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Research Article

ECIRR Learning Model with QSH Strategy and Environmental Literacy: Evaluation of Mathematical Problem-Solving Abilities

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Abstract

This study aimed to determine the effect of the ECIRR (Elicit, Confront, Identify, Resolve, and Reinforce) learning model with the QSH (Question Student Have) strategy on mathematical problem-solving abilities in terms of students' environmental literacy. This type of research was quasi-experimental with a 2×3 factorial design. The data collection techniques were problem-solving tests and environmental literacy questionnaires. The data analysis techniques employed were normality test, homogeneity test, and two-way ANOVA test. Based on the results of the study, it was concluded that the ECIRR learning model with the QSH strategy had an effect on students' mathematical problem-solving abilities. There was no influence of environmental literacy on students' mathematical problem-solving abilities. There was no interaction between the treatment of the ECIRR learning model with the QSH strategy with the environmental literacy category on students' mathematical problem-solving abilities.

Keywords:
ECIRR Learning Model; QSH Strategy; Mathematical Problem-solving abilities; Environmental Literacy.

INTRODUCTION

One of the most crucial 21st century talents is problem-solving, which should be learned at a young age [1]–[3]. In today's globalized world, one's ability to solve challenges determines one's level of success [4]. One of the primary purposes of learning mathematics is to develop students' problem-solving abilities [5]–[7]. A person's problem-solving abilities can be seen in how exactly, precisely, harmoniously, and rationally they solve difficulties [4], [8]. Problem-solving skills can be defined as discovering a solution to a problem [9]–[11]. Problem-solving abilities do not simply require students to solve a problem supplied by the teacher but rather a process of combining students' abilities into a new ability or knowledge [12]–[14], which can be employed in solving mathematical issues [15]. As a result, problem-solving skills must be fostered to make Indonesia's new generation more competitive in the future.

According to preliminary research, many students could not answer mathematics questions [16]–[19], which has an impact on low mathematical problem-solving abilities [20]. Low problem-solving abilities might be caused by students failing to understand the problems correctly [21], [22] or by students misinterpreting the problem-solving process [23], [24]. Furthermore, according to the North American Association for Environmental Education, environmental literacy influences the ability to propose problem-solving techniques [25], [26].

Environmental literacy is crucial because it generates ecologically literate citizens. The demographic variables in Indonesia make environmental education especially important: an expanding population, increasingly consumerist lifestyle changes, and rapid economic and industrial progress. Environmental issues involving various parts of life are growing more complex and diverse. Among these, ecological harm and biodiversity reduction continue. For example, human-caused marine deterioration has become a worldwide issue. By 2025, the world's oceans will have amassed 150 million tons of plastic [27]–[30]. This is undoubtedly a challenge in education, so education necessitates a multisystemic pedagogical approach, for example, a collaboration between schools and other agencies or systems in minimizing these negative impacts and a sustainable education system that focuses not only on cognitive aspects but also on awareness of the importance of the environment in life. This means a non-formal framework must support the classroom learning process [31].

Mathematical skills for the twenty-first century are an intriguing and timely topic in mathematics education. Many learning innovations are aimed at developing these abilities. One of these is using a novel educational strategy known as the ECIRR (Elicit, Confront, Identify, Resolve, and Reinforce) learning paradigm. The ECIRR learning paradigm can help students improve their mathematical reasoning skills [32], students' misconceptions [4], learning outcomes [33], and students' thinking skills [34]. The Question Student Have (QSH) strategy is an integrated learning strategy that has received little attention. QSH is a type of learning that encourages students to be active participants, unite their thoughts, and assess their understanding of the lecture through written questions [35].

QSH strategy integration in learning can be demonstrated in reading, writing, observation, conversation, and problem-solving skills [36], [37]. The QSH strategy improves students' problem-solving abilities, independence, and logical thinking [38]. ECIRR learning paired with the QSH strategy has never been done before. Furthermore, research on the impact of environmental literacy is rare, particularly in affecting students' problem-solving skills. As a result, research is required to explain the influence of the ECIRR learning model with the QSH strategy and environmental literacy on students' mathematical problem-solving skills.

Theoretical Background

Mathematical Problem-Solving

Mathematical problem-solving is vital in various fields, including business performance and continuous improvement. It is a mental activity that entails applying logical, analytical, and creative thinking to mathematical problems [39], [40]. This method necessitates a thorough comprehension of the mathematical ideas involved in the problem, using abstract thinking skills to uncover patterns or structures and encouraging creativity in the search for novel solutions [41]. These ideas are implemented through problem-solving techniques such as mathematical modeling, pattern recognition, experimentation, and the application of appropriate mathematical algorithms [42]. Furthermore, the engagement of metacognition, such as self-reflection and monitoring of the problem-solving process, contributes significantly to developing mathematical problem-solving skills. The theory is supported by the works of mathematicians such as George Polya, who outlines the basic principles in mathematical problem-solving in his book "How to Solve It" [43], [44], as well as Schoenfeld and Mason's research highlighting the role of abstract thinking and the application of problem-solving strategies in mathematics learning [45]–[48]. Furthermore, the research of Kandemir, M. A., and Gur, H., evaluated the characteristics of mathematical creativity [49] can enhance our understanding of creativity in mathematical problem-solving. By integrating these factors, mathematical problem-solving may be understood as a holistic process that generates solutions and improves individuals' grasp of mathematical concepts and critical thinking skills.

Environmental Literacy

The definitions of environmental literacy vary due to the underlying theoretical foundations. However, some of its components are agreed upon by many scholars, namely ecological and environmental knowledge, skills, attitudes, and behaviors [50]–[55]. The development of environmental literacy and interactive methods [56]–[58] leads us to broaden the definition of the class to include nature itself, addressing communication and interaction between teachers and students, students and students, students and society, and students and their environment. Environmental literacy affects environmental awareness and concern [59], [60], pro-environmental attitude [61], [62], environmental sensitivity, self-efficacy, cognitive ability, problem analysis, problem-solving, prevention of new problems, and environmental behavior. Consequently, people who care about the environment have knowledge, dedication, and abilities that drive and enable them to take environmental responsibility [60]. People who care about the environment can be identified by their conduct; they make environmentally friendly decisions [63]. Environmental education fosters environmental literacy. Environmental literacy strives to instill environmentally conscious attitudes among schools and the general public. There is significant research-based advice in learning to do so [64], [65].

METHODS

Type of Research

The research design was quasi-experimental with a 2X3 factorial and a posttest-only control group design. The ECIRR learning model with the QSH strategy was used in the experimental class, and the conventional learning model was employed in the control class. Figure 1 depicts the research design.

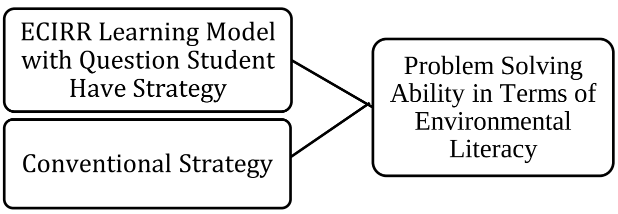

Figure 1. Experimental Research Design

Participants

The population in this study were all seventh-grade students in a junior high school in Lampung province, namely students in classes VII A, VII B, and VII C. This research was conducted in the first semester of the 2021/2022 academic year. The sampling technique employed was the Cluster Random Sampling. Classes VII A and VII B were selected as research samples. Class VII B, as the experimental class (treatment), applied the ECIRR learning model with the QSH strategy, and class VII A, as the control class, applied the conventional learning model.

ECIRR Learning Model with QSH Strategy

The learning stages are displayed in Table 1.

Table 1. The Stages of the ECIRR Learning Model with QSH Strategy

Stage	Activity
Elicit	The teacher explores students' prior knowledge to stimulate students to think.
Confront	The teacher confronts students' prior knowledge so that students experience cognitive conflicts.
Identify	The teacher asks students to explain the reasons for believing the answers at the elicit stage.
Resolve	Students associate their prior knowledge with new knowledge.
Reinforce	The teacher reviews the existence of students' alternative conceptions at the end of learning.

Instrument

Research data was collected through tests and questionnaires. The test instrument is constructed based on problem-solving indicators according to Polya. According to Polya [44], four stages can be done to problem-solving, which are: understanding the problem, planning on problem-solving, carrying out the plan, and reviewing the completion of the problem-solving. Polya indicator was chosen because is more suitable for use as a strategy for solving story problems. Apart from that, it will be easier for students to develop a solution strategy that suits the problem they are facing, because the structure of problem-solving according to Polya is more structured. This is because the Polya indicator is more suitable for use as a strategy for solving story problems. Apart from that, it will be easier for students to develop a solution strategy that suits the problem they are facing, because the structure of problem-solving according to Polya is more structured starting from understanding the problem, planning the solution, resolving the problem and checking back on the results obtained [66]–[68].

Meanwhile, the use of questionnaires in this research aims to determine students' environmental literacy levels. This questionnaire is prepared based on environmental literacy indicators according to McBeth [50]. Indicators of environmental literacy abilities can be seen in Table 2.

Table 2. Indicators of environmental literacy abilities

Mathematical Literacy Indicators	**Operational Forms**
Knowledge	Environmental knowledge that includes environmental basics
Cognitive skills	Attitudes towards the environment which include views about the environment, sensitivity to environmental conditions, and feelings towards the environment
Attitude towards the environment,	Cognitive skills include identifying environmental problems, environmental analysis and planning implementation
Behavior towards the environment	Behavior that includes real actions towards the environment

Procedure and Data Analysis

Tests and questionnaires were employed to obtain data. As data collection techniques, the present research used mathematical problem-solving abilities test instruments in the form of description questions and environmental literacy questionnaires. Because the present research attempted to compare the population averages of two or more data groups, the data analysis used in this study was two-way ANOVA.

RESULTS AND DISCUSSIONS

Results

The results of the research on the mathematical problem-solving abilities of the experimental and control classes can be seen in Table 3.

Table 3. The Results of the Mathematical Problem-solving Abilities Test

Group	$\mathbf{X_{Max}}$	$\mathbf{X_{Min}}$	**Central Tendency**		
			$\bar{x}$	M_o	M_e
Experimental Class	100	67,50	84,29	85,00	85,00
Control Class	100	52,50	76,39	70,00	72,50

Table 3 reveals that the experimental class employed the ECIRR learning model with the QSH technique outperformed the control class regarding mathematical problem-solving abilities. This result is seen by the average value ($\bar{X}$) of 84,29 and the value that frequently appears (M_o) of 85. The difference between the highest and lowest scores in the class was insignificant. In conclusion, the ECIRR learning model with the QSH strategy resulted in higher mathematical problem-solving abilities scores. The results of the environmental literacy questionnaire obtained that the number of students in the experimental and control classes fit into the low, medium, and high criteria can be seen in Table 4.

Table 4. Student Environmental Literacy Category Data

Group	Number of Students in the Environmental Literacy Category		
	Low	Moderate	High
Experimental	6	14	8
Control	7	14	7

Table 4 illustrates that six student in the experimental class and seven in the control class had low environmental literacy. Furthermore, students with moderate environmental literacy accounted for 14 in the experimental group and 14 in the control group. The number of students with high environmental literacy criteria in the experimental class was eight, while it was Seven in the control class.

Furthermore, the acquired data were examined for normality, homogeneity, and hypothesis testing. The first step was ensuring that the mathematical problem-solving abilities test and the student environmental literacy questionnaire were normal. The data is normally distributed if the p-value is greater than or equal to 0.05. Table 5 displays the normality test results on data from students' mathematical problem-solving abilities and environmental literacy.

Table 5. Normality Test Results of Mathematical Problem-solving Abilities

Group	$p-Value$	Sig.	Description
Experimental	0,200	0,05	Normally distributed
Control	0,137	0,05	Normally distributed

Using the α significance level of 0.05, it was possible to conclude that the data gathered from the experimental and control classes were from a normally distributed population because the p-values of the two classes were greater than 0.05 (p-value > α). The next stage was to ensure that the test results of students' mathematical problem-solving abilities were homogeneous. Table 6 displays the results of the homogeneity test.

Table 6. Homogeneity Test Results of Mathematical Problem-solving Abilities

Stage	Problem-solving abilities
$p-Value$	0,777
Homogeneity	$p-Value\ > 0{,}05$
Description	Homogeneous

Table 6 displays the data on mathematical problem-solving abilities from the same or homogeneous population variance since it meets the P-value criteria (0.777 > 0.05). The hypothesis testing employed a parametric test, specifically a two-way analysis of variance (ANOVA), because the data originated from a normally distributed population with the same population variance. Table 7 shows the results of the two-way analysis of variance (ANOVA) hypothesis test in the experimental class.

Table 7. ANOVA Test Results of Mathematical Problem-solving Abilities

Dependent Variable: Problem-Solving

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1147,024[a]	5	229,405	1,922	,107
Intercept	319458,000	1	319458,000	2676,956	,000
Model	750,149	1	750,149	6,286	,015

Dependent Variable: Problem-Solving					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Literasi Lingkungan	164,375	2	82,187	,689	,507
Model * Literasi Lingkungan	140,982	2	70,491	,591	,558
Error	5966,815	50	119,336		
Total	369525,000	56			
Corrected Total	7113,839	55			

a. R Squared = ,161 (Adjusted R Squared = ,077)
b. Computed using alpha = ,05

Table 7 displays the unequal cells' two-way variance analysis hypothesis test findings. H_{0A} is rejected since the p-value (0.015) is lower than α (0.05), indicating that the ECIRR learning model with the QSH strategy influences students' mathematical problem-solving skills. The H_{0B} is accepted because the p-value (0.507) is higher than α, indicating that environmental literacy does not affect students' mathematical problem-solving skills. Furthermore, H_{0AB} is accepted because the p-value (0.558) is higher than α, indicating no interaction between environmental literacy and the ECIRR learning model with the QSH strategy on students' mathematical problem-solving abilities. These calculations conclude that there is a considerable difference in students' mathematical problem-solving abilities between the experimental and control groups.

Discussion

The researchers' findings demonstrates that learning with the ECIRR learning model and the QSH strategy affects students' mathematical problem-solving abilities differently than conventional learning. The researchers' findings are also consistent with previous research using the ECIRR learning model with the QSH strategy by Diana R. et al. [69], which found that using the ECIRR learning model with the pictorial riddle method effectively reduces student misconceptions in learning. Furthermore, Askha Meliana Adi Ningrum and Suliyanah [70] discovered that utilizing the ECIRR model to learn can increase student learning outcomes. Ardiansyah et al. [71] discovered that learning utilizing the ECIRR model can increase students' problem-solving abilities.

According to the research findings, the ECIRR learning model with the QSH strategy in the experimental class had a greater impact on students' mathematical problem-solving abilities than the conventional learning model in the control class. This result is possible because the ECIRR learning model with the QSH strategy differs from conventional learning models in several ways, one of which stems from the learning model's stages. Because the findings of this study are consistent with earlier findings, it may be stated that this study strengthens previous findings.

In the ECIRR learning model with the QSH strategy, the learning process begins with pre-research to assess students' initial skills. The low value of each indicator of mathematical problem-solving abilities demonstrates that many students had not mastered mathematical problem-solving abilities. The four indicators of mathematical problem-solving abilities are the ability to analyze a problem, plan issue solving, solve problems according to plan, and re-examine the answers acquired [9], [72]–[74]. Each indicator of mathematical problem-solving abilities continues to be somewhat low and below average. The ECIRR learning model with the QSH strategy will train students to master mathematical problem-solving skills [75], [76].

The stages in the ECIRR learning model with the QSH strategy begin with the teacher setting students into several study groups of 4-6 students. In the Elicit stage, the teacher investigates the student's initial knowledge by providing activities promoting thinking, such as asking questions. This stage can teach indicators of mathematical problem-solving abilities, namely the ability to comprehend a problem.

In the confront stage, the teacher challenges the student's prior knowledge with response questions, causing cognitive conflict. This stage can teach an indicator of mathematical problem-solving abilities, specifically planning the problem-solving. Furthermore, at the Identify stage, the teacher encourages students to explain why they were confident in their answers during the Elicit stage. This Identify stage can train an indicator of mathematical problem-solving abilities, specifically the ability to re-examine the obtained results.

The Resolve stage requires students to connect their past knowledge with the knowledge they have gained through observation activities. The teacher then instructs students to write questions on blank and trade papers with other groups. Furthermore, if they wish to know the answer, students respond by placing a checkmark next to the question. Finally, the teacher marks the question with the most responses with a check mark. This Resolve stage can develop indicators of mathematical problem-solving abilities, namely the ability to re-examine obtained results.

The Reinforce stage occurs at the end of the learning process, with teachers reviewing previously discussed questions with students. This stage can be used to teach an indicator of mathematical problem-solving abilities, namely the capacity to solve problems systematically. According to the research findings, the p-value obtained in the ECIRR learning model using the QSH approach was 0.015 ($p - value \leq \alpha$). It can be concluded that experimental and control class students had significantly different mathematical problem-solving abilities. As a result, the ECIRR learning model with the QSH strategy can be used to assess the increased mathematical problem-solving abilities.

Based on the description, it is clear that there is a distinction between the treatment of the ECIRR learning model with the QSH strategy and the treatment of the conventional learning model. The ECIRR learning model with the QSH strategy yielded better results than conventional learning models because the ECIRR learning model with the QSH method outperforms the conventional learning model. The ECIRR learning model with the QSH strategy engages students more actively in learning, trains them to solve problems well, and ensures that concepts learned are retained longer. Furthermore, because it is a learning that emphasizes student activity and involvement in the learning process, the ECIRR learning model with the QSH strategy is particularly effective. They can assist students in working on mathematical problem-solving problems.

Each student has different thoughts in solving problems [77], and the presence of the ECIRR learning model with the QSH strategy to increase problem-solving abilities benefits students and teachers [78]. Teachers will have improved pedagogical skills [79]. The present research also looked at how environmental literacy affects students' problem-solving abilities by categorizing students' environmental literacy into three levels: high, medium, and low. Based on observations in the learning process using the ECIRR learning model with the QSH strategy or conventional learning models, there were students with a high environmental literacy category but were not active and did not understand the material, resulting in poor test scores. On the contrary, students with medium and low environmental literacy categories were active and understood the material, resulting in good test scores. Some students worked together to answer questions, frequently asked questions about the clarity of the topic, and enjoyed the mathematics lesson. According to the findings of this study, the p-value for environmental literacy was 0.507 ($p - value > \alpha$). Therefore, there was no difference in the mathematical problem-solving skills of students with high, medium, and low environmental literacy.

In theory, environmental literacy and teachers' use of relevant learning models can influence mathematical problem-solving abilities. However, the present research found no association between learning models and environmental literacy and students' mathematical problem-solving abilities. This finding is related to a factor, namely a lack of student accuracy in problem-solving. Students with high, medium, and low environmental literacy have a level of accuracy in problem-solving that is not significantly different during the learning process. On the other hand, the mathematical problem-solving abilities test necessitates a high level of accuracy. Another reason the research outcomes were not reached was that students were less active in talking and cooperating in the learning process. Based on the calculation, the p-value for environmental literacy and learning models is 0.558 ($p-value > \alpha$), indicating no association between the ECIRR learning model, the QSH technique, and environmental literacy on students' mathematical problem-solving abilities.

The ECIRR learning model combined with the QSH strategy integrates the learning model and strategy that ensures each student may play an active role in learning, increasing each student's problem-solving abilities. M. K. Kim et al. [80] claim that integrated learning increases students' interest and participation in learning. Schools recognize that establishing a learning model necessitates preparation for the school environment, including school management and structure. Furthermore, the availability of educational materials and resources is frequently a significant issue [81].

CONCLUSIONS

Based on the findings, it is feasible to conclude that the ECIRR learning model with the QSH strategy affects students' mathematical problem-solving abilities. Environmental literacy has little effect on students' ability to solve mathematical problems. Furthermore, there is no interaction between the treatment of the ECIRR learning model with the QSH approach and the environmental literacy category on mathematical problem-solving abilities.

The researchers believe that future researchers who want to assess students' mathematical problem-solving abilities should use different learning models that are more effective than those that have been studied. The goal is to assess the effectiveness of alternative learning strategies in increasing students' mathematical problem-solving abilities.

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Conflicts of Interest

The authors declare no conflict of interest.

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