

# Assessing Contextual Mathematical Literacy of Nautical Cadets Using PISA Proficiency Levels: Evidence from Maritime Vocational Education

**Novitasari Novitasari <sup>1\*</sup>, Eka Nurmala Sari Agustina <sup>1</sup>, Atika Tirzha Sabrina Anggraeni <sup>1</sup>**

<sup>1</sup> Politeknik Pelayaran Surabaya, Surabaya, Jawa Timur, Indonesia

\*Email Correspondence: novitasari@poltekel-sby.ac.id

ARTICLE INFO	ABSTRACT
<p><b>Article History</b></p> <p>Received : 19 Jan 2026                      Revised : 21 Feb 2026                      Accepted : 26 Feb 2026                      Available : 28 Feb 2026                      Online</p> <hr/> <p><b>Keywords:</b>                      Mathematical Literacy;                      PISA;                      Maritime Education;                      Vocational Education;                      Nautical Cadets.</p> <hr/> <p><b>Please cite this article APA style as:</b>                      Novitasari, N., Agustina, E. N. S., &amp; Anggraeni, A. T. S. (2026). Assesing Contextual Mathematical Literacy of Nautical Cadets using PISA Proficiency Levels: Evidence from Maritime Vocational Education. <i>Vygotsky: Jurnal Pendidikan Matematika dan Matematika</i>, 8(1), pp. 31-40.</p>	<p>Mathematical literacy is a crucial competence in maritime education, supporting navigation accuracy, operational efficiency, and safety-related decision-making. However, empirical studies assessing mathematical literacy within authentic maritime vocational contexts remain limited. This study investigates the contextual mathematical literacy of nautical cadets using the PISA proficiency framework embedded in authentic maritime work-related scenarios. A quantitative descriptive design was employed with 23 cadets from a maritime vocational institution. Data were collected through a Contextual Mathematical Literacy Test (CMLT) developed using authentic maritime operational tasks. Descriptive and non-parametric analyses examined proficiency distributions and group differences. The findings indicate that most cadets perform at low to medium proficiency levels, highlighting the need for context-based and PISA-oriented mathematics instruction aligned with professional maritime demands.</p>

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## 1. Introduction

The maritime industry operates in an environment characterized by high complexity, dynamic conditions, and strict safety requirements. Modern maritime operations depend heavily on accurate navigation, operational planning, and real-time decision-making, all of which require strong quantitative reasoning. Mathematical competence is therefore essential for maritime professionals to ensure operational efficiency and safety, particularly in situations involving uncertainty and risk (Akakpo, 2016; Veloo et al., 2015). Recent international

evidence further indicates that many education systems continue to face challenges in developing learners' mathematical literacy, especially in tasks requiring contextual reasoning and higher-order thinking (OECD, 2023b).

Mathematical literacy extends beyond procedural knowledge of formulas and algorithms. It involves the ability to formulate, apply, and interpret mathematics in real-world contexts through reasoning, modeling, and critical reflection (De Lange, 2003; Niss & Jablonka, 2014; Stacey, 2011). In maritime practice, this competence is reflected in tasks such as route optimization, fuel consumption estimation, stability assessment, and interpretation of navigational data (Maternová et al., 2023; Stanivuk et al., 2017). Previous studies indicate that insufficient mathematical reasoning may contribute to operational inefficiencies and increase the likelihood of human error in safety-critical maritime environments (Veloo et al., 2015).

From an educational perspective, the Organisation for Economic Co-operation and Development (OECD) conceptualizes mathematical literacy through the Programme for International Student Assessment (PISA) framework, which defines mathematical literacy as an individual's capacity to formulate, employ, and interpret mathematics in a variety of real-life contexts (OECD, 2019). The framework classifies learners' competencies into progressive proficiency levels, ranging from basic procedural skills to advanced abstraction, modeling, and reflective reasoning (OECD, 2023a). While the PISA framework has been widely applied in general education research, its application in maritime vocational education particularly among nautical cadets whose professional responsibilities require precise navigation, operational planning, and safety critical decision making remains limited.

In this study, the term *contextual mathematical literacy* refers specifically to the ability of nautical cadets to formulate, apply, and interpret mathematical concepts within authentic maritime work-related situations. While the PISA framework conceptualizes mathematical literacy in broad real-world contexts (OECD, 2019, 2023a), this research narrows the scope to domain-specific vocational contexts by embedding mathematical tasks in realistic maritime operational scenarios, such as navigation planning, fuel estimation, stability calculations, and risk assessment. Therefore, contextual mathematical literacy in this study does not merely indicate general task-based problem solving, but reflects the application of mathematical reasoning within simulated professional maritime settings.

In maritime vocational education, mathematics instruction is often delivered in a predominantly theoretical manner, with limited integration of authentic operational contexts. As a result, cadets may demonstrate adequate performance in classroom-based assessments but encounter difficulties when applying mathematical knowledge to real maritime situations, such as navigation planning and operational decision-making (Karahalil et al., 2024; Sohaimi et al., 2022). This misalignment between instructional practices and professional demands reflects a broader challenge in vocational education, where mathematics learning is frequently disconnected from workplace contexts, limiting the development of transferable and context-based competencies (Grootenboer et al., 2022; Sappa & Aprea, 2014; Wheelahan, 2015).

Preliminary classroom observations and informal academic evaluations conducted at the participating institution indicated that many cadets experience difficulties when solving non-routine and context-based mathematical problems.

Although cadets generally perform adequately on routine computational tasks, they often struggle to interpret contextual information, integrate multiple variables, and justify their reasoning in maritime-related problem scenarios. Similar challenges have been reported in vocational and applied education settings, where students demonstrate procedural fluency but limited conceptual understanding and problem-solving flexibility (She et al., 2018; Sohaimi et al., 2022). These observations suggest a potential gap between mathematical instruction and the cognitive demands of maritime professional practice.

Existing studies in maritime education have primarily focused on curriculum design, professional standards, and competency frameworks. However, empirical investigations that directly assess cadets' contextual mathematical literacy using internationally recognized frameworks are still scarce (Stanivuk et al., 2017). In particular, limited attention has been given to profiling cadets' mathematical literacy across PISA proficiency levels when confronted with authentic maritime problem scenarios (Novitasari et al., 2024). This lack of empirical evidence restricts educators' ability to design targeted instructional strategies to address specific weaknesses in cadets' mathematical reasoning.

To address this gap, the present study examines the contextual mathematical literacy of nautical cadets using the PISA proficiency framework with assessment tasks adapted to authentic maritime vocational contexts. This study contributes empirical evidence on cadets' mathematical literacy in authentic maritime contexts, extends the application of the PISA framework to vocational maritime education, and offers practical implications for the development of context-based and PISA-oriented mathematics instruction.

## 2. Method

This study used a quantitative descriptive design to describe the level of contextual mathematical literacy among nautical cadets based on the Programme for International Student Assessment (PISA) framework. The participants were 23 cadets enrolled in the Diploma III Nautical Studies Program at Politeknik Pelayaran Surabaya, Indonesia. Participants were selected using purposive sampling to ensure that all cadets had completed basic mathematics courses relevant to maritime applications. This design was chosen to obtain a clear and focused picture of cadets' mathematical literacy in a vocational maritime setting.

Data were collected using a Contextual Mathematical Literacy Test (CMLT) designed according to PISA mathematical literacy principles and adapted to real maritime situations. All test items were designed to simulate authentic maritime operational conditions to ensure alignment between PISA proficiency descriptors and professional maritime cognitive demands. The test consisted of five open-ended questions related to navigation calculations, route planning, and operational decision-making. These questions required cadets to apply mathematics in realistic maritime contexts rather than relying solely on routine calculations. Cadets' answers were scored using a rubric aligned with adapted PISA proficiency levels, ranging from Level 1c (lowest) to Level 6 (highest). The indicators used to classify each level of mathematical literacy are presented in Table 1.

**Table 1.** Adapted Mathematical Literacy Ability Level Indicators Based on the PISA Framework (OECD, 2023a)

Level	Indicator
6	<ul style="list-style-type: none"> <li>a. Cadets can solve abstract problems and demonstrate creativity and flexible thinking to develop solutions;</li> <li>b. Cadets can connect various sources of information and representations, including using simulations or spreadsheets effectively as part of a problem-solving solution;</li> <li>c. Cadets are able to think critically and have mastery of symbolic and formal mathematical operations, and are able to communicate clearly.</li> </ul>
5	<ul style="list-style-type: none"> <li>a. Cadets can develop and work with models for complex situations, identify or apply constraints, and determine assumptions;</li> <li>b. Cadets can apply systematic and planned problem-solving strategies to handle more challenging tasks;</li> <li>c. Cadets can reflect on and consider mathematical results by paying attention to real-world contexts.</li> </ul>
4	<ul style="list-style-type: none"> <li>a. Cadets can work effectively with explicit models for complex concrete situations, as well as demonstrate the ability to work with undefined models using more sophisticated computational thinking approaches;</li> <li>b. Cadets can select and integrate different information representations, and relate them directly to aspects of real-world situations;</li> <li>c. Cadets can construct and communicate explanations and arguments based on their interpretation, reasoning and methodology.</li> </ul>
3	<ul style="list-style-type: none"> <li>a. Cadets can design solution strategies or sequential decision making or flexibility in understanding familiar concepts;</li> <li>b. Cadets are able to complete tasks that require several different but routine calculations that are not all clearly defined in the problem statement;</li> <li>c. Cadets can use spatial visualization as part of a solution strategy or determine how to use simulation to collect appropriate data for the task.</li> </ul>
2	<ul style="list-style-type: none"> <li>a. Cadets can recognize situations where they need to design a simple strategy to solve a problem, including running a live simulation involving one variable as part of their solution strategy;</li> <li>b. Cadets can extract relevant information from one or more sources using slightly more complex modes of representation;</li> <li>c. Cadets are able to interpret the results literally.</li> </ul>
1a	<ul style="list-style-type: none"> <li>a. Cadets can answer questions involving simple contexts where all the required information is available, and the question is clearly defined;</li> <li>b. Cadets are able to carry out simple and routine procedures according to direct instructions in explicit situations to solve a problem;</li> <li>c. Cadets can apply basic algorithms, formulas, procedures, or conventions to solve problems.</li> </ul>
1b	<ul style="list-style-type: none"> <li>a. Cadets can respond to questions involving an easily understood context in which all necessary information is clearly provided and are able to recognize when some information is irrelevant;</li> <li>b. Cadets are able to perform simple calculations with whole numbers, following clear instructions.</li> </ul>
1c	<ul style="list-style-type: none"> <li>a. Cadets can respond to questions involving an easily understood context where all relevant information is clearly provided;</li> <li>b. Cadets are able to explain procedures or operational steps based on clear instructions.</li> </ul>

In addition to proficiency levels, the CMLT was developed to reflect the three

core mathematical processes defined in the PISA framework: formulating, employing, and interpreting (OECD, 2019, 2023a). Each item required cadets to translate maritime problem situations into mathematical representations (formulate), apply relevant procedures or models (employ), and interpret the results in relation to operational decision-making (interpret). The assigned proficiency levels (Levels 1c–6) represent increasing complexity and integration of these processes.

For analytical purposes, the six PISA proficiency levels were further grouped into three broader analytical categories to facilitate statistical comparison across performance levels. The categorization was based on the conceptual progression defined in the PISA framework rather than statistical quartile distribution, ensuring theoretical consistency with internationally recognized proficiency standards. The analytical grouping structure is presented in Table 2.

**Table 2.** Grouping of PISA Proficiency Levels into Analytical Categories

Analytical Category	PISA Proficiency Levels	Description of Cognitive Characteristics
Low Proficiency	Level 1c – Level 2	Ability limited to routine procedures, direct information use, and basic interpretation in clearly structured situations
Medium Proficiency	Level 3 – Level 4	Ability to apply mathematical reasoning in moderately complex contexts, integrate information, and construct explanations
High Proficiency	Level 5 – Level 6	Ability to model complex situations, think abstractly, evaluate solutions critically, and reflect on results

Data analysis was conducted in two stages: descriptive and inferential analysis. First, descriptive statistics were used to summarize cadets' contextual mathematical literacy levels, including the calculation of mean scores, frequency distributions, and percentage distributions across PISA proficiency levels. These analyses were used to provide an overall profile of cadets' literacy performance.

Prior to inferential testing, assumption tests were performed. The Shapiro-Wilk test was used to examine the normality of score distribution, while Levene's test was conducted to assess the homogeneity of variance across literacy groups. Because the data were not normally distributed, non-parametric statistical procedures were applied. Differences in mathematical literacy scores among the low, medium, and high proficiency categories were analyzed using the Kruskal-Wallis test. When significant differences were detected, pairwise comparisons were conducted using the Mann-Whitney U test to identify specific group differences.

### 3. Results and Discussion

#### 3.1. Results

The analysis of contextual mathematical literacy revealed statistically significant variation across proficiency categories within the sample of nautical cadets, as indicated by the non-parametric tests based on the PISA framework. Overall, the results show that the distribution of performance was concentrated at lower

proficiency levels when cadets solved problems situated in maritime contexts.

### 3.1.1. Distribution of Mathematical Literacy Levels

As shown in Table 3, more than half of the cadets ( $n = 13$ ; 56.52%) were classified in the low literacy category, corresponding to PISA Levels 1 and 2. Cadets in this category were generally able to perform simple and routine calculations when instructions were explicit. However, they experienced difficulties when problems required interpretation of contextual information, consideration of multiple variables, or application of mathematical reasoning to unfamiliar maritime situations.

Approximately 8 cadets (34.78%) reached the medium literacy category (PISA Levels 3 and 4). These cadets were able to apply appropriate mathematical procedures to contextualized problems, such as basic navigation planning and operational calculations. Nevertheless, their problem-solving approaches were predominantly procedural, with limited evidence of deeper reasoning or mathematical justification.

Only 2 cadets (8.70%) achieved high mathematical literacy levels (PISA Levels 5 and 6). Cadets in this category demonstrated the ability to analyze complex maritime scenarios, construct mathematical models, evaluate alternative solution strategies, and justify their reasoning. Their responses reflected greater flexibility and higher-order reasoning in addressing non-routine maritime problems.

**Table 3.** Distribution of Contextual Mathematical Literacy Levels Based on the PISA Framework

PISA Proficiency Level	Category	Frequency (n)	Percentage (%)
Level 6	High	1	4.35
Level 5	High	1	4.35
Level 4	Medium	3	13.04
Level 3	Medium	5	21.74
Level 2	Low	6	26.09
Level 1a	Low	4	17.39
Level 1b	Low	2	8.70
Level 1c	Low	1	4.35
<b>Total</b>		<b>23</b>	<b>100</b>

### 3.1.2. Assumption Testing and Inferential Analysis

Before conducting inferential analysis, assumption testing was performed. The Shapiro–Wilk normality test showed that the distribution of contextual mathematical literacy scores was not normal ( $W = 0.891$ ,  $p = 0.018$ ). In contrast, Levene’s test indicated that the variance of scores across literacy groups was comparable ( $F = 1.124$ ,  $p = 0.342$ ).

Given the non-normal distribution of the data, non-parametric statistical procedures were applied. As shown in Table 4, the Kruskal–Wallis test revealed a statistically significant difference in contextual mathematical literacy scores among the low, medium, and high proficiency groups ( $H = 15.276$ ,  $df = 2$ ,  $p = 0.001$ ), indicating meaningful differences in performance across literacy categories.

Subsequent pairwise comparisons using the Mann–Whitney U test confirmed statistically significant differences between all literacy groups. Significant differences were found between the low and medium proficiency groups ( $U = 18.50$ ,  $p = 0.004$ ), between the low and high proficiency groups ( $U = 2.00$ ,  $p = 0.001$ ),

and between the medium and high proficiency groups ( $U = 5.00$ ,  $p = 0.012$ ). These findings demonstrate consistent performance gaps in contextual mathematical literacy across all proficiency levels.

**Table 4.** Summary of Statistical Test Results

Statistical Test	Statistic	Value	p-value
Shapiro-Wilk Normality Test	W	0.891	0.018
Levene's Test for Homogeneity	F	1.124	0.342
Kruskal-Wallis Test	H (df = 2)	15.276	0.001
Mann-Whitney U (Low-Medium)	U	18.50	0.004
Mann-Whitney U (Low-High)	U	2.00	0.001
Mann-Whitney U (Medium-High)	U	5.00	0.012

### 3.2. Discussion

The findings of this study indicate that the contextual mathematical literacy of nautical cadets is predominantly situated at low to medium proficiency levels. As shown in Table 3, most cadets were classified within PISA Levels 1 and 2, suggesting that their performance was largely limited to routine procedures and direct information use. This pattern aligns with previous research in vocational and applied education contexts, where learners often demonstrate procedural fluency but limited higher-order reasoning when mathematical instruction emphasizes computation over contextual understanding (She et al., 2018; Sohaimi et al., 2022).

The relatively small proportion of cadets achieving high proficiency levels (PISA Levels 5 and 6) indicates a substantial gap between current mathematical performance and the cognitive demands of maritime professional practice. Maritime operations require the ability to interpret contextual data, integrate multiple variables, and evaluate alternative solutions in dynamic environments. In this study, cadets classified at these levels demonstrated such competencies by systematically identifying relevant operational variables, constructing appropriate mathematical models, and providing justified interpretations of their results. For instance, in navigation-related tasks, high-proficiency cadets explicitly incorporated distance, fuel consumption rates, and time constraints into structured calculations and explained the operational implications of their chosen strategies. Prior studies have highlighted that insufficient mathematical literacy may constrain professionals' decision-making accuracy and increase the risk of operational errors in safety-critical settings (Akakpo, 2016; Maternová et al., 2023; Veloo et al., 2015).

The statistically significant differences identified through the Kruskal-Wallis and Mann-Whitney U tests further confirm that mathematical literacy develops progressively across proficiency levels rather than as a uniform skill. This finding is consistent with the PISA framework, which conceptualizes mathematical literacy as a continuum of increasingly complex competencies involving reasoning, modelling, and reflective thinking (OECD, 2019, 2023a).

From an educational perspective, the dominance of lower proficiency levels suggests a misalignment between instructional practices and professional maritime demands. When mathematics is taught primarily through routine procedural exercises without sufficient contextual integration, cadets may struggle to apply their knowledge in operational situations. Integrating maritime-relevant problem scenarios within instruction can support the development of flexible

reasoning, modelling competence, and adaptive expertise required for real-world problem solving (Schukajlow et al., 2024). Such approaches also enhance learners' ability to connect mathematical concepts with authentic applications and engage more effectively with complex tasks (Boaler, 2016; Hong et al., 2020; Jablonka, 2003; Karahalil et al., 2024; Ojose, 2011).

Assessment practices likewise influence learning outcomes. Evaluations that focus exclusively on procedural correctness may not adequately capture reasoning quality or contextual interpretation. Incorporating open-ended and context-based assessment formats, aligned with PISA-oriented principles, can provide more meaningful insights into cadets' mathematical literacy and professional readiness (Brookhart, 2010).

Despite its contributions, this study has several limitations. The relatively small sample size and focus on a single maritime vocational institution may limit generalizability. In addition, the cross-sectional design does not capture developmental changes over time. Future research should involve larger and more diverse samples, apply longitudinal or experimental designs, and examine the effectiveness of context-based instructional interventions in strengthening mathematical literacy among maritime cadets. Comparative studies across institutions and countries would further enrich understanding of contextual mathematical literacy in maritime education (OECD, 2023a).

Overall, this study contributes by extending the application of the PISA mathematical literacy framework to a rarely researched maritime vocational context and by empirically profiling the contextual mathematical competencies of nautical cadets.

#### **4. Conclusions**

This study examined the contextual mathematical literacy of nautical cadets using an adapted PISA proficiency framework embedded in maritime-related scenarios. The findings reveal that most cadets are concentrated at the lower to medium levels of mathematical literacy, indicating that their competencies remain largely procedural and context-limited. Only a small proportion demonstrated advanced modelling and reflective reasoning skills aligned with higher PISA proficiency levels.

Rather than representing isolated categories, the low, medium, and high classifications reflect a progressive continuum of mathematical development. The dominance of lower proficiency levels suggests that many cadets have not yet transitioned toward the higher-order reasoning and modelling competencies required in complex maritime operations. These findings highlight the need for instructional approaches that support gradual progression from procedural fluency to contextualized, adaptive problem solving.

Overall, this study contributes empirical evidence on contextual mathematical literacy within maritime vocational education and underscores the importance of aligning mathematics instruction with authentic professional demands.

#### **Author Contributions**

The first author was responsible for the conceptualization of the study, research design, methodology development, data curation, formal data analysis, and preparation of the original manuscript draft. The second author, contributed through academic supervision, validation of the research process and findings,

conducted the preliminary data analysis, and performed critical review and editing of the manuscript. The third author, assisted in data collection, supported data organization, and contributed to the manuscript writing under the supervision of the first and second authors.

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### Declaration of Competing Interest

The authors declare no competing interests.

### References

- Akakpo, D. (2016). Mathematical competence in maritime education and training. *WMU Journal of Maritime Affairs*, 15(2), 289–306.
- Boaler, J. (2016). *Mathematical Mindsets: Unleashing Students' Potential through Creative Math, Inspiring Messages and Innovative Teaching*. Jossey-Bass.
- Brookhart, S. M. (2010). *How to Assess Higher-Order Thinking Skills in Your Classroom*. ASCD.
- De Lange, J. (2003). Mathematics for literacy. In B. L. Madison & L. A. Steen (Eds.), *Quantitative Literacy: Why Numeracy Matters for Schools and Colleges* (pp. 75–89). National Council on Education and the Disciplines.
- Grootenboer, P., Edwards-Groves, C., & Choy, S. (2022). Recontextualising mathematics learning in vocational education. *Journal of Vocational Education & Training*, 74(4), 623–641.
- Hong, Y.-Y., Chiu, C.-Y., & Dweck, C. S. (2020). Mindsets and mathematical learning: A social-cognitive perspective. *Nature Reviews Psychology*, 1(1), 33–44.
- Jablonka, E. (2003). Mathematical literacy. *Educational Studies in Mathematics*, 52(1), 75–102.
- Karahalil, E., Akyuz, E., & Celik, M. (2024). Competency development and training effectiveness in maritime education. *WMU Journal of Maritime Affairs*, 23(1), 45–62.
- Maternová, D., Zitrický, V., & Gašparik, J. (2023). Decision-making and quantitative reasoning in transport operations. *Transport Problems*, 18(2), 5–16.
- Niss, M., & Jablonka, E. (2014). *Mathematical Literacy*. Springer.
- Novitasari, N., Agustina, E. N. S., Fachrudin, A. D., & Irfan, S. (2024). Mathematical literacy as a key competency for maritime education: Systematic literature review of cadet competencies. *Vygotsky: Jurnal Pendidikan Matematika Dan Matematika*, 6(2), 131–140. <https://doi.org/10.30736/voj.v6i2.1112>
- OECD. (2019). *PISA 2018 Assessment and Analytical Framework*. OECD Publishing.
- OECD. (2023a). *PISA 2022 Mathematics Framework*. OECD Publishing.
- OECD. (2023b). *PISA 2022 Results (Volume I): The State of Learning and Equity in Education*. OECD Publishing.
- Ojose, B. (2011). Mathematics literacy: Are we able to put the mathematics we learn into everyday use? *Journal of Mathematics Education*, 4(1), 89–100.

- Sappa, V., & Aprea, C. (2014). Conceptions of competence in vocational education: A systematic literature review. *Educational Research Review, 12*, 90–101.
- She, H.-C., Stacey, K., & Schmidt, W. H. (2018). Enhancing mathematical literacy: Research perspectives. *Educational Research Review, 24*, 1–13.
- Sohaimi, N. A., Zain, N. M., & Abdullah, A. H. (2022). Context-based mathematics learning and its impact on mathematical literacy. *International Journal of Instruction, 15*(2), 457–472.
- Stacey, K. (2011). The PISA view of mathematical literacy. *Educational Studies in Mathematics, 77*(2--3), 95–126.
- Stanivuk, T., Lušić, Z., & Katalinić, M. (2017). Mathematical competence in maritime navigation. *The Journal of Navigation, 70*(2), 421–435.
- Veloo, A., Krishnasamy, H. N., & Abdullah, W. S. (2015). Decision making and human error in safety-critical environments. *Safety Science, 78*, 78–86.
- Wheelahan, L. (2015). Not just skills: What a focus on knowledge means for vocational education. *Journal of Vocational Education & Training, 67*(4), 1–16.