EFFECTIVENESS OF NAUTICAL LEARNING WITH HEURISTIC STRATEGY IN SCIENTIFIC APPROACH IN TERMS OF CRITICAL THINKING ABILITY AND REPRESENTATION FLEXIBILITY

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Abstract: This study evaluates the effectiveness of implementing Heuristic Strategies within a Scientific Approach in nautical learning, focusing on Collision Prevention Regulations at Sea (P2TL). Despite the material's potential to enhance critical thinking skills and flexibility of representation, research applying Heuristic Strategies in the Scientific Approach still needs to be explored. Employing a quasi-experimental method with experimental and control classes, data collection involves written measurements. Research hypotheses are elucidated through inferential analysis, encompassing normality, homogeneity, and mean similarity tests on learning outcome scores. The results demonstrate that nautical learning with heuristic strategies in a scientific approach surpasses ordinary scientific approaches in fostering critical thinking skills and flexibility of representation. This research significantly contributes to advancing learning methodologies in nautics, particularly reinforcing students' critical thinking and representational flexibility. The implications provide educators with grounds to consider integrating Heuristic Strategies within Scientific Approaches to enhance nautical learning quality, aligning with evolving educational demands and student needs.

Keywords: Nautical Learning, Critical Thinking, The Flexibility of Representation

INTRODUCTION

Environmental education, especially in the nautical context, is important in shaping students' understanding of the complexity of marine ecosystems and the environmental challenges. However, several fundamental problems in nautical learning have been identified, demonstrating the need for innovative and effective approaches (Kim et al., 2013).

As an important aspect, the nautical environment often needs more attention in the educational curriculum. Students' limited understanding of the complexity of marine ecosystems often requires more awareness of the urgency of preserving the marine environment (Arpaci et al., 2023; Elia et al., 2009).

Conventional learning methods, which focus on providing information without involving strategies that stimulate critical thinking, could be more effective in helping students develop an in-depth understanding of the nautical. Previous research has shown that integrating heuristic strategies in learning can enhance student creativity and understanding (Chernoff & Sriraman, 2020). However, the extent to which this strategy can be effectively applied in the context of nautical learning still needs to be clarified.

The ability to think critically, considered a key intellectual skill in dealing with the complexity of environmental issues, faces challenges in its development, especially in relating it to complex concepts in nautical learning (Tanujaya et al., 2017). The skill of flexibility of representation, i.e., the ability to represent information through various media and forms, is an important aspect often overlooked. These capabilities are increasingly vital in the digital and technology age, although it is still being determined to what extent the nautical learning curriculum can accommodate these developments (Markula & Aksela, 2022; Peter, 2012).

Critical thinking skills are related to the cognitive ability domain (Akmam et al., 2019). Cognitive ability consists of three domains, namely knowledge, application, and reasoning. The knowledge domain consists of recalling, recognizing, classifying, computing, retrieving, and measuring (Rich, 2021). The application domain consists of determining, representing/modeling, and implementing. The reasoning domain consists of analyzing, integrating/synthesizing, evaluating, drawing conclusions, generalizing, and justifying. The survey results of several studies show that the percentage of students' critical thinking skills and cognitive abilities is still below the international average. In addition to critical thinking skills, representation skills must be developed in classroom learning. The standard learning process aims to improve problem-solving, communication, and representation skills. Representation is an essential element in learning, not only because of the importance of using symbols, syntax, and semantics, but there are two strong reasons, namely: (1)

representations play an essential part in shaping real-world concepts and (2) the link between structures to other structures is essential ideas need to be realized in various forms of representation, such as pictorial representation, verbal representation, symbols, tables, etc. Students can communicate and connect concepts and ideas well with good representation skills. This representation ability is needed so that students can understand and relate concepts or ideas that have been learned to construct their knowledge. Representation is a bridge in learning, so flexibility is needed in applying it. The ability to transform one representation into another will help students solve the problems. For students to use representations well, they must be fluent in operating different representations of the same concept and flexibly selecting, using, and transforming representations.

Generally, in learning, representation is only a complement to solving problems. This leads to minimal representation skills. Previous research shows that students' ability to use and change representations still needs to improve (Sarama et al., 2011). Therefore, using representations and changing one representation to another needs serious attention in learning. Effective learning must be designed to help and train students to think critically and use representations flexibly (Goos et al., 2020). One learning that can be used as a solution is learning with heuristic strategies in a scientific approach (Leifler et al., 2020). The scientific approach required to be used aligns with the learning objectives that lead to students' critical thinking and representation skills. The scientific approach prepares students to be brave in innovating and to improve this ability. Each must be involved in questioning activities, making observations, forming networks, and conducting experiments. The scientific approach allows students to develop reasoning and communication skills and be more active (Abidi et al., 2023; Maharani et al., 2019).

Implementing the scientific approach aligns with the heuristic strategy (Mousoulides & Sriraman, 2020). Heuristics are general problem-solving strategies that can help solve given problems. In this case, there are five heuristic problem-solving steps, namely 1) reading and thinking, 2) exploring and planning, 3) choosing a strategy, 4) finding and answering, and 5) reflecting and expanding (Prabawati et al., 2019). Heuristic strategies in learning affect critical thinking skills (Akmam et al., 2019; Atweh et al., 2023). The characteristics of the heuristic strategy and the scientific approach are appropriate and can train students' critical thinking and flexible representation skills. With the heuristic strategy in the scientific approach, students must be able to explore, choose the right strategy and reason, and communicate the answers to the problems given. This will help students to think critically and choose and use representations flexibly. The potential of the heuristic strategy in the scientific approach to improving students' critical thinking skills and flexibility of representation makes researchers feel the need to test whether learning with the heuristic strategy in a scientific approach is effective in terms of students' critical thinking skills and flexibility of representation (Kattou et al., 2013).

Previous research has provided evidence that heuristic learning models can effectively improve critical thinking skills in science learning in elementary school (Cheung, 2023; Gigerenzer, 2023). However, the focus of this research is limited to that context, and studies have yet to explore the effectiveness of heuristic strategies in nautical learning specifically. Through this research, we can fill that gap by applying and evaluating heuristic strategies in the context of nautical learning, expanding our understanding of the potential positive influences of these strategies beyond the realm of science.

In addition, although previous research has shown that heuristic learning can improve critical thinking skills, no studies have specifically measured the flexibility of representation in this context. Therefore, this research can make a new contribution by evaluating how heuristic strategies affect representation flexibility, providing deep insights into cognitive skill development that may occur during learning.

The importance of online learning in today's digital age is also a major concern (Adnan, 2021; Antoni, 2021). Although previous research suggests that critical thinking and creativity can be developed online, research has yet to specifically explore applying and evaluating heuristic strategies in scientific approaches in online learning environments. Therefore, this study can fill this gap by investigating the impact of heuristic strategies in improving critical thinking skills and creativity in online learning.

Lastly, in the context of learning, previous research suggests the need to encourage critical thinking based on a scientific approach (As’ari et al., 2019). However, no studies have specifically explored the application of heuristic strategies in learning. Therefore, this research can fill this knowledge gap by investigating how heuristic strategies can be applied and assessing their impact in improving critical thinking skills in learning. Thus, this research is expected to make valuable contributions to literature and learning practices in various contexts.

The learning journey commences with observation activities, encouraging students to keenly observe a given problem (Sambell et al., 2021). This initial phase sets the stage for the subsequent steps in the learning process. Moving forward, students make conjectures, honing their ability to articulate questions related to specific problems or topics. These questions serve as guiding beacons, leading students through a journey of exploration where answers are sought through various trying activities and information-gathering from diverse sources.

The triumvirate of observing, making conjectures, and engaging in trying activities forms a holistic approach that fosters the development of critical thinking skills, particularly in analyzing arguments and assumptions. This process is not merely about finding answers but about cultivating a mindset that questions, evaluates, and understands the intricacies of the problems (Darby & Rashid, 2017).

As students progress, reasoning activities come into play, providing a structured framework for processing the information acquired during the problem-solving journey. This step elevates the learning experience by encouraging systematic thinking and logical application of acquired knowledge (Ghanizadeh, 2017).

Finally, the students embark on the communicative phase of their learning adventure. Armed with insights, answers, and solutions from their experiences, they present their findings, whether written or oral. This communication aspect solidifies their understanding of the learned concepts and prepares them to effectively share their knowledge with others, fostering a collaborative and communicative learning environment (Goos et al., 2020). These learning activities create a dynamic and comprehensive educational experience, nurturing knowledge acquisition and developing essential skills for a well-rounded education.

METHODS

This study uses a pseudo-experimental type of research because many factors can affect the study's results, but not all of them can be controlled by the researcher. The selected quasi-experimental research design is a Pretest and Posttest Design involving two classes determined as a control class and an experimental class. Both classes were given a pretest to see the initial condition of the variables studied. The experimental class received treatment in the form of learning with heuristic strategies in a scientific approach, while the control class received learning with an ordinary scientific approach. After the treatment, both classes were given a posttest to see the variable conditions after the treatment.

The population of this study is all students of the Nautical Studies program class 2022 with material on Collision Prevention Regulations at Sea (P2TL). The sampling technique used is cluster random sampling, resulting in class D becoming an experimental class that receives heuristic strategy treatment, and class C as a control class with ordinary scientific approach treatment.

The data collection technique uses essay tests to measure critical thinking skills and representation flexibility. The instrument's validity is tested through the validity of the content, involving rational analysis by two nautical lecturers. The instrument's reliability was measured using the Cronbach alpha formula, with the critical thinking ability test reliability of 0.67 and the representation flexibility test reliability of 0.76, indicating that both are reliable.

Data analysis involves descriptive analysis and assumption tests such as normality tests and homogeneity tests. The results will provide an overview of learning outcomes and validate the influence of heuristic strategies in nautical learning related to critical thinking skills and flexibility of student representation.

RESULTS AND DISCUSSIONS

Critical Thinking Ability Data

The data described in this section are the results of student critical thinking skills tests obtained by researchers before and after treatment. Data on the results of critical thinking skills tests in classes with heuristic strategies in a scientific approach (experimental class) and classes with a scientific approach (control class) are shown in the following table:

Table 1. Student Critical Thinking Skills Scores

Indicator	Experiment Class		Control Class	
	Pre-test	*Post-test*	*Pre-test*	*Post-test*
Argument analysis	31,03	37,14	71,03	86,43
Assumption analysis	27,59	22,86	68,97	73,57
Evaluation	60,69	63,57	88,97	95
Make a decision	40	47,14	78,62	90
Overall average	39,83	76,89	42,68	86,25
Standard deviation	21,28	17,19	19,11	11,68
Maximum Value	70	95	70	95
Minimum Value	0	40	5	40

The table shows that after the treatment, there was an increase in problem-solving ability for both the class with the scientific approach (control class) and the class with the heuristic strategy in the scientific approach (experimental class). The average value of the class with the heuristic strategy in the scientific approach (practical class) is better than that of the scientific process (control class). In the course with the heuristic method in the scientific method (experimental class), the average value increased by 43.57, from the initial average value of 42.68 to 86.25. In the class with a scientific approach (control class), the average value increased by 37.06, from a score of 39.83 to 76.89.

The increase in the value of students' critical thinking skills can also be seen through the average of each indicator of students' critical thinking skills. Based on Table 9, the average of each indicator of critical thinking ability in classes with heuristic strategies in a scientific approach and with a scientific approach has increased. The class whose learning used the heuristic strategy in the scientific approach increased the average in indicator one by 49.29, indicator two by 50.71, indicator three by 31.43, and indicator four by 42.86. Furthermore, the average for each indicator of critical thinking skills in classes whose learning uses a scientific approach has also increased. The increase in indicator 1 was 40; indicator 2 was 41.38; indicator 3 was 28.28; and indicator 4 was 38.62.

Representation Flexibility Data

Data on the results of the representation flexibility test in the class with the heuristic strategy in the scientific approach (experimental class) and the class with the scientific approach (control class) are shown in the following table:

Table 2. Representation of flexibility ability score

Indicator	Experiment Class		Control Class	
	Pre-test	*Post-test*	*Pre-test*	*Post-test*
Representation selection	15,52	61,64	16,96	79,02
Selection of representation form	29,89	67,24	35,71	71,43
Representation transformation	18,97	66,38	18,30	84,82
Overall average	20,69	65,20	22,56	79,54
Standard deviation	14,3	14,20	9,68	11,44
Maximum Value	50	90,90	45,45	90,90
Minimum Value	0	4,54	4	4,54

The table shows that after the treatment, there was an increase in the flexibility of student representations for both classes with a scientific approach (control class) and classes with a heuristic strategy in a scientific approach (experimental class). The average value of the class with the heuristic strategy in the scientific approach (experimental class) is better than that of the scientific approach (control class). In the class with the heuristic strategy in the scientific approach (experimental class), the average value increased by 56.98, from the initial average value of 22.56 to

79.54. In the class with a scientific approach (control class), the average value increased by 44.51, from a score of 20.69 to 65.20.

The increase in the flexibility value of student representations can also be seen through the average of each indicator of student representation flexibility. Based on the table, the average of each indicator of representation flexibility in classes with heuristic strategies in a scientific approach and with a scientific approach has increased. The class whose learning used the heuristic strategy in the scientific approach increased the average in Indicator 1 by 62.06, indicator two by 35.72, and Indicator three by 66.52. Furthermore, the average for each indicator of critical thinking skills in classes whose learning uses a scientific approach has also increased.

Hypothesis Test

Effectiveness of Nautical Learning with Heuristic Strategy in Scientific Approach

Before conducting hypothesis testing, test the assumption of univariate normality. This normality assumption test uses the Kolmogorov-Smirnov test with the help of IBM SPSS Statistic 21 software. The results of the normality assumption test for critical thinking ability and representation flexibility are shown in Table 1.

Table 3. Kolmogorov-Smirnov Test Results in Critical Thinking Ability

Kolmogorov-Smirnov	*Asymp. Sig*
1,286	0,073

Based on the table, the significant value obtained is 0.073 and more excellent than 0.05, so the data comes from a normally distributed sample.

Table 4. Kolmogorov-Smirnov Test of Representation Flexibility

Kolmogorov-Smirnov	*Asymp. Sig*
1,286	0,272

Based on the table, the significant value obtained is 0.272, which is more excellent than 0.05, so the data comes from a normally distributed sample. The effectiveness test was conducted to determine the effectiveness of nautical learning with heuristic strategy in the scientific approach in terms of critical thinking ability and flexibility of representation. Nautical learning with a heuristic strategy in a scientific approach is effective. The hypothesis test used is the univariate one-sample t-test for the first criterion. The results of the critical thinking ability test with a one-sample t-test on IBM SPSS Statistic 21 software are shown in the following table.

Table 5. Results of One-Sample t-Test of Critical Thinking Ability of Experimental Classes

T	*Sig.*
5,103	0,001

Based on the table, the t-value obtained is 5.103. Because 5.103 > 1.7, then H_0 rejected the average value of students' critical thinking skills is more than 74.99, and the first adequate criterion is met. The hypothesis test is the univariate one-sample t-test for the second adequate criterion. The results of the representation flexibility test with a one-sample t-test on IBM SPSS Statistic 21 software are shown in the following table:

Table 6. Results of One-Sample T-test of Representation Flexibility of Experimental Classes

T	*Sig.*
2,107	0,045

Based on the table, the t-value obtained is 2.107. Because 2.107 > 1.7, then H_0 rejected the average value of students' critical thinking skills is more than 74.99, and the second adequate criterion is met. The effectiveness of nautical learning with heuristic strategies in a scientific approach in terms of critical thinking ability and flexibility of student representations was tested by simultaneously testing the hypothesis of one population mean vector. The test result data can be seen in the following table:

Table 7. Hypothesis Testing of Simultaneous Average Vector Experiment Class

T^2	$\frac{(n-1)p}{(n-p)} F_{p,n-p,(a)}$
35,309	6,93777

Based on the Table, T^2 = 35.309 > 6.9377, then H_0 Furthermore, to determine its effectiveness, it can be seen from the average value of the critical thinking ability and flexibility of student representation in the experimental class, which is greater than 75. The average value of students' critical thinking ability is 86.3 and greater than 75. The average value of student representation flexibility is 79.5 and greater than 75. After comparing the two average values, it can be concluded that learning nautics with a heuristic strategy in a scientific approach is simultaneously practical in terms of critical thinking ability and flexibility of student representation.

Effectiveness of Nautical Learning with a Scientific Approach

Before conducting hypothesis testing, test the assumption of univariate normality. This normality assumption test uses the Kolmogorov-Smirnov test with the help of IBM SPSS Statistic 21 software. The results of the normality assumption test of critical thinking ability and flexibility of representation are shown in the following Table.

Table 8. Kolmogorov-Smirnov Test Results of Critical Thinking Ability of the Control Class

Kolmogorov-Smirnov	*Asymp. Sig*
0,519	0,951

Based on the table, the significant value obtained is 0.951, which is more excellent than 0.05, so the data comes from a normally distributed sample.

Table 9. Kolmogorov-Smirnov Test Results in Flexibility Representation Control Class

Kolmogorov-Smirnov	*Asymp. Sig*
1,111	0,169

Based on the table, the significant value obtained is 0.169 and more excellent than 0.05, so the data comes from a normally distributed sample. The hypothesis test used is the univariate one-sample t-test for the first criterion. The results of the critical thinking ability test with the one-sample t-test on IBM SPSS Statistic 21 software are shown in the following table.

Table 10. One-Sample t-Test Result of Critical Thinking Ability of Control Class

T	*Sig.*
0,597	0,555

Based on the table, the calculated t-value obtained is 0.597. Because 0.597 < 1.7, then H_0 accepted so that the average value of students' critical thinking skills is less than or equal to 74.99, and the first adequate criterion was not met. The hypothesis test is the univariate one-sample t-test for the second adequate criterion. The results of the representation flexibility test with a one-sample t-test on IBM SPSS Statistic 21 software are shown in the following table.

Table 11. One-Sample t-test Results of Representation Flexibility of Control Class

T	*Sig.*
-3,689	0,001

Based on the table, the calculated t-value obtained is -3.689. Because -3.689 < 1.7, then H_0 accepted so that the average value of students' critical thinking skills is less than or equal to 74.99, and the second adequate criterion is not met.

The difference in Effectiveness between Nautical Learning with a Heuristic Strategy in a Scientific Approach and Nautical Learning with a Scientific Approach

The pretest assumption test aims to see if there are differences in the initial conditions of the two groups in terms of critical thinking ability and flexibility of student representation with MANOVA.

Univariate Pretest Normality Test

A data normality test is conducted to show that the sample comes from a normally distributed population. This normality assumption test uses the Kolmogorov-Smirnov test with the help of IBM

SPSS Statistic 21 software. The results of the univariate pretest normality assumption test of critical thinking ability and flexibility of student representations can be seen in the following Table.

Table 12. Pretest Univariate Normality Test Results

	Aspects	Kolmogorov-Smirnov	Asymp. Sig
Experiment Class	KBK	0,759	0,612
	FR	1,099	0,178
Control Class	KBK	0,519	0,951
	FR	1,111	0,169

Based on the table, the significant value of the critical thinking ability of the experimental class obtained is 0.612 and more significant than 0.05, so the data comes from a normally distributed sample. The significant value of the experimental class representation flexibility obtained is 0.178 and more significant than 0.05, so the data comes from a normally distributed sample. As for the control class, the significant value of critical thinking ability is 0.951 and more excellent than 0.05, so the data comes from a normally distributed sample. The significant value of the flexibility of representation of the control class obtained is 0.169 and more significant than 0.05, so the data comes from a normally distributed sample.

Multivariate Pretest Normality Test

The test was conducted on the pretest data score of critical thinking ability and flexibility of student representation that had been obtained. The multivariate normality test used in this study is the multivariate normality test (Mahalanobis test) using the help of IBM SPSS Statistic 21 software. The data of the normality test results are shown in the following Table.

Table 13. Multivariate Pretest Normality Test Results

Pearson Correlation	Sig
0,981	0,001

Based on the table, the correlation coefficient obtained is 0.981, more significant than 0.9695, so the data comes from a multivariate normally distributed sample.

Multivariate Pretest Homogeneity Test

The test was carried out using SPSS 21 by looking at the Box'M test. The results of the Homogeneity test conducted with IBM SPSS Statistic 21 software can be seen in the following table.

Table 14. Multivariate Pretest Homogeneity Test

Box's M	F	Sig
3,959	1,268	0,284

Based on the table, information was obtained that the significance value of the Box'M test obtained is 0.284. Because 0.284 <0.05, the data comes from a homogeneous population.

Mean Equality Test

Based on the results of the assumption test, which shows that the pretest data meets standard and homogeneous assumptions, two-group Manova testing can be carried out. This test uses the help of IBM SPSS Statistic 21 software. The pretest mean equality test results are presented in the following table.

Table 15. Pretest Mean Equality Test Results

Effect	Value	F	Sig
Hotteling's Trace	0,11	0,289	0,75

Based on the table, the significance value of Hotelling's Trace is 0.75. Because 0.75 > 0.05, then H_0 accepted, there is no difference in the average score of critical thinking skills and flexibility of representation of students in the control and experimental classes. So, it can be concluded that students' initial ability in both classes can be relatively the same.

Posttest Assumption Test

A data normality test is conducted to show that the sample comes from a normally distributed population. This normality assumption test uses the Kolmogorov-Smirnov test with the help of IBM SPSS Statistic 21 software. The results of the univariate normality assumption test of posttest critical thinking ability and flexibility of student representation can be seen in the following table.

Table 16. Posttest Univariate Normality Test Results

	Aspects	Kolmogorov-Smirnov	Asymp. Sig
Experiment Class	KBK	0,999	0,272
	FR	1,268	0,073
Control Class	KBK	1,036	0,630
	FR	0,234	0,822

Based on the table, the significant value of the critical thinking ability of the experimental class obtained is 0.272 and more significant than 0.05, so the data comes from a normally distributed sample. The significant value of the experimental class representation flexibility obtained is 0.073 and more significant than 0.05, so the data comes from a normally distributed sample. As for the control class, the significant value of critical thinking ability is 0.630 and more excellent than 0.05, so the data comes from a normally distributed sample. The significant value of the flexibility of representation of the control class obtained is 0.822 and more significant than 0.05, so the data comes from a normally distributed sample.

Multivariate Posttest Normality Assumption Test

The test was carried out using the help of IBM SPSS Statistic 21 software by looking at the Mahalanobis test. The test results are shown in the following table:

Pearson Correlation	Sig
0,977	0,001.

Based on the table, the correlation coefficient obtained is 0.977, and more significant than 0.9695, so the data comes from a multivariate normally distributed sample.

Multivariate Posttest Homogeneity Test

The test was carried out using the help of IBM SPSS Statistic 21 software by looking at the Box'M test. The results of the Homogeneity test carried out with IBM SPSS Statistic 21 software can be seen in the following table.

Table 17. Posttest Homogeneity Test

Box's M	F	Sig
6,199	1,986	0,114

Based on the table, the significance value of the Box'M test obtained is 0.114. Because 0.114>0.05, the data comes from a homogeneous population.

Two Independent Group Test

After that, it will be tested whether learning with a heuristic strategy in a scientific approach is more effective than learning with a scientific approach in terms of students' critical thinking skills and flexibility of representation. The test used is multivariate hypothesis testing. The results of the critical thinking ability and flexibility of representation test using the two-group Manova difference test on IBM SPSS Statistic 21 software are shown in the following table.

Table 18. Multivariate Test Results Critical thinking ability and representation flexibility

Effect	Value	F	Sig
Hotteling's Trace	0,322	8,691	0,001

Based on the table, the significant value obtained is 0.001. Because 0.001 <0.05, then H_0 rejected, there is a difference in the average score of critical thinking skills and flexibility of representation in the control and experimental classes. The two-group Manova difference test results show a difference in the average score of critical thinking skills and flexibility of representation in the control and experimental classes; the test is continued in the independent sample t-test. This is done to see which learning is more effective in each aspect. The different test results for each aspect are shown in the following table.

Table 19. Independent Sample T-test Results of Critical Thinking Ability and Flexibility of Student Representation

Aspects	F	t	Sig
KBK	6,175	-2,395	0,02
FR	1,565	-4,175	0,001

Based on the table, the significance value of critical thinking ability is 0.02. Because 0.02 <0.05, then H_0 rejected, learning with a heuristic strategy in a scientific approach is more effective than learning with a scientific approach regarding students' critical thinking skills. The significant value of representation flexibility in the table is 0.000. Because 0.000 <0.05, H 0 is rejected, learning nautical with a heuristic strategy in a scientific approach is more effective than learning with a scientific approach regarding student representation flexibility.

Discussion

This study aims to assess the effectiveness of nautical learning with heuristic strategies in a scientific approach, especially in terms of critical thinking skills and representation flexibility. This study also tried to compare the effectiveness of nautical learning with heuristic strategies in scientific approaches and nautical learning with ordinary scientific approaches. This study has three hypotheses, and the hypothesis test results show that hypotheses 1 and 3 are fulfilled.

The characteristics and learning steps that support critical thinking skills can explain the success of learning with heuristic strategies in a scientific approach to improving students' critical thinking skills. The steps in heuristic strategies, such as reading and thinking about problems, asking questions, exploring problems, planning solutions, choosing the most appropriate strategies to find and solve problems, and reflecting on solutions and steps that have been taken, are by previous research stating that problem solving contributes to critical thinking skills, analysis, and reasoning skills.

Heuristic strategies require students to learn actively so that they can state ideas and have strong relevance to aspects of critical thinking skills. Heuristics help us find and create solutions to problems or problem-solving procedures, and in terms of problem solving, we find and create solutions to problems. This aligns with previous research stating that heuristic learning strategies are a series of learning activities emphasizing critical and analytical thinking processes to find and find answers to a problem requiring creative and flexible thinking.

The success of learning with heuristic strategies in a scientific approach in terms of student representation flexibility is due to the characteristics and learning steps supporting student representation flexibility (Sari et al., 2019; Suryaningsih, 2019). The steps in the heuristic strategy make students more active because they process the information they get independently. This aligns with previous research stating that learning is more active if students work by actively processing and transforming information. In the reflection step, students are asked to re-examine the answers to the problem solving that has been done. In some problems, students are also asked to provide answers or alternative solutions. This can help students think more flexibly when solving a given problem.

The steps in learning with heuristic strategies in the scientific approach, such as reading and thinking problems, asking questions, exploring problems, planning solutions, choosing the most appropriate strategies to find and solve problems, as well as reflecting on solutions and steps that have been taken, provide opportunities for students to explore knowledge so that they can build and develop their knowledge through experience and interaction with their learning environment (Moore, 2020)

According to Erdoğan (2019), Heuristic strategies have several advantages, including students being active participants in the learning process and feeling proud of their achievements after discovering concepts with their efforts. This gives students happiness and mental satisfaction, propelling them to their next achievement.

In conclusion, this study provides valuable insights related to the effectiveness of nautical learning with heuristic strategies in scientific approaches, especially in developing students' critical thinking skills and flexibility of representation. These findings can provide a foundation for further development in the context of nautical learning and contribute positively to improving the quality of education.

CONCLUSION

In summary, the research findings highlight three key outcomes. Firstly, incorporating a heuristic strategy within a scientific approach in nautical learning proves effective in enhancing students' critical thinking skills and flexibility of representation. Secondly, the conventional nautical learning approach, solely utilizing a scientific method, demonstrates a lower efficacy in fostering students' critical thinking skills and flexibility of representation. Thirdly, integrating a heuristic strategy within a scientific approach in nautical learning emerges as more effective than the conventional scientific approach, particularly in enhancing critical thinking ability and flexibility of representation.

Despite the insightful findings, it is crucial to acknowledge the study's limitations. Nevertheless, the conclusions drawn from this research bear significant implications for instructional practices. Educators are encouraged to carefully consider the pedagogical approaches they choose, particularly focusing on improving students' critical thinking skills and flexibility of representation. The study advocates adopting nautical learning with heuristic strategies within a scientific approach as a viable and effective teaching method.

In light of these conclusions, the study strongly recommends applying and further exploring the heuristic strategy within the scientific approach across different dimensions. This call to action aims to contribute to a more comprehensive understanding of the potential impact of the heuristic strategy and the scientific approach on learning outcomes. By embracing innovative and effective teaching strategies, educators can play a pivotal role in enhancing the overall quality of nautical education and fostering the development of critical thinking skills and flexibility of representation among students.

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