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A Mathematical Approach in Ship Navigation: The Integration of Trigonometry and Spherical Triangles in STEM Contexts

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Abstract: Trigonometry and spherical triangles are branches of mathematics that are very relevant to ship navigation. Application of the concept and formula of trigonometry and spherical triangles to the positioning of ships by observing celestial bodies. Determining the true position of the ship in the sea is very important to be done so that the ship is always on the right course and avoids navigation hazards. This research aims to explore the important role of trigonometry and spherical triangles in ship navigation, as well as how learning approaches in STEM contexts can improve students' understanding and skills in determining the position of ships at sea. This research is qualitative and uses a case study approach. This study involves a real-case analysis of the application of trigonometry and spherical triangles in ship navigation to see their impact on the accuracy of ship positioning. The data collection techniques used in this research are interviews, observations, and documentation. The instruments used were validated by mathematics lecturers and astronomy navigation science lecturers. The results of the study show that trigonometry and spherical triangles have an important role in determining the position of ships at sea; STEM learning with a PBL approach has proven to be effective in improving students' understanding and skills in the application of trigonometry and spherical triangles in ship navigation. STEM learning in the context of trigonometry and spherical triangles contributes significantly to students' understanding of ship navigation and develops students' critical thinking skills.

Keywords: STEM, trigonometry, spherical triangle, problem base learning, ship navigation.

▪ INTRODUCTION

In the era of globalization and the rapid development of technology, Education in the context of STEM (Science, Technology, Enginering, and Mathematics) is the main focus in equipping students with relevant knowledge and skills to face future challenges. One of the applications of STEM Education is in the field of ship navigation. STEM is indispensable for strengthening the understanding and application of trigonometric materials (Hsu et al., 2021; Tuong et al., 2023). In the field of ship navigation, mathematics especially trigonometry and spherical triangles (Homa, 2019), has a very important role in determining the position of ships in the vast ocean. In addition, the mastery of technology such as the use of GPS and ECDIS systems and algorithm-based computing also strengthens the ability of modern navigation equipment to determine the position of ships at sea (Pierros, 2018).

Trigonometry and spherical triangles are branches of mathematics that are very relevant to ship navigation. There are several navigation problems solved by trigonometry and spherical triangles (Hsieh et al., 2019). This is because it allows the navigator to determine the position of the ship by using celestial objects as a reference (Tsai et al., 2022). Application of the concept and formula of trigonometry and spherical triangles to the positioning of ships by observing celestial bodies. Determining the true position of the ship in the sea is very important to be done so that the ship is always on the right

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course and avoids navigation hazards. The use of azimuth and the direction of the celestial body's high line is a conventional method in determining the position of ships in the sea that is still used and has proven to be effective in assisting ships in shipping (Pierros, 2018). However, for this method to be applied effectively, a solid understanding of the underlying mathematical concepts is required (Tsai et al., 2022). Thus, material on the concept of trigonometry and spherical triangles is very important for prospective seafarers, as well as officer.

STEM learning approaches can not only improve precision and efficiency in ship navigation but also contribute to the development of students' critical and analytical thinking skills (Özçakır Sümen & Çalışıcı, 2022). By understanding the concepts of trigonometry and spherical triangles, students are expected to be able to face the challenges of modern navigation that are increasingly complex, including the integration of computerized systems in navigation systems, such as ECDIS (Pierros, 2018).

The mathematical approach in ship navigation, especially in determining the position of ships at sea, not only has the impact of increasing accuracy and efficiency in navigation, but also contributes to the development of students' critical and analytical thinking skills (Shanta & Wells, 2020). Thus, this research will make a very important contribution to the development of the mathematics education curriculum and the navigation education curriculum. In addition, the results of the research can be used as the basis for the development of applicative and contextual learning modules, so that students not only understand the theory, but also be able to apply it practically.

In recent years, research related to the application of STEM Education and its integration in the context of ship navigation has increased significantly. The results of the research conducted by Stehle & Peters-Burton (2019), that three-day learning with a STEM context has an effect on improving 21st century skills, such as critical and analytical thinking. Sari et al. (2018), From the results of his research, it was found that STEM-based learning using contextual problems in learning can help develop 21st century students' skills, make classes more fun, and increase interest in learning. In addition, the integration of PBL with STEM positively affects students' attitudes and perceptions. Hsu et al.(2021) and Tuong et al.(2023), for example emphasizing the importance of STEM learning to strengthen mathematical skills, specifically trigonometry, in solving real-life problems such as ship navigation. At the same time, research (Tsai et al., 2022) highlights how the application of spherical trigonometry and celestial body observation is still relevant and used practically in modern navigation. In addition, research by (Pierros, 2018) shows that the integration of technologies such as GPS and ECDIS is increasingly important in navigation, although mathematical fundamentals remain fundamental in the use of these technologies. However, there are shortcomings in studies that link STEM approaches in the context of ship navigation, especially those that focus on improving students' mathematical understanding and practical abilities in the application of trigonometry and spherical triangles. This makes the need for more research that combines aspects of STEM learning with the specific context of ship navigation.

Although there have been many studies examining the importance of STEM in teaching mathematics and navigation, there are still gaps related to STEM learning approaches that can specifically improve students' skills and understanding in determining the position of ships using spherical trigonometry. In addition, Most research

tends to focus on technological aspects such as GPS and ECDIS, but less highlights how the integration of STEM approaches in the curriculum of shipping colleges can provide more benefits in understanding the basic concepts of mathematics, which are the cornerstones of such technology. Therefore, this study seeks to bridge this gap by exploring in depth how STEM learning can help students in understanding spherical trigonometry and its application in ship navigation. Thus, this study aims to explore the important role of trigonometry and spherical triangles in ship navigation, as well as how learning approaches in STEM contexts can improve students' understanding and skills in determining the position of ships at sea.

The main problem that needs to be highlighted is the lack of student understanding of the application of trigonometry and spherical triangles in ship navigation. As the research conducted by Sriantini & Cholik (2021), that 21.8% of students had difficulty understanding the problem, 26.4% of students experienced errors at the process skill stage. Although trigonometry and spherical triangles are the basis of shipping navigation, many students still struggle to understand their application in determining the positioning of ships at sea. On the other hand, the development of modern technologies such as GPS and ECDIS often diverts attention from these basic concepts, even though a deep understanding of trigonometry and spherical triangles is essential as the foundation of more comprehensive navigation knowledge.

The conventional approach in teaching trigonometry and spherical triangles tends to focus on theory without connecting it to practical conditions in the field, making it difficult for students to understand the relationship between the concept of trigonometry and spherical triangles in ship navigation, as presented by Sriantini & Cholik (2021), The cause of students' difficulties in understanding trigonometry and spherical triangle problems is the lack of training involving contextual problems related to ship navigation. The gap between the theory taught in the classroom and the practical skills required in the field, shows the importance of STEM learning approaches to improve student understanding, as well as the importance of training students in critical and analytical thinking. There is an increase in the mathematical problem-solving ability of students who receive STEM-based learning with conventional learning (Priatna et al., 2022).

To answer these problems, this study focuses on the following questions: (1) What is the role of trigonometry and spherical triangles in ship navigation, (2) How can STEM learning approaches improve students' understanding and skills in the application of trigonometry and spherical triangles to determine ship positions, (3) How much influence does STEM approaches have on the development of students' critical and analytical thinking skills in solving navigation problems ship.

▪ METHOD

Research Design and Procedures

This research is qualitative with a case study approach. This study involves a real-case analysis of the application of trigonometry and spherical triangles in ship navigation to see their impact on the accuracy of ship positioning. The data collection techniques of this research are interviews, observations and documentation. The interview was conducted with the aim of digging deeper into the application of trigonometry and spherical triangles in ship navigation and how to integrate them in a STEM context. Observation is carried out by observing directly in the Voyage Education class during the

mathematics lesson. Observations include the teaching methods used, student responses, and the use of navigation equipment involving trigonometry and spherical triangles. Documentation is carried out by collecting information from, the curriculum of shipping education, learning materials.

This research began by providing a pre-test on basic concepts and a general understanding of trigonometry and spherical triangles. Furthermore, STEM-based learning is carried out. STEM methods are integrated to teach the concepts of trigonometry and spherical triangles using the Problem Based Learning (PBL) approach. In the PBL approach, students are given real problems related to the positioning of ships in the sea and must be solved using the concepts of trigonometry and spherical triangles. During the learning, observations were made. Observations include: student involvement in solving problems, application of trigonometry and spherical triangle concepts, student interaction with calculators, sextants, and nautical almanac. In the PBL approach, students solve the problems given in several stages, which include:

Problem Orientation

Students were given problems about ship navigation, where the ship departed from Tanjung Perak Port Surabaya to Argentina. Furthermore, students understand the context of the problem by finding the shortest route so that the ship is efficient in using fuel with a shorter sailing time.

Independent Learning

Students study in groups in learning the concepts of trigonometry and spherical triangles related to ship navigation, namely determining the sailing distance and course of the ship. Students seek information from various sources from books and the internet to understand how the concepts of trigonometry and spherical triangles are applied in ship navigation.

Collaboration and Discussion

Students discussed how to use trigonometric formulas and spherical triangles to determine distances, course, celestial azimuths, and lines of position.

Troubleshooting App

Students apply trigonometric formulas and spherical triangles in solving ship navigation problems. Students calculate the shortest distance, the bow of the ship, the azimuth of the celestial body, and the line of position. Students perform calculations using a trigonometric calculator.

Reflection and Evaluation

After solving the problem, students reflect on the learning process that has been carried out and the results obtained. The evaluation was carried out to assess the accuracy of the solution, the efficiency of the method, and how students can improve the problem-based learning approach in the future.

Participants

This research was conducted at the Faculty of Shipping Vocational Engineering, Hang Tuah University Surabaya, with 40 students of the Ship Operations Engineering

Technology (TROK) study program in the second semester. The selection of subjects was using purposive sampling. Purposive sampling is a sampling technique that is carried out by selecting participants based on certain characteristics that are relevant to the research objectives. The purpose of using purposive sampling is to ensure that only participants who have a nautical education background will be involved. In this study, the inclusion criteria for participants are shipping students who are or have studied trigonometry and spherical triangle materials applied to ship navigation. In addition, participants must be willing to participate in the entire research process, which includes pre-test, post-test, and interview if necessary. At the interview stage, students who have high, medium, and low pre-test scores are selected, 1 student is selected each.

Instruments

Before data collection is carried out, researchers develop pre-test questions, post-tests, assessment rubrics, and interview guidelines. The total test questions are 3 items and are in the form of descriptions. The indicator determines course of the ship and shipping distance totals 2 questions, and the indicator determines the azimuth of the celestial body totals 1 question. The interview was conducted to dig deeper into the participants' answers. Furthermore, the instrument was validated by 2 lecturers, namely a mathematics lecturer and a lecturer in astronomical navigational science. The validation of the instrument carried out is content validation, namely by requesting expert assessment. Content validation is carried out to check the suitability of the instrument with the material in the shipping education curriculum. The reliability test carried out was Inter-Rater Reliability, with a kappa coefficient value of 0.75. The pre-test and post-test questions are in the form of description questions, with many 3-item questions. The material taught focuses on the application of trigonometry and spherical triangles in ship navigation, such as: determining the shortest distance through a large circle in a voyage, determining the bow of the ship, and determining the Azimuth and Line of Position from observing celestial bodies. Examples of problems given are:

A ship departs from the Port of Tanjung Perak in Surabaya, Indonesia with coordinates 07º12.3'S/ 112º 35.7'E heading to Argentine Harbor with coordinates 34º 36' S/ 58º 23' W. Using the principles of trigonometry and spherical triangles, calculate: 1) Shipping distance from the Port of Tanjung Perak to the Port of Argentina (in nautical miles). 2) What is the degree of the course on the voyage? Test item indicators as shown in Table 1. as follows:

Table 1. Question indicators

Indicator	Question number
Determining the ship's course and sailing distance	1.3
Determining the Azimuth of celestial bodies	2

Data Analysis

The data analysis used in this study is thematic analysis. Thematic analysis is one way to analyze data with the aim of identifying patterns or to find themes through the data that has been collected (Braun & Clarke, 2006). The stages of thematic analysis include understanding data, compiling code, and finding themes that are in accordance with the research objectives (Heriyanto, 2018)

▪ RESULT AND DISSCUSSION

Application of Trigonometry and Spherical Triangles in Ship Navigation

Based on the results of the study, it shows that trigonometry and spherical triangles are essential components in ship navigation. By using the principles of trigonometry and spherical triangles, namely . Using this formula, Cos a=Cos b.Cos c+Sin b.Sin c.Cos ∠A . The navigator can determine the distance and course of the ship at the time of the voyage. As the results of the answer of the S-1 subject in Figure 1 below :

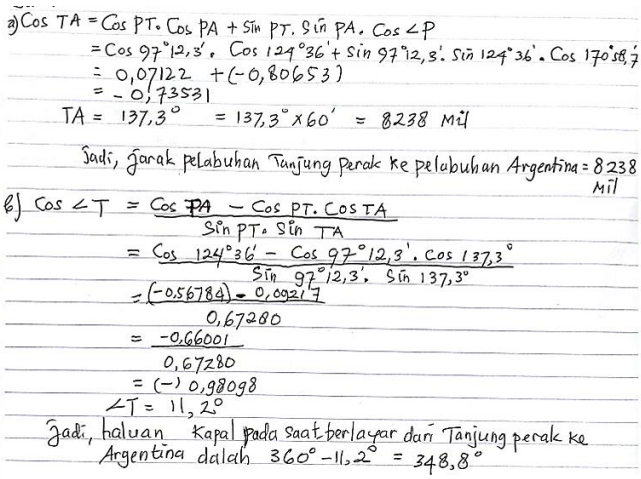

Figure 1. Subject S-1 answer in calculating distance and ship course

Based on the results of the study, it is shown that the determination of the azimuth of celestial bodies using the principle of spherical triangle has proven to be effective in determining the coordinates of the ship's position in the sea, especially when GPS is experiencing problems, so the position designation is very limited. As the results of Subject S-5's answer in Figure 2 below:

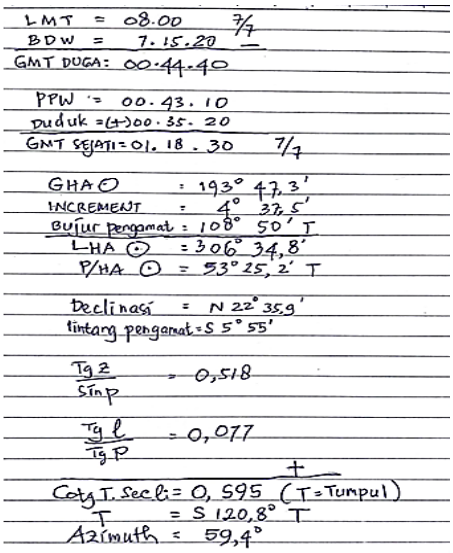

Figure 2. Subject S-5 answer in calculating the Sun's Azimuth

In the context of traditional and modern navigation, the role of trigonometry and spherical triangles is not only important for navigators, but also equips students with basic knowledge of technological navigation concepts such as GPS and ECDIS. This is as stated (Pierros, 2018), that the integration of technologies such as GPS and ECDIS is increasingly important in navigation, although mathematical fundamentals remain fundamental in the use of these technologies. At the same time Tsai et al.(2022), conveying the application of spherical trigonometry and celestial body observation is still relevant and used practically in modern navigation. This shows the importance of mathematical concepts in navigation, especially determining the distance of the voyage, the course of the ship when sailing, and the determination of the position of the ship at sea, especially in an emergency or when the GPS signal is weak.

Learning about spherical trigonometry also trains students to think critically and analytically in determining solution strategies from the information provided, because the problems used are real problems. As conveyed by Pierros (2018), By understanding the concepts of trigonometry and spherical triangles, students are expected to be able to face the challenges of modern navigation that are increasingly complex, so that they can spur students to think critically and analytically.

STEM Learning with PBL Approach to Improve Student Understanding and Skills in Trigonometry and Spherical Triangles

STEM-based learning approaches have proven to be effective in improving students' understanding of trigonometric and spherical triangle concepts and the ability to apply them in real-life situations. This is shown by the results of the student post-test, where students who learn with a STEM approach, perform calculations using a calculator, showing an increase in understanding of concepts. Using the help of scientific calculators, students in solving navigation problems get the results of the right ship position with faster calculation time. In line with what was conveyed by the S-5 subject that by using a calculator, students are more able to solve the problems given quickly and accurately.

In this case, STEM learning with a PBL approach provides space for students to connect theory and practice where the concepts of trigonometry and spherical triangles are applied directly. With the PBL approach, students experience an improvement in critical thinking skills through group discussions. In the study of trigonometry and spherical triangles, students can better understand when they see real applications in determining the distance, course, and position of ships at sea. This is because the problem is given in a real context. As conveyed by Mater (2020), that learning with a STEM approach spurs students to solve problems, learn complex concepts and their application. This is in line with what was conveyed by Reinke (2020), that contextual requires conceptual anchors.

The Influence of STEM Approaches on the Development of Students' Critical and Analytical Thinking Skills in Ship Navigation

STEM approaches have a significant influence on improving students' critical and analytical thinking skills. Based on the results of the research, it is known that students who study with a STEM approach are more skilled in analyzing situations, evaluating data, and solving navigation problems better, which is shown by an increase in the average pre-test and post-test of 45.54, where the average pre-test score is 38.69, and the

average post-test score is 84.23. In addition, students taught with a STEM approach show better ability to make decisions and consider various factors in the state of navigation, such as the influence of current and wind speed in shipping. Students work in teams to discuss the proper way to use trigonometric and spherical triangle formulas to calculate sailing distance, course, celestial azimuth, and line of position. Collaboration strengthens teamwork, communication, and critical thinking skills in finding solutions to complex problems. The results of the interview with the S-7 subject that by discussing, students become more active and can more easily determine strategies for solving the problems given. As stated Bustami et al., (2018), that contextual learning is very good to be used to improve students' critical thinking skills. Group discussions allow students to share ideas and problem-solving strategies with each other.

The critical thinking skills developed through STEM help students to be more independent and better prepared to face real-world challenges, especially in making decisions quickly when the ship is sailing. This is as conveyed by Lestari (2021), pencarian sumber belajar secara mandiri mendorong mahasiswa untuk berpikir lebih dalam tentang permasalahan yang diberikan dan menghubungkan teori dengan praktik, sehingga dapat memacu mahasiswa untuk berpikir kritis. Senada juga dengan yang disampaikan oleh Bustami et al., (2018), that contextual learning is very good to be used to improve students' critical thinking skills. STEM-based learning involves data analysis, such as analysis of the shortest distance that a ship must travel on a voyage and determining the position of a ship in the sea with the help of celestial bodies. With continuous practice, students can improve their analytical skills, which are the main capital as navigators.

▪ CONCLUSION

Trigonometry and spherical triangles have an important role in determining the position of ships in the sea. The results of the study prove that the calculation method using trigonometry and spherical triangles, although traditional, is still relevant and effective in determining the position of ships in the sea using celestial bodies as a reference. A basic understanding of spherical trigonometry is also expected to be an important foundation for students in understanding and developing modern navigation equipment.

STEM learning with a PBL approach has proven to be effective in improving students' understanding and skills in the application of trigonometry and spherical triangles in ship navigation. The PBL approach allows students to understand the concepts of trigonometry and spherical triangles in depth through practical and collaborative experience. In addition to improving analytical and problem-solving skills, collaboration in group discussions helps students to be prepared for real-world challenges. With a problem-based STEM approach, students will gain a better understanding of applying trigonometry theory to real-life problems, especially ship navigation. In addition, STEM not only improves technical abilities, but also develops students' critical thinking skills.

STEM learning has a strong influence on the development of students' critical and analytical thinking skills. A significant increase in post-test hasis compared to pre-test shows that students who learn with a STEM approach are better able to analyze, evaluate, and solve navigation problems. Group discussions in PBL strengthen cooperation skills,

communication, as well as critical and analytical thinking skills that are important in solving complex navigation problems.

It is recommended that STEM abbreviations, particularly PBL-based, be widely applied in the shipping education curriculum. In addition, educational institutions must provide adequate learning facilities, including teaching aids, as well as supporting devices such as scientific calculators. STEM learning should be accompanied by data analysis exercises that are relevant to real conditions such as current and wind analysis that affects navigation.

▪ REFERENCES

Bustami, Y., Syafruddin, D., & Afriani, R. (2018). The implementation of contextual learning to enhance biology students' critical thinking skills. Jurnal Pendidikan IPA Indonesia, 7(4), 451–457. https://doi.org/10.15294/jpii.v7i4.11721

Canning, E. A., Muenks, K., Green, D. J., & Murphy, M. C. (2019). STEM faculty who believe ability is fixed have larger racial achievement gaps and inspire less student motivation in their classes. Science Advances, 5(2). https://doi.org/10.1126/sciadv.aau4734

Han, S., Capraro, R. M., & Capraro, M. M. (2016). How science, technology, engineering, and mathematics project based learning affects high-need students in the U.S. Learning and Individual Differences, 51, 157–166. https://doi.org/10.1016/j.lindif.2016.08.045

Heriyanto, H. (2018). *Thematic analysis sebagai metode menganalisa data untuk penelitian kualitatif*. Anuva, 2(3), 317. https://doi.org/10.14710/anuva.2.3.317-324

Homa, A. I. R. (2019). Robotics simulators in STEM education. Acta Scientiae, 21(5), 178–191. https://doi.org/10.17648/ACTA.SCIENTIAE.5417

Hsieh, T. H., Wang, S., Liu, W., & Zhao, J. (2019). New formulae for combined spherical triangles. Journal of Navigation, 72(2), 503–512. https://doi.org/10.1017/S0373463318000772

Hsu, Y. C., Ching, Y. H., Callahan, J., & Bullock, D. (2021). Enhancing STEM majors' college trigonometry learning through collaborative mobile apps coding. TechTrends, 65(1), 26–37. https://doi.org/10.1007/s11528-020-00541-0

Lestari, F. P. (2021). The implementation of mathematics comic through contextual teaching and learning to improve critical thinking ability and character. European Journal of Educational Research, 10(1), 497–508. https://doi.org/10.12973/EU-JER.10.1.497

Mater, N. R. (2020). The effect of the integration of STEM on critical thinking and technology acceptance model. Educational Studies. https://doi.org/10.1080/03055698.2020.1793736

Özçakır Sümen, Ö., & Çalışıcı, H. (2022). The effects of STEM activities applied in mathematics courses for elementary pre-service teachers in Turkey. International Journal of Mathematical Education in Science and Technology, 53(12), 3352–3376. https://doi.org/10.1080/0020739X.2021.1944679

Pierros, F. (2018). Stand-alone celestial navigation positioning method. Journal of Navigation, 71(6), 1344–1362. https://doi.org/10.1017/S0373463318000401

Reinke, L. T. (2020). Contextual problems as conceptual anchors: an illustrative case. Research in Mathematics Education, 22(1), 3–21. https://doi.org/10.1080/14794802.2019.1618731

Shanta, S., & Wells, J. G. (2020). T/E design based learning: assessing student critical thinking and problem solving abilities. International Journal of Technology and Design …. https://doi.org/10.1007/s10798-020-09608-8

Tsai, K. C., Tseng, W. K., Chen, C. L., & Sun, Y. J. (2022). A Novel analytical solution method for celestial positioning. journal of marine science and engineering, 10(6). https://doi.org/10.3390/jmse10060771

Tuong, H. A., Nam, P. S., Hau, N. H., Tien, V. T. B., Lavicza, Z., & Hougton, T. (2023). Utilising stem-based practices to enhance mathematics teaching in vietnam: developing students' real-world problem solving and 21st century skills. Journal of Technology and Science Education, 13(1), 73–91. https://doi.org/10.3926/jotse.1790