Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram
https://e-journal.undikma.ac.id/index.php/prismasains/index
e-mail: prismasains.pkpsm@gmail.com
April 2025. Vol. 13, No. 2
p-ISSN: 2338-4530
e-ISSN: 2540-7899
pp. 306-321

Profiling 4C Skills Through PISA-Based Mathematics Tasks: A Contextual Analysis of Junior High School Students

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Received: January 2025; Revised: March 2025; Published: April 2025

Abstract

The 4C skills—Critical Thinking, Creativity, Communication, and Collaboration—are essential for preparing students to navigate 21st-century challenges. However, results from PISA 2022 and Indonesia's Education Report 2024 reveal that foundational competencies remain low, particularly in rural contexts. This study aims to explore the manifestation of 4C skills among ninth-grade students at SMP Budhi Dharma Balige, North Sumatra, through performance on PISA-based mathematics questions. Employing a qualitative descriptive design, data were collected from 31 students using two PISA tasks and an unstructured teacher interview. Responses were assessed using a rubric-informed framework, and analysis followed the Miles and Huberman model. Results show that while students demonstrate strong communication and procedural reasoning (96.77% correct in Q1 Part 2), performance in critical thinking and argumentation remains limited (only 35% success in Q2 Part 3). The main barrier is the lack of integrated instructional strategies that promote higher-order and collaborative learning. The study concludes that while 4C skills are beginning to develop, their progression is fragmented and requires targeted pedagogical reforms. Recommendations include the use of project-based learning, culturally responsive instruction, and formative assessments to ensure equitable 4C development in under-resourced schools.

Keywords: 4C Skills; PISA; Critical Thinking; Mathematics Education; Junior High School Context

How to Cite: Simanjuntak, S., Saragih, S., Sitepu, I., & Noverica, S. (2025). Profiling 4C Skills Through PISA-Based Mathematics Tasks: A Contextual Analysis of Junior High School Students. *Prisma Sains : Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram*, *13*(2), 306-321. doi:https://doi.org/10.33394/j-ps.v13i2.15294

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INTRODUCTION

In the evolving landscape of globalization and digital transformation, education systems across the globe are being recalibrated to equip students with essential 21st-century competencies. Among these, the 4C skills—Critical Thinking, Creativity, Communication, and Collaboration—have emerged as foundational competencies needed to thrive in an increasingly complex and interconnected world (Partnership for 21st Century Skills, 2015). These skills transcend disciplinary boundaries and are crucial not only in the humanities and social sciences but also in mathematics, where students must increasingly engage in problem-solving that demands logical reasoning, innovative thinking, clear articulation of ideas, and cooperative interaction.

The Partnership for 21st Century Learning (P21) framework, widely adopted by policymakers and educators alike, has established a pedagogical standard for embedding 4C skills into school curricula (Ayudhia et al., 2023; Handayani et al., 2023). Complementary pedagogies such as Project-Based Learning (PBL) and cooperative learning models further operationalize this framework by creating authentic, performance-based environments in which students' 4C competencies can be fostered and assessed (Fuldiaratman & Ekaputra, 2023; Chrisyarani & Setiawan, 2021). Together, these frameworks form the theoretical foundation for both defining and evaluating 4C skills, making them especially relevant for studies attempting to measure these competencies within localized educational contexts.

In the context of mathematics education, the 4C skills are increasingly recognized as essential for deeper conceptual understanding and real-world problem-solving. Critical thinking enables students to analyze problems logically, assess solutions, and make sound decisions (Mohamed Nor & Sihes, 2021; Paul & Elder, 2019). Creativity is reflected in their ability to generate novel approaches and alternative solutions (Dwi Hastuti Listiyani, 2021; Putri & Suripah, 2022). Communication in mathematics facilitates the articulation of abstract ideas, procedural understanding, and collaborative reasoning through both verbal and written expression (Faizah & Sugandi, 2022; Hanipah & Sumartini, 2021; National Council of Teachers of Mathematics, 2015). Collaboration, in turn, promotes the development of shared strategies and the co-construction of meaning among peers, enhancing problem-solving through diverse perspectives (Johnson & Johnson, 2014; Putri, Murtafiah, & Hartanto, 2024; Sipayung, Sani, & Bunawan, 2018).

Despite these pedagogical imperatives, Indonesia's performance in global assessments such as the Programme for International Student Assessment (PISA) remains a cause for concern. PISA 2022 reported that Indonesian students scored below the OECD average in reading literacy (359) and mathematics (366), reflecting a persistent struggle to master foundational skills critical for 4C development (OECD, 2023b; OECD, 2024). Compared to the 2018 PISA scores, where reading literacy stood at 371 and mathematics at 379, this downward trend suggests that the country is regressing in areas fundamental to nurturing critical thinking and problem-solving. The Indonesian Education Report (Kemdikbud, 2025) further underscores these findings, pointing to systemic gaps in the integration of 4C skills in classroom practices. These challenges are not merely instructional but structural, reflecting deficiencies in curriculum design, teacher training, and assessment models.

This decline in performance necessitates urgent pedagogical reform. While urban schools may have begun integrating 4C frameworks due to better resource allocation, technological access, and curriculum infrastructure (Ma, 2025), rural schools often lag behind. Research by Khoiri et al. (2021) illustrates that although rural educational environments in Indonesia benefit from strong communal values conducive to collaboration, they lack the institutional scaffolding necessary for fostering creativity and critical reasoning. These disparities are exacerbated by uneven teacher preparedness and limited digital literacy, especially in under-resourced regions such as Papua and West Papua (Rusli & Rusdin, 2024).

The disparity between urban and rural 4C skill development reveals a major empirical gap. Studies such as those by Amrianto et al. (2024) highlight that assessment tools and pedagogical models validated in urban settings often fail to capture the cultural and contextual nuances present in rural and remote regions. The instruments used may not align with localized values or classroom realities, resulting in either misinterpretation or underestimation of students' actual competencies. Thus, educational research in Indonesia must adopt culturally responsive frameworks that are attuned to local contexts. This is especially critical in non-Java regions, where research remains sparse.

Against this backdrop, the present study seeks to address these gaps by examining the development of 4C skills among ninth-grade students at SMP Budhi Dharma Balige, a school located in the Toba Regency of North Sumatra. Unlike urban educational institutions, this school represents a localized, non-elite setting where infrastructural and curricular limitations persist. The rationale for choosing this site lies in its underexplored status and potential to offer empirical insights into how 4C skills manifest in rural or semi-rural environments.

While national studies and policy documents have stressed the importance of integrating 4C into learning outcomes, very few have investigated the operationalization of these skills in local school settings using authentic tasks. To bridge this gap, this study employs the PISA framework—especially its Collaborative Problem Solving (CPS) components—as a proxy for assessing the 4C skills. Sarlin et al. (2022) demonstrated that PISA's CPS items are aligned with critical thinking, communication, and collaboration, making them suitable benchmarks. Sumardi & Herianto (2024) further emphasize the utility of PISA data in diagnosing the specific areas where Indonesian students falter, particularly in reasoning and analytical thinking. Moreover, Irfana et al. (2022) advocate the integration of PISA-informed, technology-enhanced models to support the development of 4C skills among students with lower baseline proficiencies.

Earlier research on integrating 4C into mathematics education offers valuable insights but often lacks contextual adaptation. Exploratory and problem-based learning approaches, validated through rubric-driven assessments, have shown improvements in students’ critical thinking and communication (Haji et al., 2021; Yohannes et al., 2021; Susanti et al., 2020; Anam et al., 2020). Irham et al. (2022) and Kamaruddin et al. (2023) have proposed models such as the 4C Teaching Model and Think-Talk-Write (TTW) to scaffold students’ creative reasoning and reflective articulation. However, these studies have predominantly been conducted in well-supported urban or suburban schools. Little is known about how such models function in rural educational ecosystems, where both student and teacher capacities may differ.

Teacher-related variables further complicate this issue. Wijayanto et al. (2024) found that limited understanding of the 4C concept, inadequate professional development, and outdated teaching approaches were key obstacles to effective 4C integration. Putri & Usmeldi (2023) and Rudianto et al. (2022) emphasize the need for targeted training programs that align pedagogical strategies with authentic assessment tools. This is particularly relevant for mathematics education, where abstract reasoning must be translated into student-centered activities that support the 4Cs. Thus, any meaningful integration of 4C skills into the curriculum must begin with empowering teachers and equipping them with context-appropriate methodologies.

The current study responds to these multifaceted challenges and gaps by exploring the profile of 4C skills among students in a rural Indonesian school setting using PISA-based mathematical problems. Specifically, the study aims to: (1) assess the degree to which ninth-grade students at SMP Budhi Dharma Balige exhibit critical thinking, creativity, communication, and collaboration in solving mathematics problems; and (2) identify the key instructional and contextual factors that hinder or facilitate the development of these competencies. The research employs a descriptive qualitative approach, utilizing two PISA mathematics items and unstructured interviews with the school’s mathematics teacher.

The novelty of this study lies in its contextual focus. It diverges from mainstream research by examining the development of 4C skills in a localized, rural environment that has not been the focus of prior studies. Furthermore, it adopts an integrative analytical framework combining PISA indicators, rubric-based assessments, and qualitative teacher insights. This design offers a holistic view of student competencies and pedagogical dynamics, thereby contributing to the growing discourse on equitable and localized education in Indonesia. Ultimately, this research is expected to provide empirical evidence that can inform both local practice and national policy. By identifying how 4C skills are being fostered (or neglected) in rural schools, and by highlighting the systemic barriers to their integration, this study can serve as a reference point for future reforms. In doing so, it aims to support a more inclusive and contextually responsive approach to 21st-century education in Indonesia.

METHOD

Research Design and Procedure

The methodology of this research follows a structured qualitative descriptive design intended to examine the manifestation of 4C skills (Critical Thinking, Creativity, Communication, and Collaboration) in the context of mathematics learning among junior high school students. The research stages began with the identification of national learning challenges based on the PISA 2022 results and the 2024 Indonesian Education Report. Subsequently, researchers selected two PISA mathematics problems and designed an unstructured teacher interview to gain qualitative insights into instructional practices. These steps are illustrated in Figure 1 (Research Procedure), which outlines the sequence: problem identification, test selection, student administration, interviews, data analysis, and conclusion drawing.

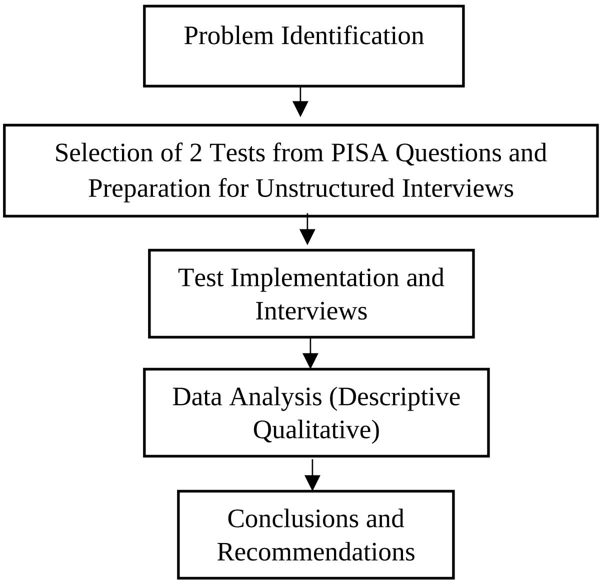


Figure 1. Research Procedure

Research Setting and Participants

This study was conducted at SMP Budhi Dharma Balige, located in Toba Regency, North Sumatra. The population consisted of all ninth-grade students, with the sample comprising 31 students selected through purposive sampling. The selection was based on recommendations from the mathematics teacher, who considered student experience in mathematics learning and their representativeness in classroom participation. Such purposive sampling is consistent with established qualitative research protocols, ensuring the inclusion of participants with relevant exposure to 4C-based instructional activities (Septiyanti et al., 2023; Kousloglou et al., 2023).

Instruments and Assessment Framework

The instruments used were two mathematics test items adapted from the PISA framework (OECD, 2023a) and an unstructured interview guide focused on the 4C competencies. These test items, summarized in Table 1 (PISA Test Instrument), were selected to reflect multiple dimensions of the 4C skills. The items assessed critical thinking, creativity, communication, and collaboration across different content areas, including quantity and change and relationships. The matrix of content areas, cognitive processes, and targeted skills ensured a diverse assessment context that aligns with the multidimensional nature of the 4Cs.

Table 1. PISA Test Instrument

Unit Name	Content Area	Ability	Process	Proficiency Level
Solar System	Quantity	Critical Thinking	Interpret or Evaluate	3
Solar System	Quantity	Collaboration and Communication	Employ	2

Unit Name	Content Area	Ability	Process	Proficiency Level
Triangular Pattern	Quantity	Collaboration and Communication	Employ	1a
Triangular Pattern	Change and Relationships	Creativity, Critical Thinking	Formulate	2
Triangular Pattern	Change and Relationships	Critical Thinking	Reason	5

Rubric Development and Data Collection

To evaluate students' responses, this research relied on a rubric-based assessment framework that was designed to reflect performance across each of the four 4C domains. The rubric drew from models previously proposed by Marwa et al. (2024), Nurhaifa et al. (2020), and Amri et al. (2024), which have been validated for classroom use in STEM and project-based learning environments. The rubric employed a four-point scale to rate the degree of student proficiency in each skill. Responses were analyzed qualitatively using a coding scheme adapted from Maryuningsih et al. (2020), enabling the researchers to categorize and interpret patterns in student thinking.

Teacher Interviews and Triangulation

The unstructured teacher interview provided contextual information that supported data triangulation. While structured interviews offer standardized responses, the unstructured format was intentionally chosen to capture the nuances of instructional practices and the teacher's perceptions of student performance in the 4C domains. To strengthen the validity of findings, triangulation was achieved through the integration of test responses, teacher interviews, and classroom context analysis (Brata et al., 2025; Ponnusamy & Hassan, 2023).

Inter-Rater Reliability and Calibration

The research team developed a detailed rubric and conducted a pilot scoring session to ensure the reliability and validity of qualitative judgments. During this session, two independent raters reviewed student responses and calibrated their interpretations through guided discussion. Inter-rater reliability was supported by standardized scoring guidelines and consensus-building activities, reflecting the rigorous approaches suggested by Shirazi et al. (2021) and Asli & Matore (2023). The structured calibration process minimized subjective bias and enhanced scoring consistency.

Data Analysis Procedure

Data analysis followed the Miles and Huberman model of qualitative data analysis, comprising three main stages: (1) data reduction, in which relevant information from student work and interviews was selected and summarized; (2) data display, where findings were organized into tables, coded narratives, and thematic charts; and (3) conclusion drawing/verification, in which patterns were interpreted and aligned with existing literature. This methodological approach is well suited for exploratory educational research, particularly in capturing context-specific patterns of 4C skills (Ekowati et al., 2023).

Research Scope and Analytical Orientation

This study employed descriptive qualitative reporting to highlight detailed observations rather than statistical generalizations. This choice reflects the aim of exploring localized manifestations of 4C skills, particularly in underrepresented school contexts such as those in North Sumatra. While acknowledging the limited sample size, this approach allows for a deep, context-rich understanding of how global competencies like the 4Cs are enacted in diverse educational landscapes.

RESULTS AND DISCUSSION

Overview of Student Performance on 4C Skills

This study aimed to analyze the extent to which students at SMP Budhi Dharma Balige demonstrated the 4C competencies—Critical Thinking, Creativity, Communication, and Collaboration—through their responses to two PISA-based mathematical problems. The overall findings indicate a generally positive trend in 4C performance, with noticeable strengths in some areas and weaknesses in others. Specifically, the data shows that 77.41% of students answered question number 1 part 1 accurately, while 96.77% succeeded in question number 1 part 2. However, questions 2 part 1 and part 3 reflected a significant drop in analytical engagement and reflective reasoning. These differences highlight the nuanced performance across the 4C domains, which will be analyzed below in greater detail using theoretical frameworks and supported by visual evidence in Figures 2 through 5.

Performance on Question 1: Assessing Critical Thinking and Reasoning

Figure 2 illustrates student responses to question 1, part 1, which required identifying three planets in the correct order and distance based on the model. This question predominantly assessed critical thinking by requiring students to interpret numerical relationships and apply logical comparisons. A high percentage (77.41%) correctly answered the question, demonstrating the ability to evaluate information and justify decisions—a critical thinking indicator supported by rubric criteria from Fardah et al. (2021) and Hamdu et al. (2020). Nonetheless, 19.35% of students misinterpreted the problem, and 3.22% left it incomplete, suggesting difficulty in managing abstract quantitative comparisons.

Question **Answer**

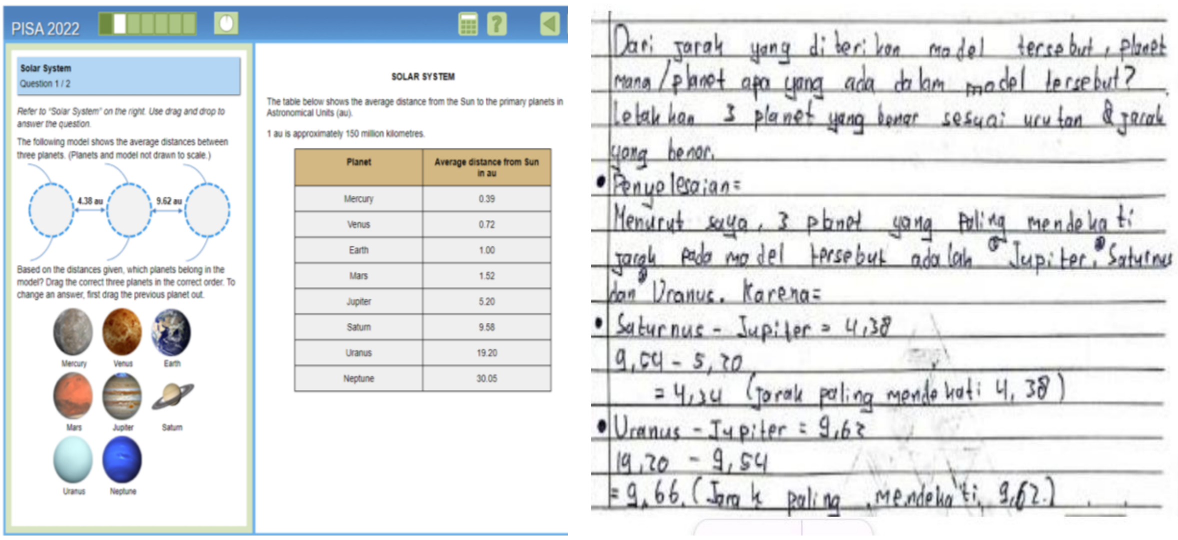


Figure 2. Question and Answer Number 1 Part 1

In part 2 of the same question (Figure 3), students were asked to convert astronomical units (AU) into kilometers, which involved multiplication and unit conversion. This task demonstrated both communication and creativity aspects—students had to articulate their reasoning clearly while applying mathematical modeling. Impressively, 96.77% of students answered correctly. These results imply a strong ability to carry out procedural tasks and explain solutions, reinforcing evidence of effective mathematical communication (Faizah & Sugandi, 2022). The clarity of written explanation here indicates functional mathematical literacy and the application of structured problem-solving, aligned with Bloom's levels of application and analysis (Ramos et al., 2024).

Question **Answer**

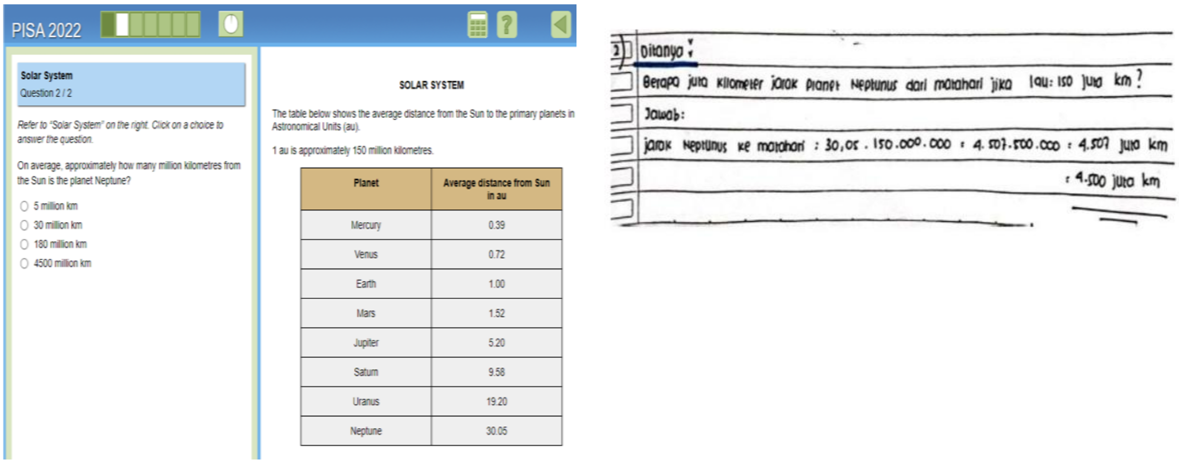


Figure 3. Question and Answer Number 1 Part 2

Analysis of Question 2 Part 1: Mixed Performance in Problem Formulation

In question number 2 part 1 (Figure 4), students were asked to determine the percentage of blue triangles from a visual pattern in the first and fourth rows. This item targeted students' ability to formulate problems based on pattern recognition and probabilistic reasoning—a task involving both critical and creative thinking. Only 58.06% of students were successful, with 22.58% producing incomplete or incorrect analysis, and 6.45% leaving the question blank.

Question **Answer**

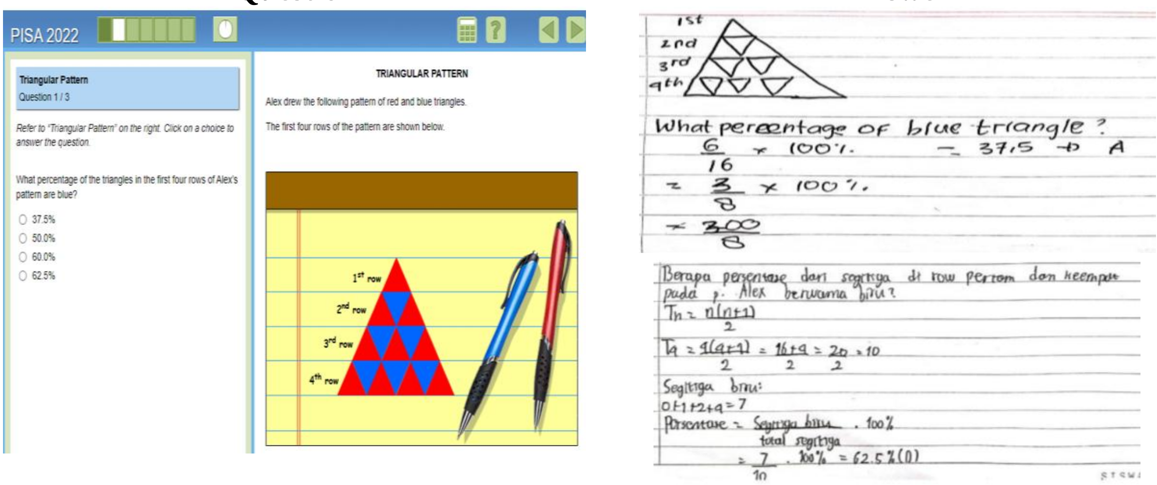


Figure 4. Question and Answer Number 2 Part 1

Incorrect answers often stemmed from flawed interpretation or procedural errors in the formula used as follows.

$$T_n = \frac{n(n+1)}{2}$$

$$T_4 = \frac{4(4+1)}{2} = \frac{16+4}{2} = \frac{20}{2} = 10$$

Blue triangles:
0+1+2+4 = 7

$$Persentase = \frac{Segitiga\ Biru}{Total\ Segitiga} x\ 100\%$$

$$Persentase = \frac{7}{10} x\ 100\% = 62{,}5\%$$

This reinforces findings by Sari et al. (2023) and Rudianto et al. (2022) that indicate a general weakness among students in translating patterns into mathematical expressions—key elements of critical and creative thinking. The low rate of complete, accurate responses suggests that more explicit instruction on pattern recognition and representational fluency is needed.

Question 2 Part 2: Evaluating Creativity in Predictive Reasoning

In part 2 of question 2 (Figure 5), students were asked to extrapolate the number of blue triangles in the fifth row and express it as a percentage. This task required them to analyze trends and make mathematical predictions—representative of both creative thinking and communication. Here, 70.96% succeeded in solving the problem, indicating the ability to synthesize numerical patterns and justify their projection.

Question **Answer**

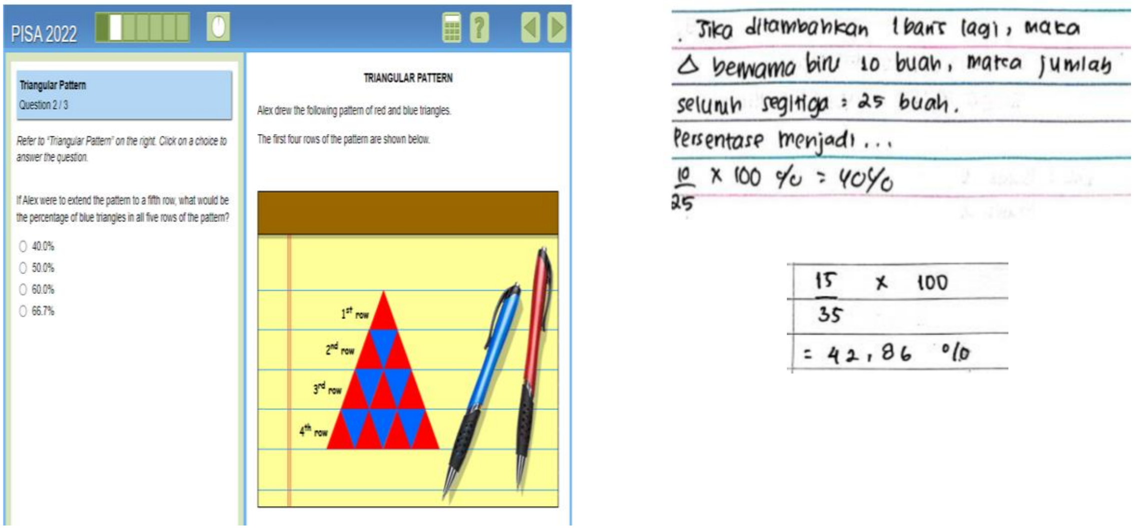


Figure 5. Question and Answer Number 2 Part 2

The variation in student success—16.12% performed with flawed analysis, 3.22% offered incomplete methods, and 9.67% provided no response—suggests that predictive reasoning remains a developmental area. As supported by research from Achmad & Utami (2023), students often struggle with non-routine questions that require speculative reasoning and conceptual transfer. Classroom strategies such as project-based learning and simulation tasks may be needed to develop these skills more holistically (Wijayanto et al., 2024).

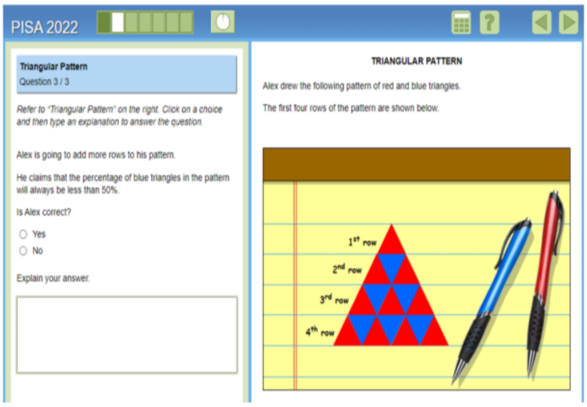
Question 2 Part 3: Interpretation, Argumentation, and Critical Dialogue

Question 2 part 3 (Figure 6) required students to evaluate a claim about the percentage of blue triangles always remaining below 50%. This task measured the highest levels of critical thinking and communication. Students needed to formulate an opinion based on data, argue logically, and connect their conclusion to a conceptual rule. The responses revealed three patterns:

- 35% provided reasoned responses with evidence.
- 45.16% gave unsupported agreement ("yes" only).
- 19.35% left the answer blank.

These results indicate a sharp drop in critical argumentation and reflective writing. Students demonstrated difficulty articulating abstract ideas independently—an outcome that resonates with findings from Hiltrimartin et al. (2024) who observed that tasks involving metacognition and argumentation often show the greatest variability in student response quality.

Question



Answer

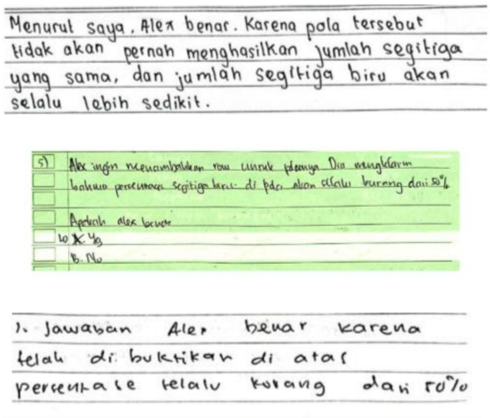


Figure 6. Question and Answer Number 2 Part 3

Interpreting Student Performance Through 4C Lenses

Critical Thinking. The most evident challenges relate to problem formulation and argumentative reasoning. While routine calculation and pattern identification were moderately successful, higher-order skills such as analyzing a rule's implications or justifying generalizations revealed gaps in students' critical thinking development. This aligns with the national challenge observed in PISA 2022 (OECD, 2023b) and calls for more consistent integration of analytical activities (Sumardi & Herianto, 2024).

Creativity. Creativity emerged through pattern extrapolation and unique solutions, particularly in responses to Figure 5. Students who generated non-linear predictions or offered novel justifications reflect the creative process in problem-solving. However, the proportion of such responses was limited, suggesting that creativity is underdeveloped, likely due to conventional teaching methods that prioritize singular solutions (Fardah et al., 2021).

Communication. The ability to clearly present reasoning and solutions was most evident in responses to question 1, part 2. Students used mathematical language effectively and explained their answers step-by-step. However, when asked to articulate opinions or evaluate abstract rules, many reverted to superficial statements. This supports findings from Faizah & Sugandi (2022) that written mathematical communication often excels in procedural contexts but is weaker in reflective argumentation.

Collaboration. While not directly observable in individual test items, collaborative competencies were inferred through triangulated teacher interviews, which indicated varying degrees of peer support and group problem-solving prior to testing. Teachers reported that students who actively engaged in prior group discussions generally performed better, consistent with Vygotskian theory that emphasizes learning as a socially mediated process (Sinaga et al., 2021).

Integrating Theoretical Models and Empirical Insights

Bloom's Taxonomy provides a cognitive framework to interpret the stratification of student performance. Tasks requiring recall, application, and basic analysis (questions 1 and 2, parts 1–2) yielded higher correct response rates. In contrast, synthesis and evaluation (question 2 part 3) had the lowest accuracy, indicating developmental lag in upper-level cognitive operations (Muliana et al., 2023). Vygotsky's Sociocultural Theory complements this view by highlighting how collaborative scaffolding could enhance performance in abstract and evaluative tasks. As students engage in guided group discussions or teacher-moderated reasoning, they internalize complex reasoning processes, improving their independent responses (Hiltrimartin et al., 2024).

The findings from SMP Budhi Dharma Balige are emblematic of broader challenges faced by rural schools across Indonesia. Teachers face structural constraints such as limited professional development opportunities, lack of digital resources, and overpopulated classrooms (Ali, 2024; Putri & Dwikoranto, 2022). These factors hinder the integration of tasks that promote higher-order thinking, creativity, and collaborative problem-solving. Furthermore, assessment designs and curriculum materials often fail to reflect the cultural and contextual realities of rural learners (Amri et al., 2024). The results of this study, as summarized in Figures 2 to 5, offer important insights into the current state of 4C skill development among students at SMP Budhi Dharma Balige. The data demonstrates varying levels of proficiency across different competencies (Table 2). These findings reflect an uneven but emerging mastery of 4C competencies.

Table 2. Summary of Key Results

Question Segment	4C Skill Assessed	Correct (%)	Incorrect/Incomplete (%)	Notes on Skills Performance
Q1 Part 1	Critical Thinking	77.41	22.57	Strong in analysis, weaker in logic formulation
Q1 Part 2	Communication, Quantitative Reasoning	96.77	3.22	High precision, clear explanations
Q2 Part 1	Pattern Recognition, Creativity	58.06	41.94	Moderate success, creativity lacking
Q2 Part 2	Predictive Reasoning	70.96	29.04	Difficulty in extending patterns
Q2 Part 3	Critical Thinking, Argumentation	35.00	65.00	Poor reflective reasoning and justification

The overall strength in procedural communication and quantitative reasoning suggests that students are capable of following structured mathematical logic when provided with familiar contexts and clear steps. However, the consistently lower performance in abstract reasoning and justification—particularly in open-ended problems like Q2 Part 3—highlights a crucial need for pedagogical shifts. Specifically, the development of reflective reasoning and creative exploration must be systematically embedded into instructional design. To enhance the development of 4C skills holistically, this study recommends the implementation of five integrated instructional strategies. First, the adoption of rubric-based assessments tailored to the four competencies can provide structured and formative feedback. Rubrics enable students to identify their strengths and weaknesses, fostering metacognitive awareness and self-regulated learning (Marwa et al., 2024). These tools should not only accompany summative assessments but also guide ongoing classroom activities.

Second, project-based learning (PjBL) should be utilized to simulate interdisciplinary, real-world challenges that demand creativity, problem-solving, and collaboration (Pratiwi & Khotimah, 2022). Through PjBL, students can apply critical thinking to ill-structured problems, engage in peer dialogue, and practice solution iteration—all of which are essential for cultivating higher-order thinking skills. When aligned with curricular content, such projects can bridge the gap between abstract mathematics and authentic contexts. Third, classroom practices must provide dedicated opportunities for peer dialogue and structured discussions. The low performance on tasks requiring argumentation (as in Q2 Part 3) signals a need for dialogue-based learning. When students are encouraged to articulate, defend, and revise their reasoning in group settings, they develop not only communication and collaboration skills but also deeper conceptual understanding, as supported by Vygotsky's theory of social learning (Sinaga et al., 2021). Fourth, the integration of educational technology should be expanded to support collaborative simulations and enhance digital communication. In resource-limited rural settings, this can be done through scalable, low-cost tools such as offline interactive software or mobile learning platforms. Technology provides students with new modes of expression and cooperative problem-solving environments that are vital for engaging 21st-century learners. Lastly, it is essential to contextualize instruction through culturally responsive pedagogy. Teaching strategies and content should resonate with the students' lived experiences, local knowledge, and community values (Rusli & Rusdin, 2024). This approach not only increases engagement but also supports the development of meaningful communication and collaboration skills within familiar socio-cultural frameworks.

The instructional strategies above must be deployed in a cohesive and context-sensitive manner. The challenges identified through this study—particularly in fostering creativity and reflective thinking—are not insurmountable. Instead, they point to the urgent need for instructional reorientation. With targeted investment in teacher training, curriculum adaptation, and assessment reform, schools like SMP Budhi Dharma Balige can better prepare students to navigate the complex demands of the 21st century. By integrating assessment-driven feedback, experiential learning, peer engagement, digital innovation, and culturally grounded instruction, educators can transform classrooms into dynamic spaces for 4C skill development. These findings provide both a diagnostic lens and a roadmap for strengthening future educational interventions in similar rural school contexts across Indonesia.

CONCLUSION

This study set out to examine the extent to which 4C skills—Critical Thinking, Creativity, Communication, and Collaboration—are exhibited by ninth-grade students at SMP Budhi Dharma Balige through their performance on PISA-based mathematics tasks. The findings indicate that while students show proficiency in procedural reasoning and mathematical communication, significant gaps remain in higher-order competencies, particularly in critical thinking and creativity. For instance, while 96.77% of students successfully performed in tasks requiring structured quantitative reasoning (Q1 Part 2), only 35% demonstrated sufficient argumentative reasoning in open-ended tasks (Q2 Part 3). These discrepancies reflect the limited integration of complex cognitive and collaborative practices within the current instructional design.

Moreover, the uneven performance across 4C dimensions suggests a systemic challenge in embedding these competencies into everyday mathematics instruction, especially in rural or under-resourced educational contexts. The lack of opportunities for reflective dialogue, creative exploration, and evidence-based argumentation inhibits deeper learning and 21st-century readiness. While the study confirms that 4C skill development is beginning to take shape, the process is fragmented and calls for stronger pedagogical frameworks that go beyond basic content delivery. The research also acknowledges limitations, notably the small sample size, the use of only two PISA items, and reliance on unstructured interviews for teacher input. These factors limit generalizability but are nonetheless valuable for drawing in-depth, context-specific insights. Future studies could expand the sample, diversify assessment instruments, and include longitudinal designs to better capture the progression of 4C competencies over time.

RECOMMENDATION

Based on the findings, several recommendations are proposed for stakeholders aiming to enhance 4C skill development in mathematics education, particularly in similar rural school contexts. First, it is essential to integrate explicit 4C learning objectives into curriculum design, instructional strategies, and assessment tools. Educators should adopt holistic rubrics that measure each 4C domain separately and provide feedback to support continuous improvement. Second, teacher professional development programs must emphasize instructional methods that foster 4C competencies, such as project-based learning, inquiry-based tasks, and peer-driven dialogue. Equipping teachers with the knowledge and tools to design cognitively rich, socially engaging learning environments is key to addressing the observed weaknesses in student argumentation and creativity. Third, schools should promote collaborative classroom cultures through structured group activities and reflective exercises. This includes the use of discussion prompts, structured peer reviews, and shared problem-solving sessions to strengthen communication and collaboration in mathematical reasoning.

Fourth, in the context of limited resources, efforts should be made to leverage local knowledge and culturally responsive practices to contextualize instruction. This approach can enhance engagement and relevance, particularly in rural settings where standard materials may not align with students' lived experiences. Lastly, future policy and research agendas should prioritize the development of equitable, scalable models for assessing and cultivating 4C skills in diverse Indonesian educational settings. Such models should be inclusive of both urban and rural contexts and sensitive to the infrastructural and cultural nuances that shape student learning outcomes. Through these recommendations, this study hopes to contribute meaningfully to national conversations on educational reform and provide a roadmap for developing well-rounded, critically engaged, and collaborative learners ready to face the demands of the 21st century.

ACKNOWLEDGMENT

The author extends sincere gratitude to Mrs. Esra Sidebang, Mathematics teacher at SMP Budhi Dharma, for her generous support in facilitating the implementation of this research and for her willingness to participate in an interview as part of the study. Special thanks are also due to Margaret Gulo for her kind assistance in the data analysis process.

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