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The Development of RBL-STEM Learning Materials to Improve Students' Information Literacy in Solving Rainbow Antimagic Coloring Problem for ETLE Technology

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ABSTRACT: Students often struggle to solve complex mathematical problems in real-world contexts due to low information literacy skills. To improve information literacy skills, an effective learning approach can be RBL-STEM, which provides research-based learning and can be practically applied in the real world. This study aims to investigate RBL-STEM activities, describe the process and results of developing RBL-STEM materials, and analyze data from the results of developing these materials to improve students' information literacy skills. The method of research used is research and development (R&D). The purpose of this research is to develop RBL-STEM materials and produce learning material products in the form of semester learning plans, student assignment designs, student worksheets, and learning outcomes tests. The results of the materials development showed validity with a validity criterion of 92.75%. The trial was conducted with 40 students, and the implementation using the RBL-STEM materials was found to be practical with a practical criterion of 98.75% and effective with an effectiveness criterion of 94%. In addition, the students were highly engaged and responded very positively to the learning experience. Pretest and posttest analysis showed an increase in students' information literacy in solving the rainbow antimagic coloring problem. The study also identified three levels of information literacy skills: high, medium, and low. Statistical analysis, phase portrait, NVivo, and word cloud confirmed the research findings and showed an increase in students' information literacy skills. Thus, RBL-STEM has the potential to improve students' information literacy in real-world contexts, such as the application of ETLE using graph neural network techniques.

KEYWORDS: Information Literacy, RBL-STEM, Rainbow Antimagic Coloring

INTRODUCTION

Education is a planned and conscious effort to create a learning process and learning atmosphere so that students can have self-control and develop their potential actively, intelligently, skillfully, and morally noble. Education must also have national standards so that the goals of education can be achieved. The government has regulated the national standards of education which indicate that numeracy or mathematics material must be included at every level of education. From this regulation, it can be seen that mathematics is a very important material in various scientific developments. Students who study mathematics, especially at the university level, are expected to be able to adapt well to the development of science.

Mathematical concepts and principles are used in every daily activity such as counting and measuring. In addition, the role of mathematics is very important in solving a problem of daily life activities. In the industrial era 4.0, it will be very difficult for someone to live a normal life in the world without using math. Therefore, it is very necessary for each individual to study mathematics, the goal is that each individual is able to meet the needs of development and problems in everyday life. Problems in mathematics can be found in the application of rainbow antimagic coloring material which is one of the sub-sciences of graph theory (Chartrand et al., 2019). Rainbow antimagic coloring is a combination of two concepts: antimagic labeling and rainbow coloring (Dafik et al., 2021). The selected rainbow antimagic coloring application problem is in Electronic Traffic Law Enforcement (ETLE) technology (Indarsih, 2021). The selection of this problem is a development of mathematics itself and can also involve several components of other fields of science, such as graph neural networks (GNN) (Dafik et al.).

The development of complex mathematics certainly requires a skill that uses digital technology in accordance with the industrial era 4.0, these skills can be information literacy skills. Information literacy is a person's ability to explore, find, use, evaluate whether information is accurate or not, and communicate it in various formats (Dalton, 2013). Students need to have these seven indicators in order to solve mathematical problems in everyday life (Septiyantono, 2014). Information literacy skills need to be improved because most students are not familiar with the new dimensions of information literacy and the key concepts that define information literacy in the 21st century, and they do not recognize the importance of learning how to search, distinguish and manage information to accomplish their academic tasks.

The university system in the United States mentions that most undergraduate students have low information literacy despite the fact that their academic training is increasingly needed. It has been proven by McGraw Hill Education that only 4 out of 10 undergraduate students feel highly prepared for the future workforce (Cahyono, 2021). This figure puts the gap at less than half and shows that low information literacy skills have an impact on future life readiness. Therefore, information literacy skills are needed and can help students to solve and communicate a mathematical problem in everyday life, which also has an impact on future readiness or at the next level of education (Yudistira, 2017). In this case, the desire for the development of complex mathematical science is achieved by improving information literacy skills.

Information literacy skills in this 4.0 era are also not spared in relation to digital technology, an educator can use models and approaches to support the learning process, and one model and approach that can be applied is RBL-STEM. Research-Based Learning (RBL) is a learning method with a multifaceted concept that refers to various learning and teaching strategies that combine research and teaching (Blackmore & Fraser, 2007). The learning syntax of the Research-Based Learning model was revised and updated by Gita et al (2021) and then expressed graphically. Meanwhile, STEM (Science, Technology, Engineering, Mathematics) is a multidisciplinary curriculum that focuses on science, technology, engineering, and mathematics that is integrated into the educational process and focuses on solving problems in everyday and professional life (Healey et al., 2014). Mary Margaret Capraro (2019) states that STEM helps others apply standards-based instruction that requires learning to greater accountability through integrated and meaningful tasks.The application of RBL-STEM in learning can encourage students to construct, develop, evaluate, communicate, use technology, and apply knowledge.

Some research related to RBL is the analysis of effectiveness of RBL in improving higher order thinking skills (Dafik et al., 2019), and then the next year any analysis of students' creative-innovative thinking skills in solving rainbow antimagic coloring problems with the Research-Based Learning model (Sulistiyono et al., 2020). Another research is the development of a Research-Based Learning material with a STEM approach in improving students' metaliteracy in solving sequential pair set problems (Jannah et al., 2022). By paying attention to the implementation of RBL-STEM that other researchers have done in solving a problem in the field of mathematics, a similar study was conducted in developing an RBL-STEM material to improve students' information literacy skills in solving RAC.

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METHOD

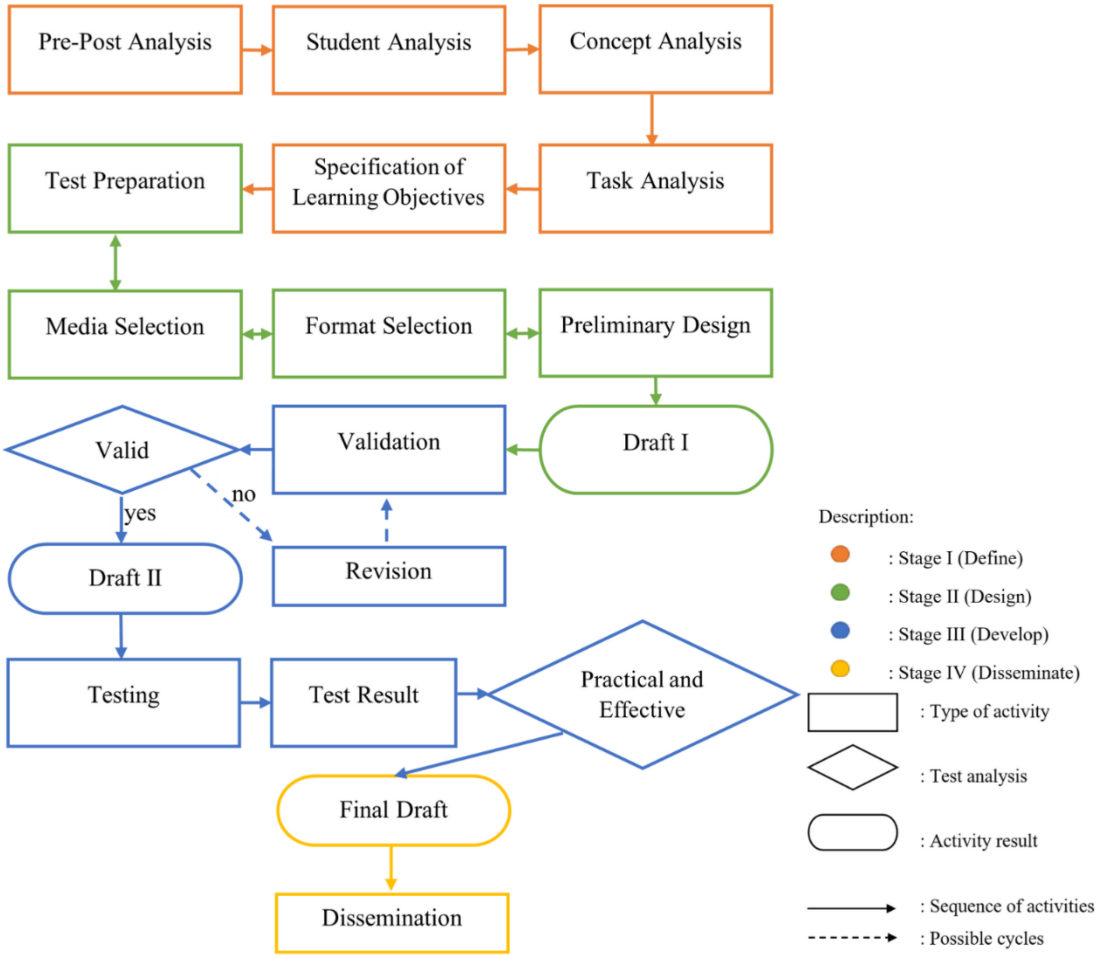

Figure 1. 4-D Model Design

All the results of the material validity assessment data are calculated based on the average of each aspect of the indicator value which will be followed by determining the criteria for the validity of the learning material. The table of validity criteria for learning materials can be seen in Table 1.

Table 1. Criteria for Learning Materials Validity

Score (V_a)	Interpretation
$V_a = 4$	Very Valid
$3,25 \le V_a < 4$	Valid
$2,5 \le V_a < 3,25$	Fairly Valid
$1,75 \le V_a < 2,5$	Less Valid
$1 \le V_a < 1,75$	Not Valid

Material practicality data is data that represents the implementation of a learning material that has been developed. Data on the practicality of this material is obtained from the observation sheet, namely from the results of observing the implementation of learning. The table of criteria for practicality of learning materials can be seen in Table 2.

Table 2. Criteria for Learning Materials Practicality

Score	Interpretation
$90\% \le SR \le 100\%$	Very Good
$80\% \le SR < 90\%$	Good
$70\% \le SR < 80\%$	Fairly Good
$40\% \le SR < 70\%$	Less Good
$0\% \le SR < 40\%$	Not Good

To measure the effectiveness of learning materials can be seen from student activity data. Student activities are all forms of student activities carried out in the classroom during teaching and learning activities. The table of criteria for student activity observation results can be seen in Table 3.

Table 3. Criteria for Student Activity Observation Results

Score	Interpretation
$90\% \le P \le 100\%$	Very Active
$80\% \le P < 90\%$	Active
$70\% \le P < 80\%$	Fairly Active
$40\% \le P < 70\%$	Less Active
$0\% \le P < 40\%$	Not Active

The student response survey data obtained will be analyzed to determine the response of students in the implementation of learning that has been done. The results of student responses to learning materials can be seen from the percentage of responses obtained. The table of student response criteria can be seen in Table 4.

Table 4. Student Response Criteria

Score	Interpretation
$80\% \le P_r \le 100\%$	Very Positive
$60\% \le P_r < 80\%$	Positive
$40\% \le P_r < 60\%$	Fairly Positive
$20\% \le P_r < 40\%$	Less Positive
$P_r < 20\%$	Not Positive

The procedure used in this study refers to the development of Thiagarajan, namely the 4D-model which consists of the define stage, design stage, develop stage, and disseminate stage. The 4D model can be seen on the Figure 1. In addition to using the 4D model, the statistical analysis that used is paired sample t-test using the SPSS software. The paired sample t test is a different test of two paired samples with the same subject, but experiencing different treatments with two tests at different times. Before conducting this analysis, it is required to examine the research data with the requirements test, namely the normality test. The t-test in this study was used to determine whether there was an increase in students' information literacy skills after the application of RBL-STEM approach to the RAC problem with GNN. The hypothesis is formulated in the form of pairs of null hypothesis (H_0) and alternative hypothesis (H_1). For the assessment criteria, if sig > 0.05 then H_0 is accepted, but if sig < 0.05 then H_0 is rejected.

RESEARCH FINDINGS

This research uses research-based learning with STEM approach so that students can learn and develop skills in the fields of science, technology, engineering, and mathematics. This RBL-STEM model requires students to be more active in learning through research. In the initial stage, the syntax of the research-based learning model poses problems arising from the open problem research group. An explanation of the STEM aspects of the study can be seen in Figure 2.

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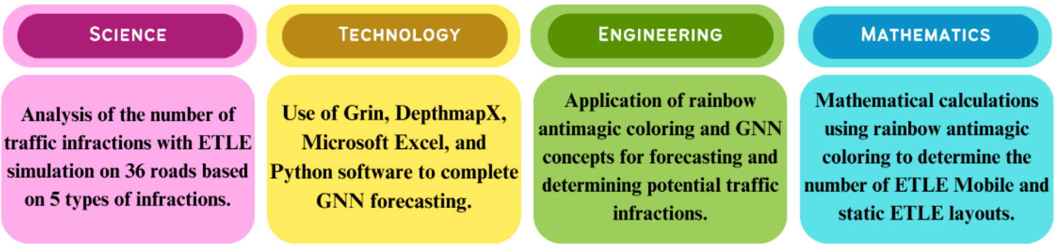

Figure 2. STEM aspects in research

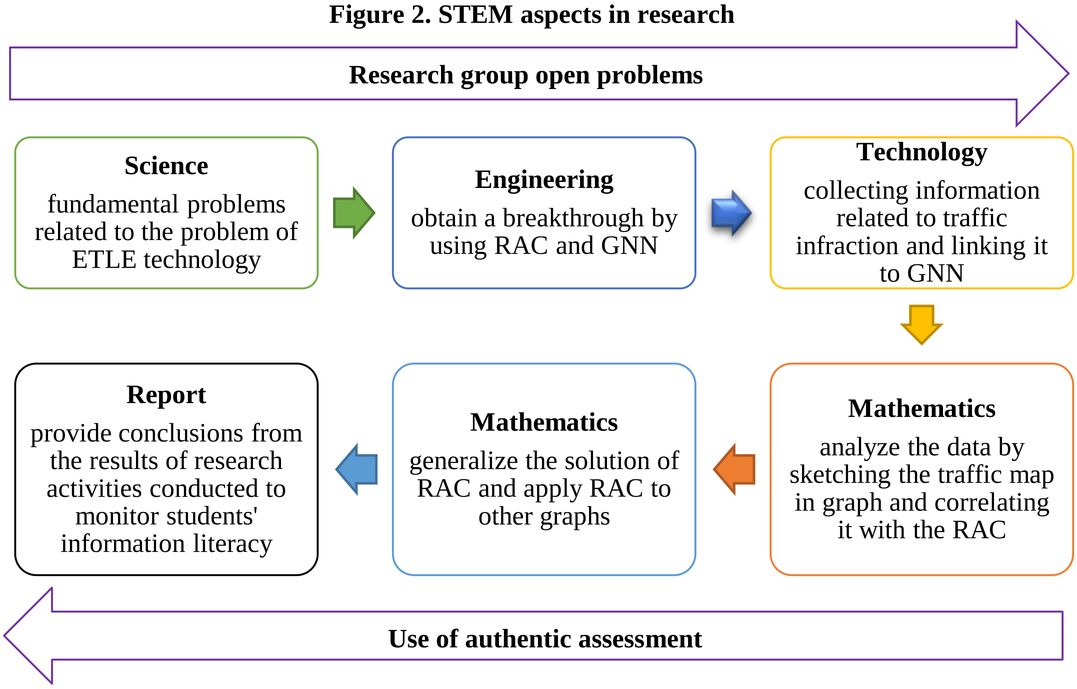

Figure 3. RBL-STEM Syntax Framework

This research aims to solve the ETLE mobile placement problem using the RAC method and traffic infraction prediction using the GNN method. Therefore, the RBL-STEM model has the following activity framework, 1) the first stage that students must do is to understand previous research related to the fundamentals of problems related to ETLE technology, 2) obtain breakthroughs in problem solving using RAC and GNN for forecasting, 3) collect information related to traffic violation data from the Central Bureau of Statistics website and traffic map data from Google Maps, 4) analyze the data by representing the previously searched roads for the placement of traffic cameras to the graph form representation, 5) look for RAC generalization patterns from the previously created graph representation, 6) finally by explaining or presenting the results and conclusions of a series of previous activities.

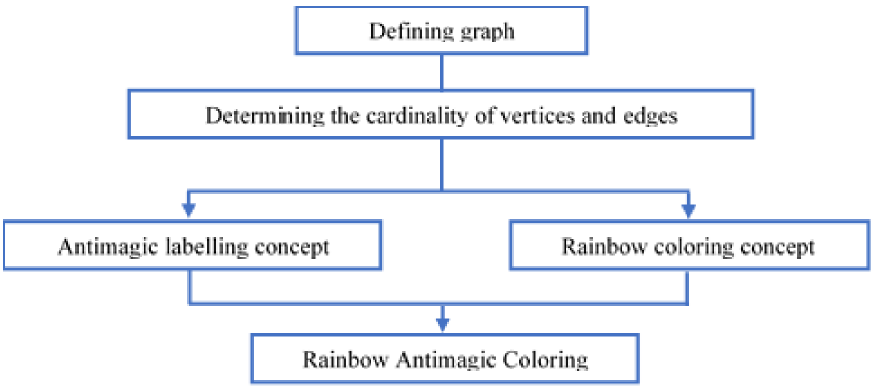

Figure 4. Rainbow Antimagic Coloring Concept Analysis

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The first stage of the 4D model is define, the purpose of this stage is to determine and define the learning needs by analyzing the objectives and limitations of the material to be provided. The defining stage is divided into four stages, namely beginning-end analysis, student analysis, concept analysis and task analysis. The beginning-end analysis is carried out to study the basic problems faced by students in learning as an illustration to determine how the learning materials to be developed. Student analysis was used to obtain data on the characteristics of undergraduate students of mathematics education at Jember University. Concept analysis was conducted to identify, detail, and systematically arrange the concepts learned by students on the concept of rainbow antimagic coloring. The result of the concept analysis can be seen in Figure 4. Task analysis aims to identify the main skills required in learning according to the curriculum.

The second stage is the design stage, which aims to design the learning materials that will be used so that the initial design is obtained. At this stage, the design of the RBL-STEM material is carried out to determine the effect of learning materials on increasing students' information literacy on the RAC concept. There are four steps in this stage, namely test preparation, media selection, format selection, and initial design. Test preparation is based on predetermined learning indicators. Media selection is based on student analysis, concept analysis, and previous task analysis. The media selected include PowerPoint as the medium for delivering RAC materials and RBL-STEM LKM, which includes information literacy indicators. Format selection in the development of learning materials aims to formulate and determine the design of models, approaches and learning resources that will be used. The initial design is the overall design of the learning materials that must be done before the trial. The learning materials are in the form of semester learning plans, student task designs, learning outcomes tests, and student worksheets. The visualization of the learning materials can be seen in Figure 5.

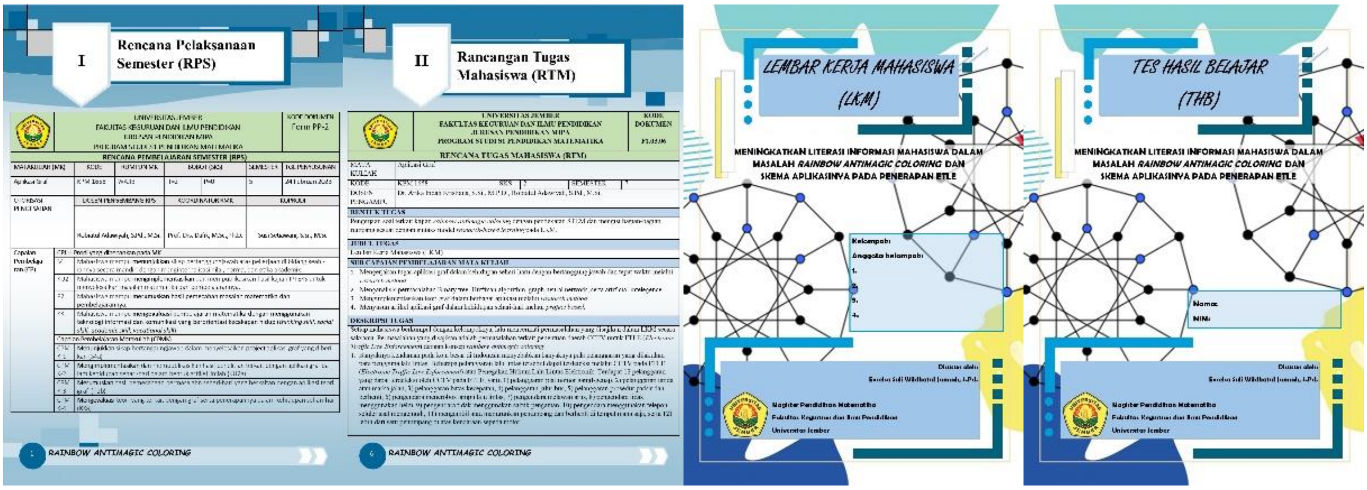

Figure 5. Preliminary Design of Learning Materials

The third stage is the development stage, which is divided into 4 stages, namely validity testing, learning material testing, practicality testing and effectiveness testing. Each material produced in the development stage is validated by the validator and revised according to the recommendations. The materials had been validated by two validators of lectures of the Mathematics Education Study Program, Jember University. According to the evaluation of both validators, the material can be used with minor modifications. Based on the results of the recapitulation of the validation of RBL-STEM materials and instruments in Table 5, the average score of validation is 3.71 with a percentage of 92.75%. Based on the validity criteria in Table 1, the compiled learning materials meet the validity criteria because they reach the score of $3.25 \le V_a < 4$.

Table 5. Recapitulation of Learning Materials Validation

Validation Results	Average Score	Percentage
Learning Materials	3.65	91.25%
Student Activity Observation Sheets	3.67	91.75%
RBL-STEM Implementation Sheets	3.69	92.25%

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Student Response Surveys	3.79	94.75%
Questionnaire	3.72	93%
Overall average score	**3.71**	**92.75%**

After the learning materials is declared valid, the revised and validated materials were applied on students. This test was conducted in a class of 40 students. After testing the practicality of the learning materials, the implementation of learning in the classroom was analyzed. The analysis of the implementation of learning is based on the RBL-STEM implementation observation sheet, which was evaluated by 8 observers. Based on Table 6, the average score of the overall learning implementation observation results is 3.95 with a percentage of 98.75%. Based on the criteria of practicality on Table 2, the prepared learning material meets the criteria of very high practicality because it reaches the score of $90\% \leq SR \leq 100\%$.

Table 6. Recapitulation of Learning Implementation Observation Results

Assessed Aspects	Average Score	Percentage
Syntax	3.875	96.875%
Social System	4	100%
Principles of Reaction and Management	3.975	99.375%
Overall average score	**3.95**	**98.75%**

The effectiveness test of the learning materials consists of 3 indicators, namely by analyzing the students' learning outcomes, the results of observing the students' activities, and the results of the students' response questionnaires. Based on the post-test results, it was found that 36 students (90%) had scores above the minimum completeness, which means classically complete. The observations used were observation of the introduction, core activities, and conclusion. The results of the score recapitulation can be seen in Table 3. Based on Table 7, the average score of the total student activity observation was 3.76 with a percentage of 94%. Based on the effectiveness criteria on Table 3, the learning material meets the criteria of effective very active because it meets the score of $90\% \leq P \leq 100\%$.

Table 7. Recapitulation of Student Activity Observation Results

Assessed Aspects	Average Score	Percentage
Introduction	4	100%
Main Activities	3.96	99%
Closing	3.32	83%
Overall average score	**3.76**	**94%**

The third criterion is the student response surveys. Student questionnaire sheets were distributed in hardfile form. Based on student responses criteria on Table 4, the recapitulation of student response scores is presented in Table 8. Overall, the average positive percentage is 90.31%. This shows that the learning material has been effective because the three requirements are met.

Table 8. Data Recapitulation of Student Response Survey Results

Assessed Aspects	Percentage
Enjoyment of learning components	91.25%
Students' information literacy skills feel trained	90.55%
Learning components are new	86.875%
Students clearly understand the language used	87.5%
Students understand the meaning of each problem presented	86.25%
Students are attracted by the appearance (text and images)	95%
Students are interested in learning	87.5%
Students enjoy discussing with group members	97.5%
Overall average score	**90.31%**

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The final stage of the 4D model is the dissemination stage, which involves the use of learning materials that have been developed on a larger scale, such as in classes that have not been tested or in study programs that have similar courses. The goal is to find out if the developed material works well for learning activities.

In addition, we will use quantitative data analysis to analyze the improvement in students' information literacy skills. The following is a graph of the distribution of students' pretest and posttest scores, which can be seen in Figure 6. Meanwhile, Figure 7 shows the percentage of students' information literacy level.

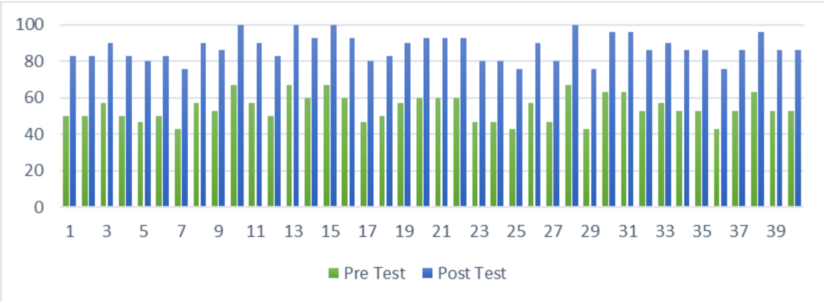

Figure 6. Distribution of Students' Pretest and Posttest Scores

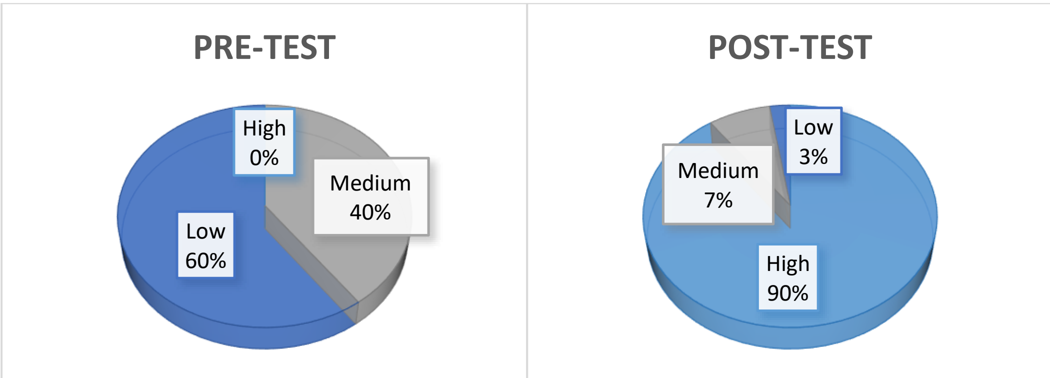

Figure 7. Percentage of Students' Information Literacy Level

In the pre-test results, students categorized with high level information literacy skills did not exist, students with medium level literacy skills were 40%, and students with low level information literacy skills were 60%. Whereas in the post-test results, students categorized with high level information literacy skills reached 90%, students with medium level literacy skills decreased to 7%, and students with low level information literacy skills decreased to 3%. In addition, a normality test was conducted as a condition for the paired samples t-test. This statistical test was performed using SPSS software.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	.128	40	.095	.948	40	.065
Posttest	.129	40	.090	.949	40	.070

Figure 8. Normality Test Results

Based on the results of the data normality test in Figure 8, it shows that the pretest and posttest scores are normally distributed because the significance value (Sig.) is > 0.05. Next, a paired samples t-test is performed as shown in Figure 9 below.

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Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Pretest & Posttest	40	.983	.000

Figure 9. Paired Samples Correlations Results

The test results in Figure 9 with a lot of data as much as 40, namely the pretest and posttest correlation with sig value is 0.000<0.05. This shows that the correlation or relationship between the two average pretest and posttest scores is significant.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Pretest - Posttest	-30.725	1.648	.261	-31.252	-30.198	-117.883	39	.000

Figure 10. Paired Samples Test Results

The test results in Figure 10 are the probability or Sig. (2-tailed) is equal to 0.000 < 0.05. In conclusion, there are differences in students' information literacy scores before and after learning with RBL-STEM materials.

DISCUSSION

Research-based learning materials with a developed STEM approach must meet valid criteria, practical, and effective criteria. Furthermore, the material was validated by two validators of mathematics education lecturers FKIP Jember University. The validation results show that this learning material belongs to the category of valid, practical, and effective. This research-based learning model is recommended in the implementation of education in order to produce higher student motivation, can improve student learning outcomes, and be able to apply what is learned in everyday life. The purpose of research-based learning is to make students more active, creative, and able to think more critically when compared to students who use conventional learning. This is in accordance with Jannah (2022) who explained that learning in conventional classes makes students more passive and lack the drive to develop their potential. The results of the application of learning materials have been proven to significantly improve students' information literacy skills. This can be seen from the results of the paired sample t-test between the pre-test score and the post-test score which shows an influence in the form of increasing student learning outcomes.

CONCLUSION

The results of the analysis of this RBL-STEM material meet the criteria of validity, practicality and effectiveness. The average score of validation is 3.71 with a percentage of 92.75%. Based on the criteria of validity, the compiled learning materials meet the criteria of validity because they reach the score of $3.25 \le V_a < 4.$. The average score of the overall observation results of learning implementation is 3.95 with a percentage of 98.75%. Based on the criteria of practicality, the compiled learning materials meet the criteria of very high practicality because they reach the score of $90\% \le SR \le 100\%$. Furthermore, based on the post-test results, it was found that as many as 36 students (90%) had scores above the minimum completeness, which means classically complete. The average score of the student activity observation results as a whole is 3.76 with a percentage of 94%. Based on the student responses in the questionnaire sheet, the recapitulation of the overall student response score, the average positive percentage is 90.31%. This shows that the learning materials are effective because the three requirements of effective materials are met.

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