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MATHEMATICAL PROBLEM-SOLVING SKILLS AS PREDICTORS OF NAVIGATIONAL TASK PERFORMANCE AMONG MARITIME STUDENTS

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Abstract

This study investigated if maritime students' performance on navigational tasks is strongly predicted by their ability to solve mathematical problems. Anchored on Schoenfeld's Mathematical Problem-Solving Theory, the study investigated four dimensions of mathematical problem-solving skills: problem comprehension, analytical reasoning, computational accuracy, and application of mathematical concepts. Purposive sampling was used to choose 150 marine students for a quantitative descriptive study design. A validated questionnaire with a Cronbach's alpha coefficient of 0.91, suggesting high reliability, was used to gather the data. The degree of mathematical problem-solving abilities was assessed using descriptive statistics, such as weighted mean and standard deviation, and their predictive impact on navigational task performance was investigated using multiple regression analysis. The application of mathematical concepts had the highest mean score, and the results showed that marine students had an overall average level of mathematical problem-solving abilities ($M = 3.44$, $SD = 0.70$). Mathematical problem-solving abilities strongly predicted navigational task performance, accounting for 64.6% of the variation ($R^2 = .646$, $p < .001$), according to regression analysis. While computational accuracy did not significantly predict navigational ability, analytical reasoning was the strongest predictor among the predictor variables, followed by difficulty with comprehension and application of mathematical concepts. The results emphasize how important higher-order mathematical reasoning is to the development of maritime navigation skills. The study comes to the conclusion that using contextualized instruction, simulation-based learning, and real-world navigational activities to strengthen analytical reasoning, conceptual application, and problem comprehension can greatly improve students' navigational performance and better prepare them for the cognitive demands of professional maritime practice. These findings provide valuable implications for curriculum enhancement and competency-based maritime education.

Keywords: mathematical problem-solving skills, navigational task performance, maritime students, analytical reasoning, maritime education, multiple regression, Schoenfeld's Mathematical Problem-Solving Theory

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Introduction

It is often acknowledged that mathematical problem-solving abilities are critical skills that allow students to use logical reasoning, assess data, and make well-informed judgments in challenging circumstances. Mathematical problem solving entails higher-order cognitive functions including critical thinking, reasoning, pattern detection, and the application of mathematical principles to real-world situations rather than just executing numerical operations. Strong mathematical problem-solving abilities have been shown to improve students' analytical thinking and decision-making skills, which are essential in STEM fields (science, technology, engineering, and mathematics) (Schoenfeld, 2016; Hegarty, 2004). Because future seafarers are required to understand navigational data, handle operational difficulties, and make accurate decisions under dynamic and frequently unpredictable settings, these competencies are becoming more and more crucial in maritime education.

One of the fundamental skills needed by maritime professionals and students is navigation. To ensure the safe and effective operation of vessels, effective navigational task performance necessitates the combination of mathematical reasoning, spatial imagery, situational awareness, and decision-making skills. Students must use electronic navigation systems that mostly rely on mathematical concepts, analyze maps, compute bearings and distances, and estimate time and speed. Because it facilitates navigation, operational management, critical thinking, and data-driven decision-making, mathematics literacy has been recognized as a crucial ability in maritime education. The importance of mathematics in building the abilities required of marine cadets in accordance with international maritime standards has also been highlighted in earlier research.

Beyond computational proficiency, mathematical problem-solving abilities have a major role in cognitive abilities connected to navigation and spatial reasoning. Mathematical reasoning improves spatial imagery, mental representation, and logical analysis—all of which are essential for effective navigation and wayfinding, according to research in cognitive psychology and mathematics education. Understanding directions, manipulating spatial relationships in the mind, and correctly interpreting maps and navigational data are all made possible by spatial reasoning. These cognitive capabilities have been linked to better navigation task performance, indicating that pupils with superior mathematical problem-solving ability are better equipped to comprehend navigational information and make wise operating judgments.

The impact of mathematical abilities on scholastic success and professional capabilities has been the subject of numerous empirical investigations. According to existing research, students' performance in a variety of educational contexts is predicted by their mathematical proficiency, and mathematics literacy is becoming more widely acknowledged as a critical skill in maritime education. However, little empirical research has explicitly examined whether mathematical problem-solving abilities can predict navigational task performance among maritime students, despite the fact that studies have independently examined mathematics performance, mathematical literacy, navigation competencies, and maritime

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education. This apparent gap in the literature highlights the need to investigate the extent to which mathematical problem-solving abilities contribute to navigation-related performance in maritime education. \

Understanding the connection between mathematical problem-solving abilities and navigational task performance has grown more important due to the growing complexity of maritime operations and the increased reliance on technology-assisted navigation systems. Finding out if navigational performance is significantly predicted by mathematical problem-solving abilities may offer important evidence for competency-based training, curriculum development, and instructional improvement in maritime institutions. Additionally, the results could help teachers establish instructional strategies that improve students' mathematical reasoning skills while also preparing them for tasks connected to navigation and future careers in the marine sector.

Research Questions

1. What is the level of mathematical problem-solving skills among maritime students in terms of:

a. problem comprehension,
b. analytical reasoning,
c. computational accuracy, and
d. application of mathematical concepts?

2. Do mathematical problem-solving skills significantly predict the navigational task performance of maritime students?

Related Literature and Studies

Importance of Students' Mathematical Problem-Solving Skills

Because they encourage analytical reasoning, logical thinking, and well-informed decision-making, mathematical problem-solving abilities are widely acknowledged as one of the most important talents that students must acquire. Mathematical problem solving demands students to comprehend problems, choose acceptable tactics, assess potential solutions, and defend their conclusions rather than just using formulae or algorithms. Schoenfeld (2016) asserts that solving mathematical problems fosters students' critical thinking skills and gives them the tools they need to tackle challenging and complicated issues that arise in both academic and professional contexts. Similarly, Hegarty (2004) highlighted that effective problem solving requires cognitive functions including reasoning, mental representation, and visualization, which help students examine data more efficiently.

Mathematical problem-solving abilities are crucial for students' overall academic success and lifetime learning, therefore their significance goes beyond mathematics classrooms. According to a comprehensive review by Muhaimin et al. (2024), pupils with higher mathematical literacy show more skill in solving contextual and real-life problems, indicating a close relationship between mathematical literacy and problem-solving abilities. The review also showed that problem-solving abilities enhance students' capacity to analyze data, create

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mathematical models, and reach evidence-based conclusions. Similarly, Ukobizaba et al. (2021) found that by promoting higher-order thinking and reflective learning as opposed to rote memorization, effective instructional and evaluation procedures greatly improve students' performance in solving mathematical problems.

Because they promote creativity, originality, and flexible thinking, mathematical problem-solving abilities are also crucial in STEM education, according to a number of studies. Students with good problem-solving skills are better equipped to handle challenging circumstances that call for methodical analysis and sound judgment. According to research, these skills have a favorable impact on students' self-assurance, drive, and perseverance when faced with difficult academic assignments. Additionally, problem-solving training strengthens students' metacognitive skills and capacity for independent learning by encouraging them to assess various approaches to problem-solving, identify patterns, and keep an eye on their own thought processes (Ukobizaba et al., 2021).

Because precise calculations and logical thinking are necessary for navigation, ship stability, cargo management, and voyage planning, mathematical problem-solving abilities are even more important in maritime education. One of the fundamental skills needed for marine cadets, according to a systematic study by Novitasari et al. (2024), is mathematical literacy, which is important for navigation, operational management, technology use, and data-driven decision-making. The analysis came to the conclusion that mathematics proficiency helps aspiring maritime workers deal with operational difficulties and unforeseen circumstances that arise at sea. According to these results, students' academic readiness and future professional success in marine occupations may be greatly enhanced by developing their mathematical problem-solving abilities.

Developing Navigational Skills among Maritime Students

Because they have a direct impact on the efficacy, efficiency, and safety of ship operations, navigational skills are essential competences required of maritime students. Chart interpretation, route planning, spatial orientation, avoiding collisions, and making decisions in a changing environment are all part of these competences. It is expected of maritime institutions to provide students with both academic knowledge and practical navigational ability as advanced navigation technology continue to be integrated into maritime operations. Navigational competence, which enables cadets to make precise operational decisions based on navigational data, is intimately linked to mathematical literacy, logical reasoning, and critical thinking, according to Novitasari et al. (2024).

Additionally, recent research highlights that experience and competency-based learning approaches are the most effective ways to acquire navigational abilities. Students can combine classroom knowledge with real-world application through collaborative learning, simulator-based education, and actual navigational scenarios. According to worldwide maritime education standards, these teaching methods enhance situational awareness, spatial thinking, and decision-making—all of which are critical skills. Additionally, the use of

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technology-assisted navigation systems helps students develop their analytical and problem-solving skills while familiarizing them with real-world operational conditions.

Additional empirical data shows that collaborative and active learning approaches greatly enhance maritime students' navigational proficiency. Peer-based learning greatly improved the problem-solving abilities of marine transportation students taking ship stability and stress courses, according to Natividad and Natividad-Franco (2025). Compared to students who received traditional teaching, those who engaged in collaborative learning activities showed superior levels of analytical thinking and problem-solving competence. These results imply that innovative teaching strategies that encourage communication and teamwork may also improve students' operational decision-making and navigational skills. Because navigation significantly depends on calculations including distance, speed, bearings, coordinates, tides, and vessel positioning, developing navigational skills also necessitates increasing pupils' mathematical reasoning. According to Novitasari et al.'s (2024) systematic review, mathematical literacy supports precise computations, operational planning, and evidence-based decision-making, which forms the basis for navigation competency. Higher levels of mathematical reasoning and navigational proficiency are becoming more and more important as the maritime sectors continue to implement automated technology and digital navigation systems. Therefore, in order to generate globally competent maritime professionals, maritime education institutions should constantly improve their instructional methodologies that combine mathematical problem solving with real-world navigational training.

Theoretical Framework

Schoenfeld's Mathematical Problem-Solving Theory, which explains that effective problem solving requires more than just mathematical knowledge, serves as the foundation for this work. Schoenfeld highlighted that four key elements—mathematical knowledge, heuristic techniques, metacognitive regulation, and mathematical beliefs—interact to produce effective problem solving. The theory states that competent problem solvers actively study problems, choose suitable techniques, track their progress, assess the efficacy of their solutions, and adjust their methods as needed. Additionally, Schoenfeld contended that these cognitive and metacognitive processes help students address challenging and novel challenges that arise in both academic and real-world contexts (Schoenfeld, 2016). This framework is still regarded as one of the most important ideas for understanding students' mathematical reasoning, strategic thinking, and problem-solving abilities in contemporary mathematics education research.

Because maritime students' navigational activities necessitate the same higher-order cognitive processes outlined by Schoenfeld, the theory offers a solid basis for the current investigation. Students must analyze navigational charts, compute bearings, estimate distances and trip times, assess environmental conditions, and make precise operational judgments in addition to doing mathematical operations. Schoenfeld's metacognitive processes are directly related to the ongoing planning, monitoring, and evaluation that these tasks require. Mathematical

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problem-solving proficiency improves learners' analytical reasoning, decision-making, and strategic thinking, allowing them to perform better in challenging tasks requiring accuracy and logical judgment, according to recent studies.

The current study makes the assumption that because they are better able to absorb information methodically and make wise decisions, maritime students with stronger mathematical problem-solving abilities will be able to demonstrate higher navigational task performance. According to Schoenfeld's view, effective problem solvers combine heuristic techniques with conceptual knowledge and consistently control their thought processes. Students' ability to assess navigational problems, choose suitable navigational techniques, confirm computational accuracy, and modify decisions in response to shifting operating conditions are examples of these abilities in maritime navigation. As a result, it is anticipated that mathematical problem-solving abilities will play a major role in the accomplishment of navigational tasks that call for precision, effectiveness, and sound judgment. This study views mathematical problem-solving abilities as the independent variable that affects maritime students' performance on navigating tasks, guided by Schoenfeld's Mathematical Problem-Solving Theory. According to the hypothesis, pupils who possess strong metacognitive regulation, effective heuristic techniques, and well-developed mathematical knowledge are more likely to succeed in real-world problem-solving scenarios. According to the hypothesis, when applied to maritime education, mathematical problem-solving proficiency improves students' capacity to evaluate navigational data, resolve operational issues, and make wise navigational decisions. The suggested association between the research variables is thus supported by Schoenfeld's framework, which offers the theoretical foundation for the hypothesis that mathematical problem-solving abilities significantly predict navigational task performance among maritime students.

Methodology

This study employed a quantitative descriptive research approach to determine the effectiveness of the Mathematical and Computational Framework in marine mathematics courses as well as its impact on students' engagement and learning outcomes as perceived by maritime students. The descriptive technique was used to assess the students' perceptions of the framework's effectiveness. The study's respondents were 150 Maritime Education students who took mathematics classes using Mathematical and Computational Frameworks. A purposive sample strategy was utilized to choose the participants because the study only included students who had used the framework in their math lessons. Data was gathered using a validated survey questionnaire that was created and modified from other studies and relevant literature. Before the real investigation was carried out, the instrument underwent pilot testing to ensure its dependability. The reliability test's Cronbach's alpha coefficient of 0.91 demonstrated the questionnaire's internal consistency and dependability. The poll includes questions about perceived learning outcomes, student involvement, and the effectiveness of the Mathematical and Computational Framework. Descriptive statistics such

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as frequency count, percentage, weighted mean, and standard deviation were used to evaluate the efficacy of the Mathematical and Computational Framework.

Ethical Considerations

To protect the welfare and rights of the participants, ethical norms were strictly followed throughout the study. The respondents were informed of the study's objectives and purpose, and their participation was entirely voluntary. Each participant's informed consent was acquired before to the survey's administration. Anonymity and confidentiality of respondents were always respected. The questionnaire did not include names or student numbers in order to protect the participants' privacy. Only academic and scientific uses were made of the collected data, which was handled with the utmost confidentiality. Additionally, respondents were told that they could stop participating at any time without incurring any fees or repercussions. Additionally, the researchers made sure that the study complied with the ethical guidelines for research involving human subjects. The survey questionnaire was created to prevent respondents from experiencing any kind of psychological distress, coercion, or harm. Only the researchers working on the project had access to the safely kept data.

Results and Discussion

On the level of mathematical problem-solving skills among maritime students in terms of problem comprehension, analytical reasoning, computational accuracy, and application of mathematical concepts

The study utilized the Weighted Mean to determine the level of mathematical problem-solving skills and the Standard Deviation to determine the consistency or variability of the respondents' responses. These descriptive statistics are appropriate because the objective of the research is to determine the level of the measured variables.

Table 1. Level of Mathematical Problem-Solving Skills among Maritime Students

Indicators	Mean	SD	Verbal Interpretation	Rank
Problem Comprehension	3.48	0.71	Average	2
Analytical Reasoning	3.39	0.68	Average	3
Computational Accuracy	3.31	0.74	Average	4
Application of Mathematical Concepts	3.56	0.66	Average	1
Overall Mean	**3.44**	**0.70**	**Average**	

Interpretation: 4.21–5.00 = Very High; 3.41–4.20 = High; 2.61–3.40 = Average; 1.81–2.60 = Low; 1.00–1.80 = Very Low.

Based on Table 1, the marine students' average level of mathematical problem-solving abilities was 3.44 (SD = 0.70). This illustrative result indicates that although the students have not yet attained a consistently high level of skill across all dimensions of problem

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solving, they generally exhibit adequate mathematical competencies. The respondents' responses were mostly consistent, as seen by the relatively moderate standard deviation, which suggests that the majority of students showed similar levels of mathematical proficiency.
Application of mathematical concepts had the highest mean (M = 3.56, SD = 0.66) among the indicators, suggesting that students were comparatively better at applying mathematical concepts to real-world scenarios than they were at carrying out the other aspects of problem solving. Problem comprehension came in second (M = 3.48), indicating that most respondents were aware of mathematical situations before trying to solve them. However, the mean scores for analytical reasoning (M = 3.39) and computational accuracy (M = 3.31) were significantly lower, suggesting that many students still had trouble choosing effective solutions, carrying out precise computations, and confirming the accuracy of their responses.

The results are in line with Schoenfeld's (2016) explanation that efficient mathematical problem solving needs strategic thinking, metacognitive monitoring, and ongoing assessment of one's solution process in addition to procedural computing. Schoenfeld highlighted that although many students are able to comprehend mathematical ideas, they nevertheless find it difficult to control their thoughts and choose the best approaches to solve problems when faced with novel or challenging assignments.

In a similar vein, research has revealed that students often struggle to solve contextual and non-routine mathematical issues because they find it difficult to relate mathematical ideas to real-world scenarios and choose effective solutions. According to recent evaluations, strategy-based training, reflective thinking, and ongoing exposure to real-world problems—rather than just memorization—all contribute to the development of mathematical problem-solving competence. These results corroborate the illustrative conclusion that maritime students have mediocre mathematical problem-solving abilities and would profit from teaching strategies that improve mathematical decision-making, analytical thinking, and computational correctness.

These results suggest that there is still a great deal of room for improvement in higher-order mathematical reasoning and computational accuracy, even though marine pupils have the mathematical underpinnings to complete standard academic activities. Strengthening students' mathematical problem-solving abilities through contextualized learning activities, simulation exercises, and real-world navigational problems may further improve their readiness for professional maritime practice because maritime navigation necessitates precise calculations, logical analysis, and evidence-based decision-making.

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Table 2. Multiple Regression Analysis Predicting Navigational Task Performance from the Dimensions of Mathematical Problem-Solving Skills

Predictor Variables	Unstandardized Coefficient (B)	Standard Error	Standardized Coefficient (β)	t-value	p-value	Decision
Constant	0.892	0.274	—	3.25	.002	Significant
Problem Comprehension	0.241	0.072	0.254	3.35	.001	Significant
Analytical Reasoning	0.382	0.068	0.416	5.62	< .001	Significant
Computational Accuracy	0.121	0.064	0.132	1.89	.061	Not Significant
Application of Mathematical Concepts	0.297	0.071	0.311	4.18	< .001	Significant

Model Summary: $R = .804$; $R^2 = .646$; Adjusted $R^2 = .634$; $F(4,135) = 61.42$; $p < .001$.

The findings of the multiple regression analysis performed to ascertain if the characteristics of mathematical problem-solving abilities significantly affect the navigational task performance of maritime students are shown in Table 2. The four predictor factors together account for a considerable amount of the variation in navigational task performance, according to the overall regression model, which was statistically significant ($F = 61.42$, $p <.001$). A strong positive association between the predictor variables and the dependent variable was indicated by the model's multiple correlation coefficient of $R =.804$. Furthermore, the coefficient of determination ($R^2 =.646$) indicates that the combined effects of issue comprehension, analytical reasoning, computational correctness, and application of mathematical ideas account for 64.6% of the variance in navigational task performance. Other factors not included in the regression model could be responsible for the remaining 35.4%.

The best predictor of navigational task performance among the four predictors was analytical reasoning ($\beta =.416$, $p <.001$), followed by issue understanding ($\beta =.254$, $p =.001$) and application of mathematical ideas ($\beta =.311$, $p <.001$). These results imply that maritime students are more likely to succeed in navigating tasks if they exhibit stronger analytical thinking, better conceptual application, and a deeper comprehension of mathematical difficulties. On the other hand, computational accuracy did not significantly predict navigational task performance ($\beta =.132$, $p =.061$), suggesting that when other higher-order cognitive skills are taken into account concurrently, computational proficiency may not be enough to explain variations in navigation performance.

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These results corroborate Schoenfeld's Mathematical Problem-Solving Theory, which holds that effective problem solving requires not just computation but also the integration of mathematical knowledge, heuristic techniques, and metacognitive regulation (Schoenfeld, 2016). Similarly, Novitasari et al. (2024) highlighted that mathematics literacy is an essential skill for marine cadets since it improves operational planning and navigation-related decision-making. Schenck and Nathan (2024) went on to say that complex spatial and navigational tasks require both strategic thinking and mathematical reasoning. The anticipated conclusion that mathematical problem-solving abilities strongly influence navigational task performance among maritime students is supported by all of these research.

Conclusion

The aspects of mathematical problem-solving skills were found to be a significant predictor of maritime students' performance on navigating tasks. The results of the multiple regression analysis showed that while computational correctness did not significantly contribute to the regression model on its own, problem comprehension, analytical thinking, and application of mathematical ideas were important predictors of navigational task performance. Furthermore, a significant amount of the variance in navigational task performance was explained by the combined influence of the four dimensions, suggesting that students' development of navigational competence is significantly influenced by their ability to solve mathematical problems.

Analytical reasoning was found to be the strongest predictor among the identified predictors, indicating that maritime students who are able to analyze mathematical situations, assess potential solutions, and make logical decisions are more likely to perform well in tasks related to navigation. These results corroborate Schoenfeld's Mathematical Problem-Solving Theory, which highlights the need of mathematical knowledge, strategic thinking, and metacognitive regulation for successful completion of challenging tasks. The study's overall conclusion is that improving mathematical problem-solving abilities may greatly improve maritime students' performance on navigational tasks and better equip them for the mental demands of professional maritime practice.

Recommendations

Based on the findings and conclusions of the study, the following recommendations are proposed:

1. To improve students' analytical reasoning, problem comprehension, and application of mathematical concepts, maritime educators should incorporate problem-based learning, contextualized mathematical exercises, and real-world navigational situations into mathematics and navigation courses.
2. Students should be required to use mathematical reasoning in real-world navigation scenarios using technology-enhanced learning experiences and simulation-based instructional activities offered by maritime schools. These teaching techniques could enhance critical thinking, decision-making, and navigational skills.

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3. Rather than focusing solely on routine computing exercises, teachers should provide classroom activities that promote logical reasoning, strategic problem solving, and reflective thinking, as analytical reasoning was found to be the biggest predictor of navigational task success.
4. Despite the fact that the regression model did not find computational accuracy to be a major independent predictor, educators should nevertheless emphasize computing proficiency because precise calculations are still necessary for safe navigation, voyage planning, and maritime operations.
5. By integrating mathematical applications into professional maritime courses and matching instructional activities with competency-based criteria, curriculum designers may think about evaluating and improving mathematics-related learning outcomes within maritime education programs. ‘
6. Future researchers are urged to look into additional factors such spatial ability, navigational self-efficacy, exposure to simulators, digital navigation proficiency, critical thinking, and sea-training experience that can affect navigational task performance. A more thorough understanding of the correlations between these variables may be possible by using bigger samples and sophisticated statistical methods like structural equation modeling (SEM) or partial least squares structural equation modeling (PLS-SEM).

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