moreover, comparative insights across culturally distinct higher education systems, such as Indonesia and Malaysia, are largely absent.

This study aims to clarify the theoretical contribution of the application of the Research Skill Development (RSD) framework in a global context, particularly in mathematics education at the postgraduate level. The RSD framework provides deeper insights into how students develop their research skills, particularly in the process of solving mathematical problems. This study also explores the implications of the RSD framework in the context of international higher education, taking into account differences in learning culture and gender

that may influence how students solve problems. Therefore, this study is expected to provide guidance for the development of a more effective and responsive curriculum to the needs of students in various countries, by integrating the RSD framework into postgraduate education globally.

Therefore, this study can clarify the theoretical contribution of applying the RSD framework in a global context and explore further implications for international higher education. By expanding the discussion on how the RSD framework can be applied with consideration for diversity (e.g., learning culture and gender), this study provides a more comprehensive insight into the application of research skills and problem-solving behaviors at the global level. This study is expected not only to provide insights to Indonesian and Malaysian scholars, but also to attract international readers by highlighting the global relevance of existing findings, such as curriculum development, understanding mathematical problem-solving behavior, integration of the RSD framework with other learning theories, enhancement of problem-solving abilities, and improvement of research skills (Ain et al., 2019; Hafizatunnisa et al., 2024; Harisman et al., 2021; Muir et al., 2008; Pérez-Reveles et al., 2021; Willison & Buisman-Pijlman, 2016). The primary objective of this study is to review how the Research Skill Development (RSD) framework influences the problem-solving behavior of postgraduate students in Indonesia and Malaysia, and to what extent the learning cultures of both countries and gender influence this behavior.

2. METHOD

This research employed the case study design. The case study design was chosen because it allows researchers to conduct an in-depth and contextual study of a limited phenomenon (Creswell & Poth, 2018). In this study, the mathematical problem-solving behavior of graduate students was examined. This design is particularly appropriate when the research aims to answer the 'how' and 'why' questions regarding a contemporary phenomenon that cannot be easily separated from its context. In this study, each participant is treated as an individual case, allowing researchers to conduct a comprehensive analysis of how each student's problem-solving behavior manifests at various levels of the RSD framework. The participants were postgraduate students taking the research methodology course at Universitas Negeri Padang (Indonesia) and Universiti Pendidikan Sultan Idris (Malaysia). Four students from each university were selected based on the RSD framework level. The RSD thinking framework utilizes a rubric in research, as described by Willison and O'Regan (2007), which can be seen in Figure 1.

The sample size in this study was determined based on purposive sampling principles, focusing on information sufficiency, not statistical representation. In qualitative research with a case study design, sample adequacy is not measured by the number of participants, but rather by the depth and richness of the data generated (Creswell & Poth, 2018). Eight participants were selected because they represented meaningful variation across three key dimensions: (1) RSD levels (Levels 3, 4, and 5), (2) problem-solving behavior categories (naïve, routine, and sophisticated), and (3) cultural learning contexts (Indonesia and Malaysia). This variation allowed for meaningful, in-depth analysis across cases. The principle of theoretical saturation

was also considered, meaning data collection ceased when new categories no longer emerged from additional data analysis (Rahimi & Khatoni, 2024). Therefore, nine participants were deemed sufficient for the purpose of this study, which was to gain a deeper understanding of problem-solving behavior within the context of the RSD framework, rather than to statistically generalize to a broader population.

The participant selection process for this study was conducted by considering each student's level of Research Skill Development (RSD). Before selecting eight students (five from Indonesia and four from Malaysia), the researchers conducted a preliminary assessment using the RSD rubric to assess the participants' research skills. This rubric classifies students into seven levels (Levels 1 to 7) based on their abilities in various research dimensions, including cognitive, metacognitive, and affective skills. Participants were selected based on their RSD levels, which included variations within the Levels 3, 4, and 5 categories, to ensure diversity in the mathematical problem-solving approaches used. This preliminary assessment began with students presenting the results of mini-research from previous assignments as part of the initial evaluation. Afterward, interviews were conducted based on indicators at the Research Skill Development (RSD) level to categorize students based on the RSD framework. This process aimed to identify students' levels of research skills, including cognitive, metacognitive, and affective abilities, as reflected in their mathematical problem-solving.

In addition to selecting participants based on their RSD levels, the RSD framework was also used as an analytical lens to analyze students' problem-solving behavior. This framework allowed us to evaluate how students at different RSD levels apply different problem-solving strategies. Each level in the RSD framework reflects a student's level of skill in managing complex problems, across cognitive, metacognitive, and affective dimensions. In this study, the RSD framework helped identify differences in problem-solving approaches used by students with different RSD levels and provided insight into how their research skills developed throughout the problem-solving process.

In this study, the students were given a test based on indicators of mathematical problem-solving behavior adapted from Muir et al. (2008).


		← supervisor instigated		→ researcher instigated		← discipline leading →		
		Prescribed Research Level 1	Bounded Research Level 2	Scaffolded Research Level 3	Self-initiated Research Level 4	Open Research Level 5	Adopted Research Level 6	Enlarging Research Level 7
www.rsd.edu.au john.willison@rsl.edu.au		Highly structured directions and instructions from the supervisor prompt the researcher(s) to ...	Boundaries set by and limited directions from supervisor channel the researcher(s) to ...	Scaffolds placed by supervisor enable the researcher(s) to ... independently...	Researcher(s) initiate and supervisor guides.	Researcher(s) determine guidelines that are in accord with discipline of context.	Researcher(s) initiate others' agendas.	Researcher(s) enlarge the field of inquiry.
Researcher's... Facets of Research a. Embark & Clarify b. Find & Generate c. Evaluate & Reflect d. Organise & Manage e. Analyse & Synthesise f. Communicate & Apply	Context	Respond to questions/ tasks provided exactly. Use a provided approach to clarify questions, expectations and ECST issues.	Respond to questions/ tasks implied in directions. Choose from several provided structures to clarify questions, expectations and ECST issues.	Respond to questions/ tasks generated from instructions. Choose from a range of provided structures or approaches to clarify salient elements including ECST issues.	Generate questionnaires/ hypotheses framed within structured guidelines. Anticipate and prepare for ECST issues.	Generate questionnaires/ hypotheses based on experience, expertise and literature. Devise info and prepare for ECST issues.	Identify previously unstated gaps in literature and articulate research directions and ECST issues in response to same.	Articulate research directions that expand or direct the field and articulate the corresponding ECST issues.
	Determining	Collect and record required information or data using a prescribed methodology from a prescribed source in which the information/data is clearly evident.	Collect and record required information/data using a prescribed methodology from prescribed sources in which the information/ data is not clearly evident.	Collect and record required information/data from self-selected sources using one of several prescribed methodologies.	Collect and record self-determined information/ data, choosing an appropriate methodology based on structured guidelines.	Collect and record self-determined information/ data, choosing an appropriate methodology.	Synthesise others' methods to formulate novel method/ methodologies or apply existing methods to novel applications.	Generate new methods/methodologies that are used widely.
	Discerning	Evaluate sources/ information/data using single prescribed criteria to specify credibility and to reflect on the research process.	Evaluate sources/ information/data using a choice of provided criteria to specify credibility and to reflect on the research process.	Evaluate information/data and inquiry process using criteria related to the aims of the inquiry. Reflect insightfully to improve own processes used.	Evaluate information/data and the inquiry process using self-determined criteria based on experience, expertise and the literature. Refine others' processes.	Evaluate information/data and inquiry process using self-generated criteria based on experience, expertise and the literature. Refine others' processes.	Generate substantial research outcomes, so that ideas, practices or interpretations are academically/ professionally endorsed by others.	Generate substantial research outcomes, so that ideas, practices or interpretations become foundational in field or discipline.
	Humanising	Organise information/data using prescribed structure. Manage linear process, and manage teams and research processes.	Organise information/data using a choice of given structures. Manage a self-process which has alternative pathways (and specify team roles).	Organise information/data using recommended structures. Manage self-determined processes (including team function) with multiple pathways.	Organise information/data using self-determined structures, and manage the processes, within supervisor's parameters.	Organise information/data using self-determined structures and management processes.	Form a research team at a level of community-based practitioner.	Form and develop research networks/communities.
	Creative	Interpret (over) information/data and synthesise knowledge into prescribed formats. Ask emergent question.	Interpret several sources of information/data and synthesise to integrate knowledge into standard formats. Ask relevant, researchable questions.	Analyse trends in information/data and synthesise to fully integrate components (including with parameters specified). Ask rigorous, researchable questions.	Analyse information/data and synthesise to fully integrate components, consistent with parameters set. Fill knowledge gaps that are stated by others.	Analyse and create information/data to fill researcher-identified gaps or extend knowledge.	Synthesise others' concepts or interpretations to frame novel outcomes. May also address substantial concerns of a community.	Develop new concepts or interpretations that expand the field or discipline. May also address substantial concerns across communities.
	Communicative	Use prescribed genre to develop and disseminate understanding and applications of the research, and respond to feedback, accounting for ethical, cultural, social and team (ECST) issues.	Use discipline-specific language and prescribed genre to develop understanding and applications of the research. Apply to different contexts the knowledge developed. Clarify ECST issues.	Use discipline-specific language and genre to develop understanding for a specified audience. Apply the findings to diverse contexts. Specify ECST issues that emerge.	Use appropriate language and genre to address gaps of a self-selected audience. Apply knowledge developed to a different context. Probe and specify ECST issues in each relevant context.	Use appropriate language and genre to address gaps of a range of audiences. Apply knowledge developed to multiple contexts. Probe and specify ECST issues that emerge broadly.	Change the conversation and genre through public- available communication of knowledge/understanding. Articulate and promote relevant ECST issues.	Change the direction of the conversation across disciplinary fields. Articulate and promote ECST issues that were previously unstated.

Figure 1. Research skill development (RSD) framework

To collect data, we used two main instruments: a semi-structured test and an interview. The test consisted of three mathematical problem-solving problems designed to measure students' understanding and application of various problem-solving strategies, which can be seen in Table 1. These three questions contained indicators of mathematical problem-solving behavior that had been validated by expert, with a level of difficulty adjusted to the abilities of the participants, and the potential for responses using various strategies, such as employing equations, measuring the height of an object, and identifying patterns or areas. Meanwhile, the reliability of the test is 0.889, indicating a fairly good level of consistency. These are non-routine types of questions, and their suitability has been evaluated by experts based on the validation results prior to use. These problems were non-routine, meaning they lacked straightforward solutions and required the application of more creative strategies. Each problem was validated by experts in mathematics education to ensure its relevance and level of difficulty suited to the varying abilities of participants. Additionally, semi-structured interviews were conducted to gain deeper insights into students' thinking processes in solving these problems and how they overcame challenges that arose during problem-solving. The interview protocol included open-ended questions focusing on the strategies participants used, the obstacles they encountered, and their reflections on the problem-solving outcomes.

Table 1. Mathematical problem-solving problems and validation results

No	Problem	Average Validation Results		Category
		Validator 1	Validator 2	
1	Mr Arya has several rabbits and several cages. When Mr Arya puts 2 rabbits in each cage, it turns out that 1 rabbit is left and does not get a cage. When Mr Arya places 3 rabbits in each cage, it turns out that there are 2 free cages. How many rabbits and cages does Mr Arya have?	5	4.75	Valid
2	Pak Budi owns a company engaged in a large-scale chicken farming. Pak Budi's company grows its corn in a rectangular garden of 538 m x 114 m to feed the chickens. Illustrate the garden after planting the corn! How much corn does Pak Budi's company plant to feed his chickens if the distance between the corn plants must be 100 cm x 40 cm! Illustrate the garden after planting corn!	5	5	Valid
3	The Eiffel Tower is one of the most famous tourist attractions in France. What would you do if you were in the area of the Eiffel Tower and wanted to measure its height?	5	5	Valid



Data were collected using instruments consisting of test questions and semi-structured interviews. The tests measured students' understanding and the application of problem-solving strategies, while interviews provided deeper insights into students' thinking processes and attitudes in solving problems. This was done because it was often difficult to explore difficulties experienced in solving problems from the written results. Furthermore, data analysis was carried out by describing the results and grouping student problem-solving behavior based on the problem-solving behavior rubric by Muir et al. (2008), which can be seen in Figure 2.

	Naive	Routine	Sophisticated
Behaviours	Employs coping strategies such as manipulating numbers	Implements strategy in a systematic manner	Generates own strategies
	Relies on one or two strategies	Does not adapt or switch strategies if one is not working	Willing to use a variety and combination of strategies
	Metacognitive thinking not displayed in written or verbal communication	Metacognitive thinking displayed verbally	Metacognitive thinking evident in written and verbal responses
	Errors occur at any and/or all 4 stages of problem solving	No attempt usually made to verify solution	Scores highly for each of the 4 stages of Polya's heuristic plan and verifies solution
	Cannot articulate having solved a similar problem before	Can identify a similar problem, but not necessarily on the basis of mathematical structure	Identifies similar problems according to their mathematical structure
	Written communication is usually inadequate	Written and verbal communication is usually clear	Scores highly for both written and verbal communication
	Often uses the same method to solve all problems	Focuses on one way to solve the problem	Identifies alternative ways to solve problems
	Equates confidence with achieving the answer quickly	Often expresses a lack of confidence in problem solving ability	Displays confidence in problem solving ability

Figure 2. Mathematical problem-solving behavior rubric

Qualitative data obtained from interviews and written student responses were analyzed using a thematic coding approach. Each participant's response was grouped based on the problem-solving behavior rubric developed by Muir et al. (2008), which classifies student

behavior into three categories: naive, routine, and sophisticated. The analysis began with the transcription of interviews and the coding of written responses using the categories in the rubric. The coding process was conducted systematically, with each step in the problem-solving process recorded and categorized according to the skill level indicated in the rubric. After coding, the findings were analyzed to identify patterns and relationships between the categories, thereby concluding the students' problem-solving and research skills.

3. RESULTS AND DISCUSSION

3.1. Results

This section explains how postgraduate students behave by using the Research Skill Development (RSD) framework, and discusses how students solve problems. It also explains how students behave at the students' RSD framework level. Data on students' behavior category and the levels of the RSD framework in Indonesia and Malaysia can be seen in [Table 2](#).

Table 2. Category of problem-solving behavior and level of RSD framework for postgraduate students in Indonesia and Malaysia

Country	Name	Behavior Category	Level of RSD Framework	Culture	Gender
Indonesia	UFA	Sophisticated	4		Women
	UFI	Naïve	3	Independent Project, teacher center, discussion, kolaboratif, inklusif	Women
	EE	Routine	5		Women
	FN	Routine	4		Women
	AD	Routine	3		Men
Malaysia	KNBA	Routine	5		Group project, student/teacher center, using technology, kolaboratif, inklusif
KCL	Naïve	3	Men		
SHN	Sophisticated	5	Women		
NAB	Sophisticated	3	Women		

UFA

The level of the RSD framework for UFA is level 4. Meanwhile, UFA is classified in the sophisticated category for problem solving. This is evident from UFA's responses when solving the problems. For the first problem, UFA illustrated a rabbit cage. Using this method, UFA determined that the number of rabbits was fifteen and that there were six cages. UFA's answer can be seen in [Figure 3](#).



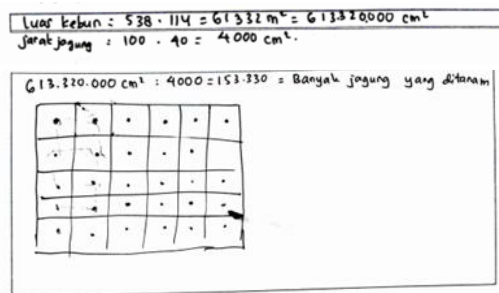
Translation :

So, there are 15 rabbits and 7 cages

Figure 3. UFA's answer to problem 1

UFA developed her strategy by making boxes containing numbers to represent the number of rabbits in the box. UFA explained that he eliminated answers that were not possible, such as the number of cages that could not be one or two, because it did not match the information given in the problem. In solving this problem, UFA could understand the information, plan the solution, and carry out the solution by making a checkered illustration because he considered it the easiest way. UFA also evaluated the answer on the paper. UFA solved similar problems according to the mathematical structure. When given a question, UFA could explain the answer in writing and orally, as well as elaborate on the answer. During the interview, UFA also showed confidence in solving a problem. To solve the problem, UFA tried to develop a strategy. However, its strategy was still classified as guessing the answer by adding boxes and rabbits until it was appropriate. UFA also focused on one method in solving this problem, and when he was asked to use other strategies, UFA could not solve the problem.

In the second problem, which involves finding a solution for how to plant corn on a plot of land given the total area and the surface area planted with corn, UFA's answer can be seen in [Figure 4](#).



Translation:

Farm area = $538,114 = 61332 \text{ m}^2 = 613320000 \text{ cm}^2$
 Corn distance = $100 \times 40 = 4000 \text{ cm}^2$
 $613320000 \text{ cm}^2 \div 4000 = 153,330 = \text{A lot of corn is planted.}$

Figure 4. UFA's answer to problem 2

UFA solved the problem by developing her own strategy. She identified important information in the problem, such as the garden area and the distance between the corn plants, and ensured that the units were consistent. UFA divided the garden area by the distance between the corn plants, resulting in an answer of 153,330. Subsequently, UFA illustrated the garden clearly and precisely, ensuring that the distance between each corn plant was uniform. UFA claimed to have solved similar problems, although not in a mathematical structure. She also verified her answers to the given problems, and UFA's metacognition was evident in both oral and written forms. UFA communicated effectively, both orally and in writing, and was able to elaborate on the answers she provided. However, UFA focused solely on one solution and was unable to adapt to other strategies.

Furthermore, to answer the third problem, UFA was asked to measure the height of the Eiffel Tower. UFA's answer can be seen in [Figure 5](#).

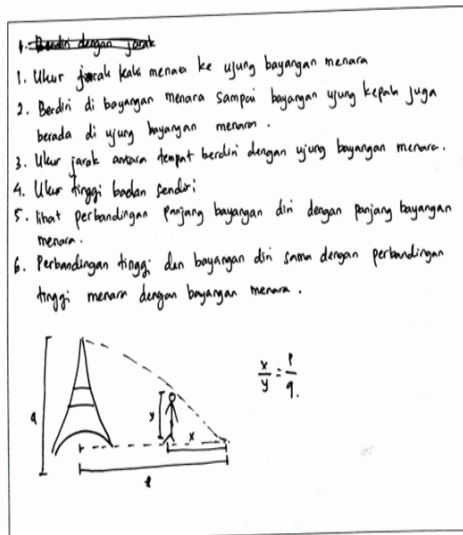


Figure 5. Illustration of UFA's answer to problem 3

In problem 3, UFA identified the problem and chose a solution using the comparison method. Based on Figure 4, UFA illustrated a picture of the tower, herself, and the resulting shadow. UFA assumed q = The height of the Eiffel Tower, p = The length of the shadow of the Eiffel Tower, x = The length of the person's shadow, and y = the height of the person's shadow. The formula can determine the height of the tower $\frac{x}{y} = \frac{p}{q}$. UFA also wrote the steps for measuring and explained the answer clearly. In solving this problem, UFA verified her answer again. In addition, UFA believed that the solution given was correct. From the answer sheet and interview, UFA's metacognition appeared in writing and orally. However, in solving problem 3, UFA continued to focus on one method and could not adapt to other approaches. UFA also stated that she often solved routine problems related to measuring the height of objects using trigonometry.

Based on the description and rubric of problem-solving behavior, UFA is in the sophisticated category because she meets the behavioral indicators: developing her own strategy, employing various strategies, demonstrating metacognition in both oral and written forms, and following problem-solving steps according to Polya. UFA also meets the sophisticated indicators for effective communication, both orally and in writing. She is able to elaborate on her answers and is confident in her chosen responses. However, UFA's problem-solving experience falls within the routine category, as she focuses solely on one solution and does not adapt to other strategies. Nevertheless, it is concluded that UFA is classified in the sophisticated category of mathematical problem solving.

KCL

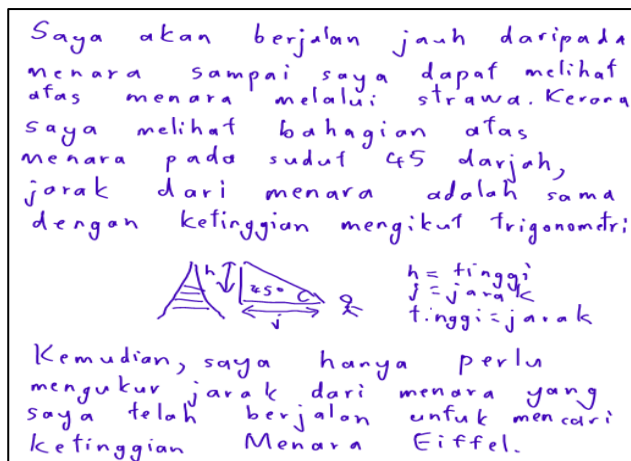
The next research subject in this study was KCL. KCL's RSD framework level is 3. KCL has a Naïve behaviour in answering questions. This is because KCL's answer is equivalent to a quick answer. KCL's answer to problem 1 can be seen in Figure 6.

Translation :

1. Measure the distance from the foot of the tower to the end of the tower's shadow.
2. Stand under the shadow of the tower until the shadow of the head end is also at the end of the shadow of the tower.
3. Measure the distance between where you stand and the end of the tower's shadow.
4. Measure your height.
5. Compare the length of your own shadow with the length of the tower's shadow.
6. The ratio of your height and shadow is the same as the ratio of the tower's height to the tower's shadow.

the area used for planting corn. He then selected the smallest value by considering only the portion of land that would be planted with corn. When the researcher asked about the meaning of the illustration in which KCL created small boxes inside a larger box, KCL explained that each piece of land was enclosed by a square fence, and corn was planted within the box. Subsequently, the researcher asked the participants to select 2850 as the number of corn plants. KCL was unable to answer this question.

KCL's answer to Problem 3 was to measure the height of the tower by asking the guide or people there, as they would know. This response was quick and did not employ a mathematical context. KCL's answer on the answer paper can be seen in [Figure 9](#).



Translation :

I would walk away from the tower until I could see the top of the tower. I will see the top of the tower at an angle of 45 degrees, and the distance from the tower is equal to the height, following trigonometry

h=height

j=distance

height=distance

Then, I must measure the distance between me and the tower to find its height.

Figure 9. Illustration of KCL's answer to problem 3

When the researcher asked about the answers on the answer sheet, KCL stated that the tower's height can be measured using the $\tan 45^\circ$ principle, where we can stand up to form a 45° angle. Then, the tower's height can be calculated by determining the distance from the tower to the person standing before it.

Based on the description and rubric of problem-solving behavior, KCL is classified in the naïve category because he does not develop his own strategy. KCL provides quick answers without employing a systematic approach; he relies solely on trial-and-error methods to solve problems. According to Polya, KCL also demonstrates errors when executing problem-solving steps. KCL's written communication is not yet adequate, and he is confident in providing quick answers. Additionally, KCL employs a guessing method to solve problems. Therefore, it is concluded that KCL is classified in the naïve category of mathematical problem solving.

SHN

In the RSD framework, SHN is at level 5. Meanwhile, in solving problems, SHN is classified as sophisticated. For problem 1, SHN answered that the number of rabbits was thirteen and the number of cages was six. SHN's answer can be seen in [Figure 10](#).

<p>Petunjuk :</p> <p>$x = \text{kandang}$</p> <p>$y = \text{kelinci}$</p> <p>$2x = y - 1$</p> <p>$2x = y - 1$ — (1)</p> <p>$\frac{y}{3} = x - 2$ — (2)</p> <p>Dari pada (1)</p> <p>$2x = y - 1$</p> <p>$y = 2x + 1$ — (3)</p>	<p>(3) dalam (2)</p> <p>$\frac{y}{3} = x - 2$</p> <p>$\frac{2x+1}{3} = x - 2$</p> <p>$2x+1 = 3x - 6$</p> <p>$-x = -7$</p> <p>$x = 7$</p> <p>$x = 7$ dalam (3)</p> <p>$y = 2x + 1$</p> <p>$y = 2(7) + 1$</p> <p>$y = 15$</p> <p>∴ kelinci yang dimiliki oleh Pak Arya adalah sebanyak 15 ekor, manakala kandang yang dimiliki beliau adalah sebanyak 7 kandang.</p>
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Translation :

Directions

$x = \text{cage}$

$y = \text{rabbit}$

than (1)

(3) in (2)

$x = 7$ in (3)

Pak Arya has 15

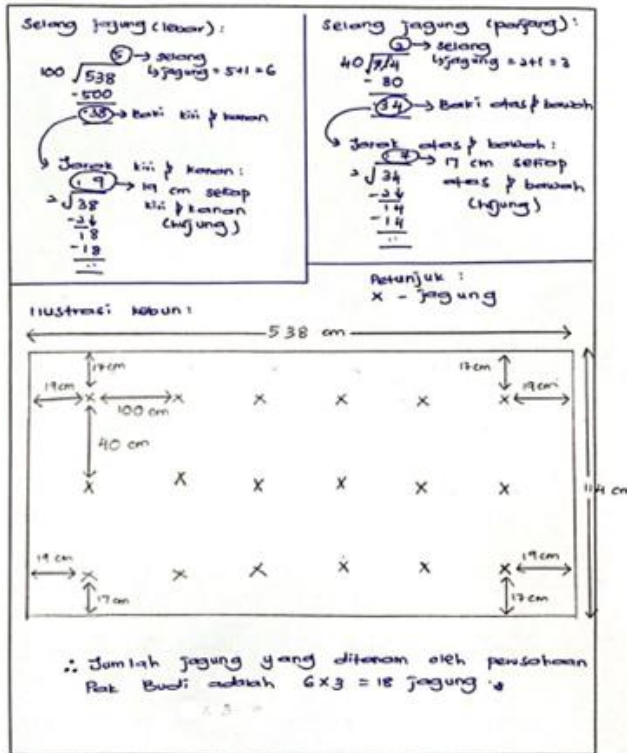
rabbits and

7 cages.

Figure 10. Illustration of SHN's answer to problem 1

SHN developed her strategy by creating a memorandum in algebraic form. She modeled x as the number of cages and y as the number of rabbits. From this, SHN derived two equations. The first one was $2x = y - 1$ and $\frac{y}{3} = x - 2$. SHN then planned the solution by substituting the manipulated equation 1 into equation 2, thus obtaining the value of x , and continued with the substitution into equation 1 to determine the value of y . SHN was also able to prove and convince that the solution was correct. SHN tried to create a sophisticated strategy. When asked whether SHN had experience solving similar problems before, SHN answered that she had and did it algebraically. SHN's verbal and written communication was clear, and she could elaborate the answer correctly. When answering questions, SHN showed confidence in her problem-solving ability. However, when asked about other ways to solve similar problems, SHN focused more on solving by substitution and rarely used other methods.

The second problem was finding a solution for planting corn on a plot of land, given the land area and the surface area of the land. SHN's answer can be seen in [Figure 11](#).



Translation :
 corn spacing(width) corn
 spacing(length)

spacing spacing
 corn=5+1=6 corn=2+1=3

balanced left and right,
 balanced bottom and top
 hint

x=corn
 garden illustration:

∴ Total corn planted by Pak
 Budi's company is 6x3=18
 corns.

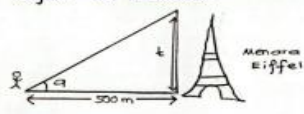
Figure 11. SHN's answer to problem 2

SHN correctly understood the problem and planned strategies for solving it. She created illustrations and divided the available land area for planting corn. However, SHN neglected to ensure that the unit area was correctly calculated for the problem when determining the area. When asked the question, SHN admitted that she had forgotten the problem involved different units. This indicates that SHN did not verify her solution to the problem. However, when asked to revise her answer, SHN was able to adapt and change her strategy to solve the problem appropriately. SHN solved the problem completely and demonstrated her understanding; however, she made a slight mistake regarding the planting of corn from the edge of the field, as the distances on the left and right sides of the field should have been accounted for. SHN's metacognition was evident in her spoken communication. When asked, she realized that the unit of the garden area differed in centimeters from the distance between each corn plant. SHN also has experience in solving similar problems.

Furthermore, in problem three, SHN was asked to measure the height of the Eiffel Tower. SHN's answer can be seen in Figure 12.

Langkah-langkah:

- 1 Berdiri di hadapan menara Eiffel dengan jarak 500 m.
- 2 Saya akan meminta orang saya untuk mengambil gambar saya bersama dengan seluruh menara Eiffel.
- 3 Berdasarkan gambar tersebut, saya akan menentukan ketinggian, a dari tapak kaki hingga ke hujung menara Eiffel menggunakan protaktor seperti di gambar rajah di bawah:



- 4 Setelah sudut ketinggian ditentukan, saya akan menggunakan formula di bawah untuk menentukan tinggi, t menara tersebut:

$$\tan a = \frac{t}{500 \text{ m}}$$

$$t = \tan a \times 500 \text{ m}$$

Translation :

Steps:

1. Stand in front of the Eiffel Tower at a distance of 500 m.
2. Ask someone to photograph me with the whole tower.
3. Based on the picture, I will determine the distance from the footprint to the tip of the Eiffel Tower using a protractor as shown below
4. Once known, I will use the following formula to determine the height, t , of the tower:

Figure 12. Illustration of SHN’s answer to problem 3

For problem 2, SHN stated that the tower can be measured by standing 500 m away from the foot of the Eiffel Tower. Then, SHN determined the elevation angle (a) between the tip of her foot and the top of the tower. SHN stated that the strategy she used after getting these two things was to use trigonometry, namely $\tan a = \frac{t \text{ (tower height)}}{500} \text{ m}$. SHN’s strategy in solving this problem was good, but SHN made a mistake in determining the elevation angle. SHN did not explain how to determine the elevation angle. SHN also stated that determining the elevation angle this way was impossible. After that, SHN was given a little hint in the form of time, and the shadow produced by the Eiffel Tower. From these clues, SHN was able to adapt and explain another way to determine the problem. SHN discovered that she could see the shadow at a certain hour, and related it to the elevation angle. SHN also mentioned that she often solved routine problems related to measuring the height of objects using trigonometry, but rarely solved open-ended problems.

Based on the description and rubric of problem-solving behavior, SHN is classified in the sophisticated category because she meets the behavioral indicators: developing her own strategy, employing a variety of strategies, and demonstrating metacognition in both oral and written forms. SHN also meets the sophisticated indicator of effective communication, both orally and in writing. She is able to elaborate on her answers and is confident in her chosen responses. SHN's problem-solving experience is classified as sophisticated because she understands similar problems according to their mathematical structure. However, SHN does not verify the results/solutions to the problem. Therefore, SHN is in the routine category. In addition, SHN has alternative methods to solve problems. Thus, SHN is included in the sophisticated mathematical problem-solving category.

Based on the analysis of the entire case, a comparison between the problem-solving behavior categories and the RSD framework levels of each participant is presented in Table 2. From the table, it can be seen that participants with sophisticated behavior (UFA, SHN, NAB) show higher RSD dimension characteristics, especially in the metacognitive and communicative dimensions, compared to participants with naive behavior (UFI, KCL).

However, this comparison also reveals a pattern that is not always linear: NAB shows sophisticated behavior despite being at RSD Level 3, while EE shows routine behavior despite being at RSD Level 5.

3.2. Discussion

Based on field findings, data indicate that both male and female students, as well as Indonesian and Malaysian students, can fall into either the sophisticated or naive categories. Therefore, there is no dominant pattern indicating a direct influence of gender or culture on behavioral categories. However, observed differences in problem-solving strategies suggest that Indonesian female students (such as UFA and EE) tend to use a systematic, step-based, analytical approach, while Malaysian male students (such as KNBA) tend to demonstrate a more creative and exploratory approach. This represents a difference in cognitive style, not problem-solving capacity. This aligns with the findings of Hasan et al. (2024) that female students tend to be more detailed in their decision-making, while males tend to use more concise procedures. This difference can be explained by differences in learning cultures. Indonesia's more teacher-centered education system encourages a structured, analytical approach, while Malaysia's student-centered approach with the use of technology (as seen in Table 2) may encourage more creative exploration. Thus, this finding is not a contradiction, but rather shows that gender and learning culture influence problem-solving styles and strategies, but do not determine the level of a student's behavior.

In addition, problem-solving can also be influenced or not by gender. As Ain et al. (2019) revealed that gender does not influence students' problem-solving abilities. Both men and women develop similar research skills, such as analyzing data, identifying problems, and developing solutions (Ain et al., 2019). However, Ain et al. (2019) found differences in how men and women use problem-solving skills in the workplace. In contrast to Hasan et al. (2024), their research discusses the differences in reasoning abilities between men and women in solving mathematical problems. According to Hasan et al. (2024), men are superior in identifying and solving problems with concise procedures, while women are more detailed in making resolutions in mathematical problem-solving performance. So far, no research has discussed how gender influences mathematical problem-solving behavior through the RSD framework level of thinking. However, from the study's findings, both women and men have mathematical problem-solving behavior that tends to be the same at the same level of the RSD thinking framework.

Analysis of mathematical problem-solving behavior of postgraduate students through the Research Skill Development (RSD) framework level shows that students with sophisticated mathematical problem-solving behavior do not always have good research skills. A high level of RSD framework also correlates with better research skills. This study highlights the importance of developing mathematical problem-solving behavior and research skills of postgraduate students through an effective learning approach to become competent researchers and be ready to face career challenges. In Missingham et al. (2018), it was concluded that project-based learning can effectively develop problem-solving and research skills in engineering students. Thus, students can be better prepared to face challenges in their careers as engineers (Missingham et al., 2018).

Meanwhile, Naive problem-solving behavior is likely due to a lack of exposure to non-routine problems in previous study programs. This is in line with Muir et al.'s (2008) view that the habit of seeking quick answers without a systematic process is an adaptive response to a learning environment that emphasizes end results over thought processes. The implication is that graduate education needs to be redesigned to emphasize metacognitive processes, rather than simply the accuracy of final answers. These findings imply that graduate programs need to integrate research-based learning more systematically from the beginning, rather than just at the thesis or dissertation stage. Using the RSD framework as a self-reflection tool can help students identify their weaknesses early and develop more diverse strategies.

In addition, Willison and Buisman-Pijlman (2016) looked at the development of research skills in undergraduate students and how this can prepare them for doctoral (PhD) studies. This study emphasizes the importance of developing research skills early in higher education (Willison & Buisman-Pijlman, 2016). Meanwhile, Mataniari et al. (2020) found that the RSD framework can be used to develop critical thinking skills in biology students. Biology students using the RSD framework significantly improved their critical thinking skills. Therefore, lecturers can use the RSD framework as an effective learning approach to improve students' critical thinking skills. Thus, it is important to develop effective teaching strategies to improve the research skills of postgraduate students (Abiddin et al., 2011; Alsaleh, 2020; Azmi & Daud, 2019; Daniel, 2022; Feldon et al., 2011; Khalaf & Alshammari, 2023; Kumari et al., 2019; Lindsay et al., 2002; Rahman et al., 2014; Zuber-Skerritt, 1987).

Experts have also discussed mathematical problem-solving behavior. It was first conducted by Muir et al. (2008), who developed a rubric for mathematical problem-solving behavior in final-year elementary school students. Muir et al. (2008) categorized students' mathematical problem-solving behavior into 3 categories: naïve, routine, and sophisticated. In addition, Harisman et al. (2021) also developed a rubric for mathematical problem-solving behavior in junior high school students. Unlike Muir et al. (2008), Harisman et al. (2021) categorized students into 4 categories: apathetic, routine, semi-sophisticated, and sophisticated. Furthermore, research on mathematics problem-solving behavior was also conducted by Hafizatunnisa et al. (2024) on high school students. In their research, Hafizatunnisa et al. (2024) categorized students into 5 mathematical problem-solving categories: apathetic, semi-routine, routine, semi-sophisticated, and sophisticated. Mathematical thinking behavior is still very common among researchers. Thus, no research has specifically discussed the mathematical problem-solving behavior of postgraduate students through the RSD thinking framework level, to explore whether students with a high RSD thinking framework level also have high mathematical problem-solving behavior.

In addition to problem-solving behavior, several studies have discussed other mathematical thinking behaviors. Among them are Gunawan et al. (2019), who explored the conceptual understanding behavior of junior high school students. Then, Rohati et al. (2022, 2023), who assessed the mathematical reasoning behavior of junior high school students. Then, Musdi et al. (2024), who developed a rubric for assessing students' mathematical communication behavior. Last, Harisman, Asra, Hafizatunnisa, et al. (2025) developed a rubric for assessing students' mathematical representation behavior.

The relationship between RSD levels and problem-solving behavior can be more deeply understood by examining the specific dimensions of RSD manifested in each behavioral category. Students with sophisticated behaviors (such as UFA and SHN) exhibit characteristics aligned with Levels 4–5 of RSD, namely the ability to develop their own strategies (cognitive dimension), reevaluate their processes (metacognitive dimension), and communicate solutions effectively both orally and in writing (affective-communicative dimension). Conversely, students with naïve behaviors (such as KCL and UFI) exhibit Level 3 RSD characteristics, where they still rely on trial-and-error methods, are unable to systematically verify answers, and exhibit limitations in the metacognitive dimension. These findings strengthen the argument that integrating the RSD framework into postgraduate education is not simply an assessment tool but also a pedagogical framework that can guide curriculum development. Specifically, programs that explicitly train students in the metacognitive dimensions of RSD, such as practicing self-reflection and solution verification, have the potential to improve the quality of problem-solving behavior from naïve or routine to sophisticated. This is in line with Gyuris (2018), who emphasized that effective postgraduate research skills training must align with the RSD framework explicitly, not implicitly.

4. CONCLUSION

The findings of this study indicate that postgraduate students in research methodology courses exhibit three distinct forms of mathematical problem-solving behavior: naïve, routine, and sophisticated. These behaviors reflect varying levels of cognitive, metacognitive, and strategic engagement when responding to both mathematical tasks and research-related problems. The results demonstrate that students with more sophisticated problem-solving behavior tend to employ broader strategies, perform more systematic evaluations, and demonstrate higher levels of inquiry, aligning with the expectations of the Research Skill Development (RSD) framework. Furthermore, learning culture and gender do not significantly determine the level of problem-solving behavior of Indonesian and Malaysian students, as well as male and female students, who can exhibit sophisticated, routine, or naïve behavior. However, significant differences were observed in the strategies and approaches used: Indonesian female students tended to adopt a systematic, analytical approach, while Malaysian male students tended to demonstrate a more creative and exploratory approach. This difference is understood as a reflection of the differences in learning cultures between the two educational systems, where the teacher-centered culture in Indonesia encourages procedural rigor, while the technology-based, student-centered approach in Malaysia encourages more open exploration.

These findings emphasize that developing an effective postgraduate curriculum requires considering not only the level of RSD and problem-solving strategies, but also the diversity of learning cultures and gender as factors that shape students' thinking styles. Explicitly integrating the RSD framework into postgraduate programs, coupled with sensitivity to cultural and gender differences, has the potential to produce graduates who are more adaptable, reflective, and prepared to face research challenges globally.

However, this study has several limitations. The analysis conducted was restricted to postgraduate students; therefore, the findings cannot be generalized to students at different

academic levels. Additionally, the study did not include a direct comparison between the problem-solving behavior of postgraduate and undergraduate students, limiting the ability to fully understand developmental differences across academic stages.

Future studies are encouraged to compare the problem-solving behaviors of undergraduate and postgraduate students using broader and more diverse participant groups. Further research may also examine how disciplinary backgrounds, levels of research experience, and learning cultures influence the interaction between the RSD framework and students' problem-solving behavior. Such investigations would extend the theoretical and practical implications of the present study and offer deeper insights into developing research skills across different educational contexts.

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Declarations

- Author Contribution** : YH: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, and Writing - review & editing; H: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, and Writing - original draft; AA: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, and Writing - original draft; A: Investigation, and Validation; S: Investigation, and Validation; MA: Investigation, and Validation; YWP: Validation; PS: Investigation; HS: Conceptualization, Investigation, and Methodology.
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- Additional Information** : Additional information is available for this paper.

REFERENCES

- Abiddin, N. Z., Ismail, A., & Ismail, A. (2011). Effective supervisory approach in enhancing postgraduate research studies. *International Journal of Humanities and Social Science*, 1(2), 206–217.
- Adhimah, O. K., Ekawati, R., & Fardah, D. K. (2020). Perilaku pemecahan masalah siswa dalam menyelesaikan masalah matematika kontekstual ditinjau dari kecemasan matematika [Students' problem-solving behavior in solving contextual mathematics problems viewed from the perspective of mathematics anxiety]. *MATHEdunesa*, 9(1), 145–154. <https://doi.org/10.26740/mathedunesa.v9n1.p145-154>

- Ain, C. T., Sabir, F., & Willison, J. (2019). Research skills that men and women developed at university and then used in workplaces. *Studies in Higher Education, 44*(12), 2346–2358. <https://doi.org/10.1080/03075079.2018.1496412>
- Alsaleh, N. J. (2020). Flipped classrooms to enhance postgraduate students' research skills in preparing a research proposal. *Innovations in Education and Teaching International, 57*(4), 392–402. <https://doi.org/10.1080/14703297.2019.1647269>
- Apino, E., Retnawati, H., Purbani, W., & Hidayati, K. (2024). The statistical literacy of mathematics education students: An investigation on understanding the margin of error. *TEM Journal, 13*(1), 293–302. <https://doi.org/10.18421/tem131-31>
- Azmi, N. A. B. M., & Daud, N. B. (2019). A relationship between research skills and autonomous learning among postgraduate students. *International Journal of Business, Economics, and Law, 18*(6), 45–51.
- Castillo, T. L., & Ho, S. (2021). Mastering environment and sustainability: How the research skills development framework brought harmony to an interdisciplinary program. In L. Torres, F. Salisbury, B. Yazbeck, S. Karasmanis, J. Pinder, & C. Ondracek (Eds.), *Connecting the library to the curriculum* (pp. 69–85). Springer. https://doi.org/10.1007/978-981-16-3868-8_5
- Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry and research design: Choosing among five approaches* (4th ed.). Sage.
- Daniel, B. (2022). The role of research methodology in enhancing postgraduate students research experience. *Electronic Journal of Business Research Methods, 20*(1), 34–48. <https://doi.org/10.34190/ejbrm.20.1.2253>
- Feldon, D. F., Peugh, J., Timmerman, B. E., Maher, M. A., Hurst, M., Strickland, D., Gilmore, J. A., & Stieglmeyer, C. (2011). Graduate students' teaching experiences improve their methodological research skills. *Science, 333*(6045), 1037–1039. <https://doi.org/10.1126/science.1204109>
- Gunawan, I., Darhim, D., & Kusnandi, K. (2019). Exploration of the behavior of understanding mathematical concepts of junior high school students. *Journal of Physics: Conference Series, 1157*(4), 042098. <https://doi.org/10.1088/1742-6596/1157/4/042098>
- Gyuris, E. (2018). Evaluating the effectiveness of postgraduate research skills training and its alignment with the research skill development framework. *Journal of University Teaching and Learning Practice, 15*(4), 5. <https://doi.org/10.53761/1.15.4.5>
- Hafizatunnisa, H., Harisman, Y., Armiaati, A., & Amiruddin, M. H. (2024). Analysis of problem-solving behavior of senior high school students. *Jurnal Pendidikan Matematika, 18*(2), 181–198. <https://doi.org/10.22342/jpm.v18i2.pp181-198>
- Hao, S., Pan, H., & Zhang, D. (2025). A process-oriented approach to assessing high school students' mathematical problem-solving competence: Insights from multidimensional eye-tracking analysis. *Education Sciences, 15*(6), 761. <https://doi.org/10.3390/educsci15060761>
- Harisman, Y., Asra, A., Hafizatunnisa, H., Elniati, S., & Adnan, M. (2025). Analytical rubrics for mathematical representation behaviour assessment: Development, validation, and cross-cultural application. *Journal on Mathematics Education, 16*(4), 1137–1166. <https://doi.org/10.22342/jme.v16i4.pp1137-1166>

- Harisman, Y., Asra, A., Suherman, S., Armiami, A., Adnan, M., Purnomo, Y. W., Hafizatunnisa, H., Sumarni, P., & Syaputra, H. (2025). Postgraduate students' problem-solving behaviour through research skill development (RSD) framework in research methodology course: Case study in Indonesia and Malaysia. *Seminars in Medical Writing and Education*, 4, 732. <https://doi.org/10.56294/mw2025732>
- Harisman, Y., & Khairani, K. (2021). Perilaku pemecahan masalah mahasiswa pada perkuliahan kalkulus secara daring [Student problem-solving behavior in online calculus lectures]. *JNPM (Jurnal Nasional Pendidikan Matematika)*, 5(2), 277–295. <https://doi.org/10.33603/jnpm.v5i2.5423>
- Harisman, Y., Noto, M. S., & Hidayat, W. (2020). Experience student background and their behavior in problem solving. *Infinity Journal*, 9(1), 59–68. <https://doi.org/10.22460/infinity.v9i1.p59-68>
- Harisman, Y., Noto, M. S., & Hidayat, W. (2021). Investigation of students' behavior in mathematical problem solving. *Infinity Journal*, 10(2), 235–258. <https://doi.org/10.22460/infinity.v10i2.p235-258>
- Hasan, B., Juniati, D., & Masriyah, M. (2024). Gender and analogical reasoning in mathematics problem solving. In *The 7th National Conference on Mathematics and Mathematics Education (SENATIK)*, (Vol. 3046, pp. 020015). <https://doi.org/10.1063/5.0195145>
- Hidayat, H., Nordin, N. M., Anwar, M., & Saputra, H. K. (2025). How students' problem-solving abilities influence their digital competence skill in the use of problem-based learning application. *TEM Journal*, 14(2), 1494–1507. <https://doi.org/10.18421/tem142-49>
- Jaedun, A., Raharjo, N., Hastutiningsih, A. D., Sutarto, S., Pratama, G. N. I. P., & Masek, A. b. (2024). International comparison of vocational pre-service teachers' character education in Indonesia and Malaysia. *Jurnal Cakrawala Pendidikan*, 43(3), 670–682. <https://doi.org/10.21831/cp.v43i3.71345>
- Jiang, Y., Gong, T., Saldivia, L. E., Cayton-Hodges, G., & Agard, C. (2021). Using process data to understand problem-solving strategies and processes for drag-and-drop items in a large-scale mathematics assessment. *Large-scale Assessments in Education*, 9(1), 2. <https://doi.org/10.1186/s40536-021-00095-4>
- Jitendra, A. K., Harwell, M. R., Dupuis, D. N., & Karl, S. R. (2017). A randomized trial of the effects of schema-based instruction on proportional problem-solving for students with mathematics problem-solving difficulties. *Journal of Learning Disabilities*, 50(3), 322–336. <https://doi.org/10.1177/0022219416629646>
- Jögi, A. L., & Kikas, E. (2016). Calculation and word problem-solving skills in primary grades – Impact of cognitive abilities and longitudinal interrelations with task-persistent behaviour. *British Journal of Educational Psychology*, 86(2), 165–181. <https://doi.org/10.1111/bjep.12096>
- Khaerudin, K., Hendrilia, Y., Dewi, R. A. P. K., Erwin, E., & Al-Amin, A. (2023). Innovative approaches to research skill development frameworks for evaluating problem-solving skills in design projects in Indonesian higher education. *Indonesian Journal of Education (INJOE)*, 2(3), 582–598.

- Khalaf, M. A., & Alshammari, A. (2023). Effects of project-based learning on postgraduate students' research proposal writing skills. *European Journal of Educational Research*, 12(1), 189–200. <https://doi.org/10.12973/eu-jer.12.1.189>
- Krulik, S., & Rudnick, J. A. (1989). *Problem solving: A handbook for senior high school teachers*. Allyn and Bacon.
- Kumari, A., Wu, D. T., Motiani, K. K., Wu, K. Y., Palumbo, M., & Tran, S. D. (2019). Career pathways and professional skills of postgraduate students from a dental research-intensive programme. *European Journal of Dental Education*, 23(2), 143–150. <https://doi.org/10.1111/eje.12413>
- Laub, J. A. (1999). *Assessing the servant organization development of the servant organizational leadership (SOLA) instrument*. Doctoral Dissertation. Florida Atlantic University.
- Lindsay, R., Breen, R., & Jenkins, A. (2002). Academic research and teaching quality: The views of undergraduate and postgraduate students. *Studies in Higher Education*, 27(3), 309–327. <https://doi.org/10.1080/03075070220000699>
- Mairing, J. P. (2020). Mathematical problem-solving behaviors of the routine solver. *International Journal of Education*, 13(2), 105–112. <https://doi.org/10.17509/ije.v13i2.23276>
- Mataniari, R., Willison, J., Hasibuan, M. H. E., Sulistiyo, U., & Dewi, F. (2020). Portraying students critical thinking skills through research skill development (RSD) framework: A case of a biology course in an Indonesian university. *Turkish Journal of Science Education*, 17(2), 302–314. <https://doi.org/10.36681/tused.2020.28>
- Méndez-Parra, C., Conde-Carmona, R. J., & Padilla-Escorcía, I. A. (2022). Characterisation of probability learning in a rural environment with the realistic mathematics education. *Acta Scientiae*, 24(4), 1–23. <https://doi.org/10.17648/acta.scientiae.6709>
- Missingham, D., Shah, S., Sabir, F., & Willison, J. (2018). Student engineers optimising problem solving and research skills. *Journal of University Teaching and Learning Practice*, 15(4), 8. <https://doi.org/10.53761/1.15.4.8>
- Muir, T., Beswick, K., & Williamson, J. (2008). “I’m not very good at solving problems”: An exploration of students’ problem solving behaviours. *The Journal of Mathematical Behavior*, 27(3), 228–241. <https://doi.org/10.1016/j.jmathb.2008.04.003>
- Musdi, E., Syaputra, H., Arnellis, A., & Harisman, Y. (2024). Students’ mathematics communication behavior: Assessment tools and their application. *Journal on Mathematics Education*, 15(1), 317–338. <https://doi.org/10.22342/jme.v15i1.pp317-338>
- Oswald, T. M., Beck, J. S., Iosif, A. M., McCauley, J. B., Gilhooly, L. J., Matter, J. C., & Solomon, M. (2016). Clinical and cognitive characteristics associated with mathematics problem solving in adolescents with autism spectrum disorder. *Autism Research*, 9(4), 480–490. <https://doi.org/10.1002/aur.1524>
- Özcan, Z. Ç. (2016). The relationship between mathematical problem-solving skills and self-regulated learning through homework behaviours, motivation, and metacognition. *International Journal of Mathematical Education in Science and Technology*, 47(3), 408–420. <https://doi.org/10.1080/0020739x.2015.1080313>

- Parange, N., & Marks, K. (2016). Teaching clinical diagnostic reasoning and research-mindedness in obstetric and gynaecologic sonography online using research skills development Framework. *Sonography*, 3(4), 154–159. <https://doi.org/10.1002/sono.12083>
- Pawar, S., & Ahirwal, M. K. (2023). A new fission fusion behavior-based Rao algorithm (FFBBRA) for solving optimization problems. *Evolutionary Intelligence*, 16(4), 1309–1323. <https://doi.org/10.1007/s12065-022-00741-y>
- Pérez-Reveles, M. d. I. L., Necoechea-Mondragón, H., & Ríos-Bolivar, H. (2021). Qualities and attributes of Mexican researchers, according to the vitae researcher development framework. *Contaduría y administración*, 66(4), 1–21.
- Polya, G. (1973). *How to solve it: A new aspect of mathematical method* (2nd ed.). Princeton university press.
- Rahimi, S., & Khatooni, M. (2024). Saturation in qualitative research: An evolutionary concept analysis. *International Journal of Nursing Studies Advances*, 6, 100174. <https://doi.org/10.1016/j.ijnsa.2024.100174>
- Rahman, S., Yasin, R. M., Salamuddin, N., & Surat, S. (2014). The use of metacognitive strategies to develop research skills among postgraduate students. *Asian Social Science*, 10(19), 271–275. <https://doi.org/10.5539/ass.v10n19p271>
- Rohati, R., Kusumah, Y. S., & Kusnandi, K. (2022). The development of analytical rubrics: An avenue to assess students' mathematical reasoning behavior. *Cypriot Journal of Educational Sciences*, 17(8), 2553–2566. <https://doi.org/10.18844/cjes.v17i8.7043>
- Rohati, R., Kusumah, Y. S., & Kusnandi, K. (2023). Exploring students' mathematical reasoning behavior in junior high schools: A grounded theory. *Education Sciences*, 13(3), 252. <https://doi.org/10.3390/educsci13030252>
- Suparman, S., Juandi, D., Turmudi, T., Martadiputra, B. A. P., Helsa, Y., Masniladev, M., & Suherman, D. S. (2025). Computational thinking in mathematics instruction integrated to STEAM education: A systematic review and meta-analysis. *TEM Journal*, 14(1), 949–963. <https://doi.org/10.18421/tem141-84>
- van der Merwe, R., van Biljon, J., & Pilkington, C. (2022). A conceptual framework for the development of argumentation skills using CSCL in a graduate students' research course. In K. Arai (Ed.), *Intelligent computing* (pp. 258–278). Springer. https://doi.org/10.1007/978-3-031-10467-1_16
- Vermeer, H. J., Boekaerts, M., & Seegers, G. (2000). Motivational and gender differences: Sixth-grade students' mathematical problem-solving behavior. *Journal of educational psychology*, 92(2), 308–315. <https://doi.org/10.1037/0022-0663.92.2.308>
- Willison, J., & Buisman-Pijlman, F. (2016). PhD prepared: research skill development across the undergraduate years. *International Journal for Researcher Development*, 7(1), 63–83. <https://doi.org/10.1108/ijrd-07-2015-0018>
- Willison, J., & O'Regan, K. (2007). Commonly known, commonly not known, totally unknown: a framework for students becoming researchers. *Higher Education Research & Development*, 26(4), 393–409. <https://doi.org/10.1080/07294360701658609>
- Zhang, Y., Wu, M., Hu, Z., Ward, R., Zhang, X., & Porter, A. (2021). Profiling and predicting the problem-solving patterns in China's research systems: A methodology of

intelligent bibliometrics and empirical insights. *Quantitative Science Studies*, 2(1), 409–432. https://doi.org/10.1162/qss_a_00100

Zuber-Skerritt, O. (1987). Helping postgraduate research students learn. *Higher Education*, 16(1), 75–94. <https://doi.org/10.1007/BF00139249>