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Development of RBL-STEM Learning Tools to Improve Students' Computational Thinking Skills Solving Rainbow Antimagic Coloring Problems and Their Application to Traffic Flow Problems with Spatial Temporal Graph Neural Network

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ABSTRACT: Computational thinking is thinking process that is needed in formulating problems and solutions, so that these solutions can be effective information processing agents in solving problems. Indicators of computational thinking consist of problem decomposition, algorithmic thinking, pattern recognition, abstraction and generalization. To improve higher-order thinking skills, we apply RBL learning integrated with STEM approach. To improve students' thinking skills, it is necessary to develop tools that support the success of learning activities. The learning tools that have been developed meet the criteria of valid, practical, and effective. The validity scores obtained by each device are 3.5 for the face-to-face plan, 3.41 for the student worksheet, and 3.56 for the learning outcomes test. The observation result of the learning implementation score was 3.8 with a percentage of 95%. There were 23 students who completed or around 88,46%, percentage of average score of student activities was 94.17%, and as many as 94.47% of students gave a positive response.

KEYWORDS: Computational Thinking, RBL-STEM, Rainbow Antimagic Coloring.

INTRODUCTION

Computational thinking is a thought process that is needed in formulating problems and solutions, so that these solutions can be effective information processing agents in solving problems (Wing, 2010). Therefore, computational thinking is one of the important abilities to hone from an early age because in the information age, the industrial era 4.0 or society 5.0, humans live in the real world and at the same time in a digital world surrounded by IoT (Internet of Things), Big Data, and Artificial Intelligence.

Improving the quality of education in Indonesia includes improving the curriculum, human resources, and facilities and infrastructure which have always been the main concern of the government. The government through Permendikbud No. 81A of 2013 implements a student-centered curriculum learning approach in improving mindset. In this learning model, students play an active role in becoming a learning center so that they can increase their potential optimally and improve their independent learning ability.

There are many independent learning models for students, one of which is research-based learning (RBL). Research-based learning is a learning system that uses authentic-learning, problem solving, cooperative learning, contextual (hand on and mind on), and an inquiry approach that based on the philosophy of constructivism. In addition, the research-based learning model integrates research activities in the learning process (Dafik, 2019). The RBL learning model in higher education is based on the provision of previous research when learning begins and aims to help students build intellectual abilities and strong practical connections between each student's research and learning boundaries. Research-based learning plays an important role in improving students' thinking skills. The RBL learning model in this study will be combined with STEM approach.

STEM is a combination of several disciplines and one of the important components to the learning experience is integrating learning models with STEM approaches (Hussen, 2019). STEM can be seen as an instructional approach with its disciplinary content being a group of sciences i.e. science, technology, engineering, and mathematics (multidisciplinary) or as an integrated idea (interdisciplinary and transdisciplinary) into an engineering design process and open investigation of real-world problems and cases (Hsu et al, 2019). STEM approach encourages students to think logically, critically, evaluative, and creatively in problem solving and decision making that relate to life problems using technology and applying it to real life (Banila et al., 2021). In addition, STEM integration aims to enable students' understanding of each discipline, expand students' understanding of each discipline in a cultural

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STEM context, and increase student interest in each discipline which presents several avenues that students can explore stem coverage (Moore, 2008).

To improve students' thinking skills, it is necessary to develop tools that support the success of learning activities. Learning tools that need to be developed in supporting the success of a research-based learning activity are student worksheets (LKM), learning outcomes tests (THB), and monographs. The learning tools used must match the learning objectives. Therefore, the development of learning tools is very necessary to meet the availability of materials according to curriculum demands, characteristics, goals, and problem-solving demands (MoNE, 2008).

Mathematics consists of many topics, one of which is graph theory. In graph theory, we assume objects as vertices and sides as relationships between one object and another. A graph G consists of the set of infinity of empty V of objects called vertices and the set E of the set of 2-elements of V called sides. Graph G is a pair of two sets of V and E. For this reason, some write $G(V, E)$ (Mursyidah et al., 2021). Graph theory originated from Konigsberg bridge problem solved by Leonhard Euler in 1736. After more than a century, graph theory underwent development until 1976, Haken and Appel made resolution relate to the Four-Colour Conjecture which discussed the use of minimal colors on maps, namely using four colors with regions that side by side should not have the same color. Graphs have many topics, one of which is rainbow antimagic coloring. Dafik et al. (2021) define rainbow antimagic coloring as a combination of two graph concepts, namely the concept of rainbow coloring and antimagic labeling.

METHOD

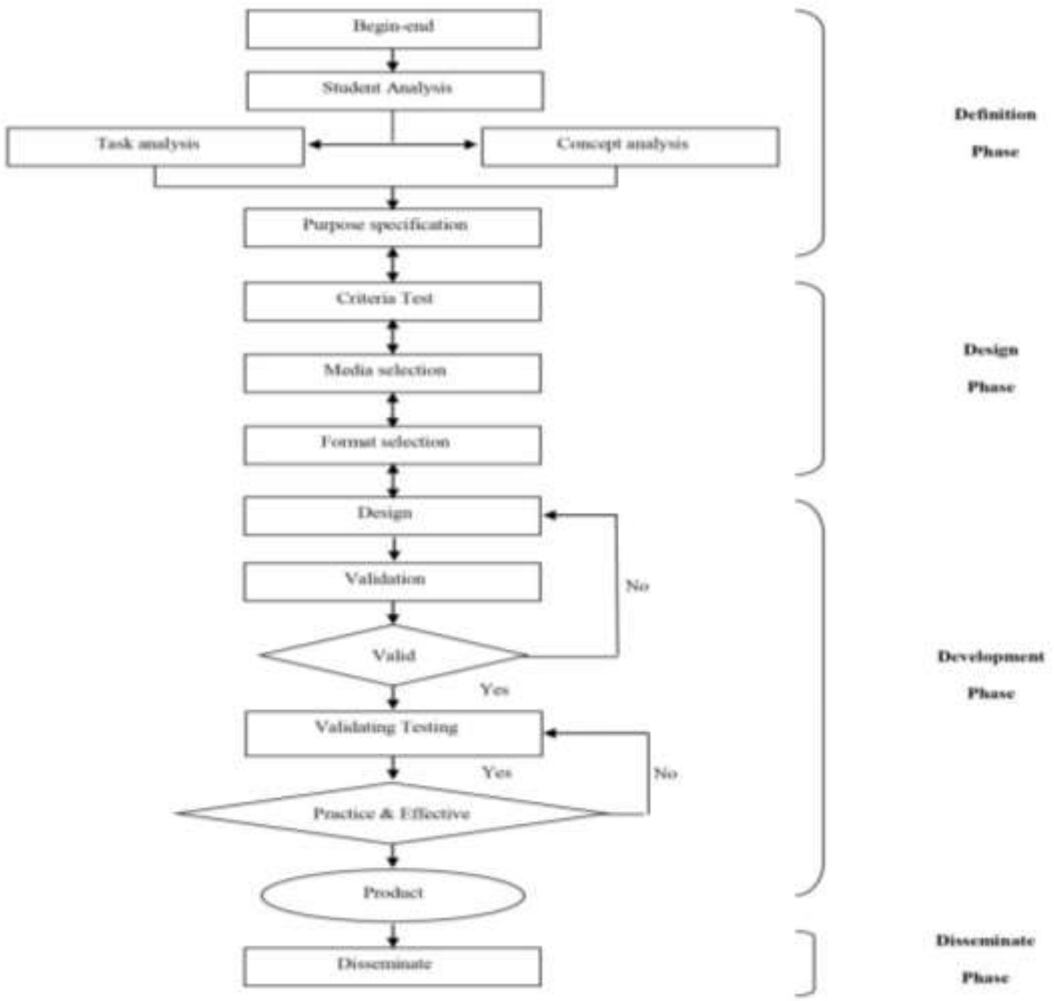

Fig. 1. Desain Model 4D.

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The stages used in this study are based on the development of the Thiagarajan 4D Model which consists of the defining stage, design stage, development stage, and dissemination stage. The 4D model can be seen on the Fig. 1. In addition to using the 4D model, the statistical analysis that used is paired sample t test using the R application which can be accessed online via the https://statslab-rshiny.fmipa.unej.ac.id/RProg/BasicStat/ link.

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. An explanation of the STEM aspects of the study can be seen in Fig. 2.

Science	Technology	Engineering	Mathematics
Traffic flow analysis with traffic flow simulation in Jember based on vehicle load, vehicle speed, rain intensity, crowds, and multiple accesses to specific roads to find out potentially congested roads and determine the number of ETLE	Matlab and Microsoft Excel software to solve spatial temporal graph neural network problems	Determination of the number of ETLE sensors using rainbow antimagic coloring studies	Mathematical calculations in determining the number of ETLE sensors using rainbow antimagic coloring

Fig. 2. STEM aspect in research

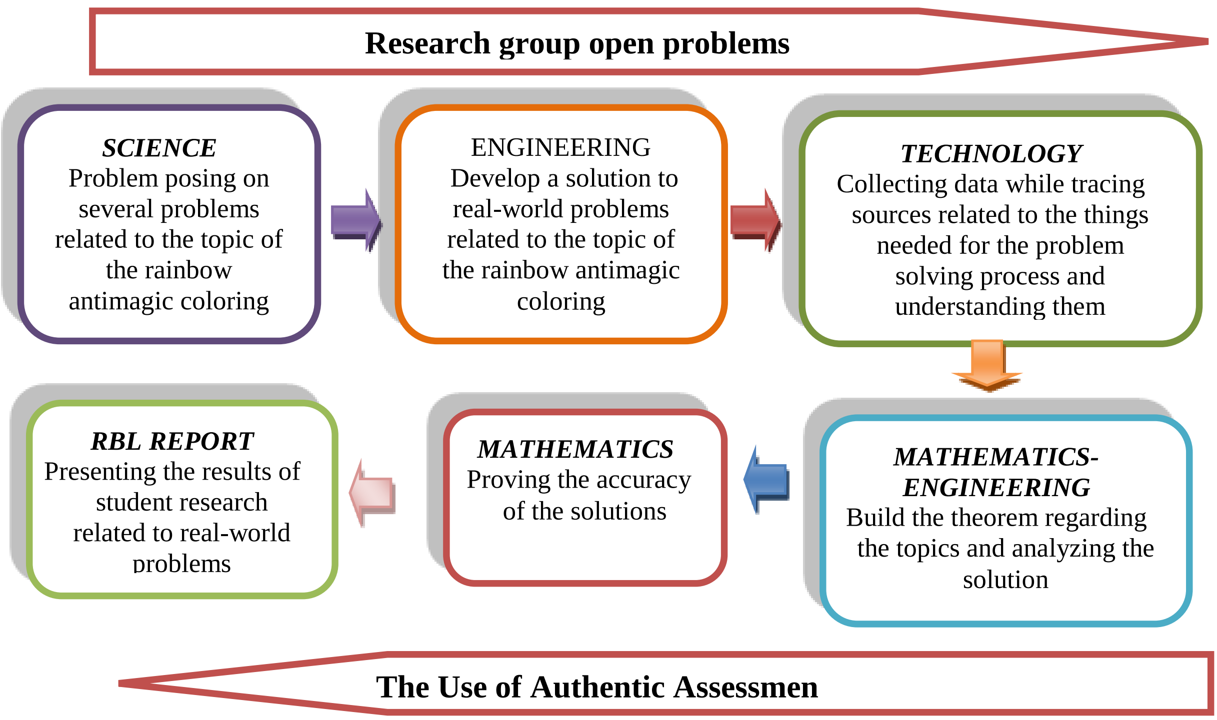

Fig.3. Stages of RBL-STEM in research

The expected results in the study based on the problems presented are the determination of the number of ETLE sensors admin based on the results of forecasting the level of traffic flow congestion using spatial temporal graph neural networks to minimize congestion and traffic violations. The determination of the number of ETLE sensors admin was determined to minimum using combination of rainbow antimagic coloring concepts and based on the results of traffic flow forecasting using spatial temporal graph neural networks. The research-based learning model with STEM approach in this study uses stages (a) Problems regarding the determination of the number of ETLE sensors admin to be placed at the confluence of two or more roads, as well as calculations about roads that have the potential to be congested and not congested; (b) Obtain breakthroughs using spatial temporal graph neural networks and rainbow antimagic coloring concepts; (c) Collection of data to be used in resolving the problems presented; (d)

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Development of the number of ETLE sensors admin based on the concept of rainbow antimagic coloring; (e) trials regarding the number of previously determined ETLE sensors admin; (f) report on the results of research and observed computational skills of students.

The first stage is the defining stage. The defining stage consists of the early-end analysis stage, student analysis, concept analysis, and task analysis. The initial analysis stage is carried out to determine problems in learning device development activities so that the resulting devices are expected to provide solutions to students who are hampered in learning in the classroom. Rainbow antimagic coloring was chosen as the topic of study because this topic belongs to a new topic that combines two topics, namely antiajaib labeling and rainbow coloring. The existence of learning on this topic is expected to add insight to students and can be used as a reference to compile the final project. Solve of this problem requires students who are active and creative so that they can find the expected coloring patterns. A suitable learning model is RBL-STEM learning to improve students' computational skills.

The next stage is student analysis. Students of the Graph Application class found it a little difficult to understand the rainbow antimagic coloring at first. But then they can understand the problem and the concept that given. After the student analysis stage, task analysis and concept analysis are carried out. Task analysis aims to identify the main skills necessary in learning that correspond to the curriculum. Meanwhile, concept analysis is carried out to identify, detail, and systematically compile the concepts studied by students on the topic of rainbow antimagic coloring. The results of the resulting concept analysis can be seen in Fig. 4.

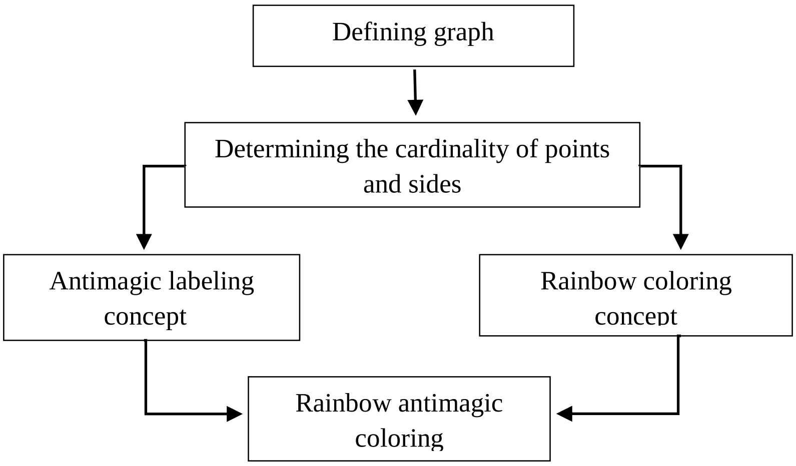

Fig. 4. Rainbow Antimagic Coloring Concept Analysis

The second stage is the design stage. The design stage has four stages, namely test preparation criteria, media selection, format selection, initial design. The cover of LKM and THB can be seen in Fig 5.

Fig. 5. LKM and THB page cover

The next stage is the development stage. At the development stage, all developed devices are validated by validators and revised according to the suggestions that given. The device was validated by two validators of lecturers of the Mathematics Education Study Program, FKIP, Jember University. The result of validation in general is that all learning tools in the form of RTM, LKM, and THB can be used with a little revision.

The validation results of the Student Assignment Design received a score of 3.5, the validation results of student worksheets were 3.41, and the validation results of the learning outcomes test were 3.56. Based on the validation results, it can be concluded that the learning tool is valid. The validation results of the three learning devices can be seen in Table 1, Table 2, and Table 3.

Table 1: RTM Validation Recapitulation Results

Assessed aspects	Average score	Average percentage
Format	3,75	93,75%
Content	3,5	87,5%
Language and Writing	3,25	81,25%
Overall aspect average score	3,5	87,5%

Table 2: LKM Validation Recapitulation Results

Assessed aspects	Average score	Average percentage
Format	3,33	83,3%
Content	3,4	85%
Language and Writing	3,5	87,5%
Overall aspect average score	3,41	85,25%

Table 3: THB Validation Recapitulation Results

Assessed aspects	Average score	Average percentage
Format	3,5	87,5%
Content	3,5	87,5%
Language and Writing	3,67	91,75%
Overall aspect average score	3,56	88,92%

After the device is declared valid, the next step is to conduct a test run of the device to test the practicality and effectiveness of the device. The practicality test of learning tools is carried out by analyzing student learning activities and lecturer activities during learning. Analysis of student and lecturer activities based on observation sheets on the implementation of the learning process assessed by six observers that taken from Master of Mathematics Education students. The results of the score recapitulation can be seen in Table 4. Based on Table 4, the overall average score of 3.78 is obtained, which means that the device meets the practical criteria.

Table 4: Results of Recapitulation of Observation Results on the Implementation of the Learning Process

No	Assessed Aspects	Average	Precentage
I.	**Syntax**		
1.	Level of implementation of all stages of learning	3,83	95,83%
2.	Implementation of the sequence of learning activities reflects computational skills-oriented research-based learning	3,5	87,5%

No	Assessed Aspects	Average	Precentage
II.	**Social System**		
1.	Level of implementation of the desired situation (atmosphere) (group formation, discussion, questioning, arguing, expressing opinions, mutual respect in work)	3,67	91,67%
2.	Level of interaction in learning (student-student and student-lecturer)	4	100%
3.	Implementation of lecturer behavior embodies computational principles and concepts in computational-based learning	3,83	95,83%
III.	**Principles of Reaction and Management**		
1.	Implementation of lecturers in accommodating and providing opportunities for students to ask questions, submit opinions, and respond to RBL-STEM learning tools to improve computational skills	4	100%
2.	Level of implementation of lecturer behavior provides assistance, instruction, guides students in RBL-STEM learning to improve computational skills	3,83	95,83%
3.	The level of implementation of lecturer behavior provides motivation in RBL-STEM learning to improve computational skills	3,33	83,33%
4.	Level of implementation of lecturer behavior involves students actively in RBL-STEM learning to improve computational skills	4	100%
5.	Level of implementation of lecturers facilitates students to learn with the RBL-STEM approach to improve computational skills	4	100%
Overall average score		3,8	
Overall average percentage score		95%	

Once the device is declared practical, it will be tested for effectiveness. The effectiveness test can be determined based on three criteria, namely the completeness of the student learning outcomes test, student activity analysis, and student response results. The first criterion is the completeness of learning outcomes. The results of the answers that collected by students were obtained by 23 students who scored above 60. Therefore, 88,46% of students are complete and have met one of the criteria for a device called effective.

The second criterion is an analysis of student activities obtained based on the Student Activity Observation Sheet. The results of the score recapitulation can be seen in Table 5. Based on Table 5, an overall average score of 3.77 is obtained, which means that the device meets the practical criteria.

Table 5: Student Activity Observation Sheet Recapitulation Results

No.	Assessed aspect	Mean	Percentage
I.	**Introduction**		
1.	Students have attention and a sense of motivation towards the presentation of learning objectives	3,83	95,83%
2.	Students listen to the lecturer's explanation regarding the study material to be studied	4	100%
II.	**Main Activities**		
1.	Students form groups	4	100%
2.	Students have attention and motivation to the presentation of references in the	3,5	87,5%

No.	Assessed aspect	Mean	Percentage
	form of RBL-STEM-based research journals		
3.	Students collect data through discussions in RBL-STEM learning	3,83	95,83%
4.	Students present data that obtained on LKM based on RBL-STEM	3,83	95,83%
5.	Students analysing data that obtained on LKM based on RBL-STEM	3,67	91,67%
6.	Students present the results of the discussion	3,5	87,5%
7.	Students take the pre-test and post-test enthusiastically on RBL-STEM learning	3,83	95,83%
III.	**Closing**		
1.	Students can make conclusions from learning activities	3,67	91,67%
Overall average score		3,77	
Overall average percentage score		94,17%	

The third criterion is the result of student response. The results of student responses were obtained by distributing student questionnaire sheets in the form of hard files. There were a total of 26 students who filled out the questionnaire. Based on the student responses in the questionnaire sheet, a recapitulation of the scores of student response results is presented in Table 6.

Table 6: Results of Data Recapitulation of Student Response Questionnaire Results

No.	Assessed aspects	Number of answers		Percentage of Answers	
		Yes	No	**Yes**	**No**
1.	Do you feel good about the following learning components:				
	Learning materials	26	0	100%	0%
	RBL-STEM-based student worksheets to improve computational skills	25	1	96,15%	3,85%
	Learning atmosphere	25	1	96,15%	3,85
	How to teach	26	0	100%	0%
2.	Are the following learning components new:				
	Learning materials	26	0	100%	0%
	RBL-STEM-based student worksheets to improve computational skills	25	1	96,15%	3,85%
	Learning atmosphere	23	3	88,46%	11,54%
	How to teach	23	3	88,46%	11,54%
3.	Are you interested in participating in this lesson?	26	0	100%	0%
4.	Whether you can clearly understand the language used on:				
	RBL-STEM-based student worksheets to improve computational skills	23	3	88,46%	11,54%
	Final research test question sheet	24	2	92,31%	7,69%
5.	Whether you can understand the meaning of each question/problem presented on:				
	RBL-STEM-based student worksheets (MFIs) to improve computational skills	22	4	84,62%	15,38%
	Final research test question sheet	22	4	84,62%	15,38%
6.	Are you interested in the appearance (writing, drawings, and location of the image) on:				

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No.	**Assessed aspects**	**Number of answers**		**Percentage of Answers**	
		Yes	No	**Yes**	**No**
	RBL-STEM-based student worksheets (MFIs) to improve computational skills	26	0	100%	0%
	Final research test question sheet	26	0	100%	0%
7.	Do you enjoy discussing with group members to solve problems by exchanging answers with each other?	26	0	100%	0%
Average				94,47%	5,53%

The results of the recapitulation of student questionnaire data showed that the lowest positive answer with a percentage of 84.62% lies in the statement about understanding the questions contained in LKM and THB. This is because the material provided has not been studied. Furthermore, the highest positive response was found in the item of novelty of the THB device. It's because the topics discussed in the THB are indeed relatively new for students of the Mathematics Education Study Program FKIP Jember University, namely about rainbow antimagic coloring and spatial temporal graph neural networks. Overall, the average positive percentage of statements was 94.47%, while the negative percentage was 5.53%. Its indicates that the majority of students give a positive response to the learning and learning tools presented. This means that all three conditions of a learning tool are said to be effective. Based on three criteria of effectiveness, it can be concluded that the learning tools are already effective.

The last stage is the deployment stage that applies the use of learning tools that have been developed on a larger scale such as in classes that have not been tested or other universities by different lecturers. The deployment stage is carried out in the class of the Combinatorics Course. The following is a description of the application of learning tools in the classroom.

Analysis of the application of learning devices using paired sample t-test so that we compare pretest values and posttest values to determine the influence of applying learning devices. The pretest value and the posttest value can be seen on the Fig. 6.

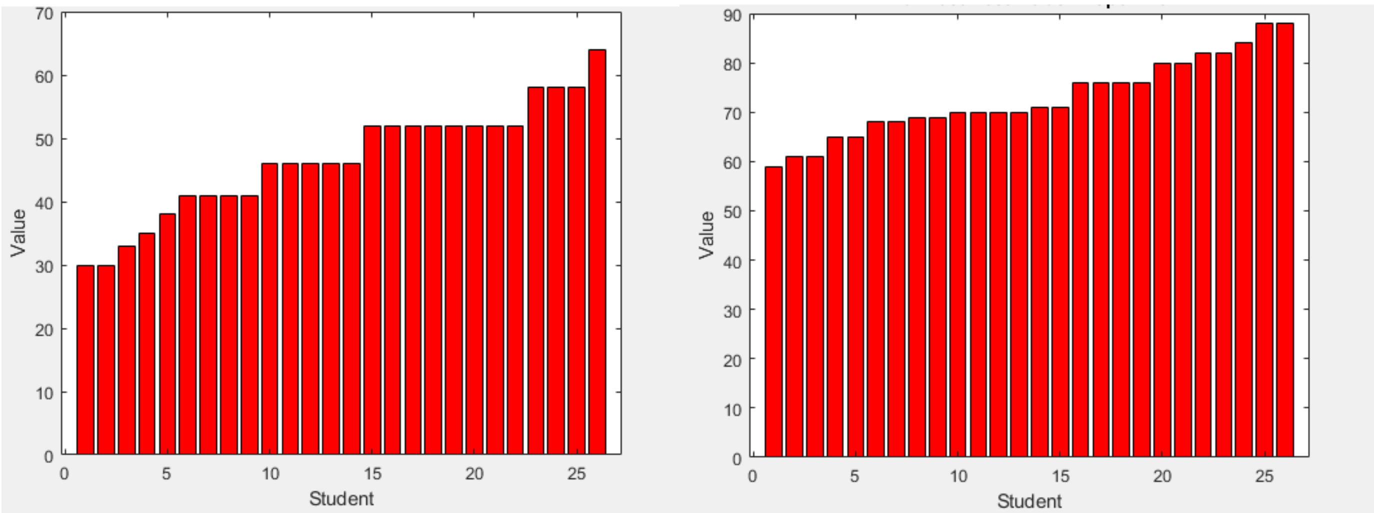

Fig. 6. Pretest Value (left) dan Posttest Value (right).

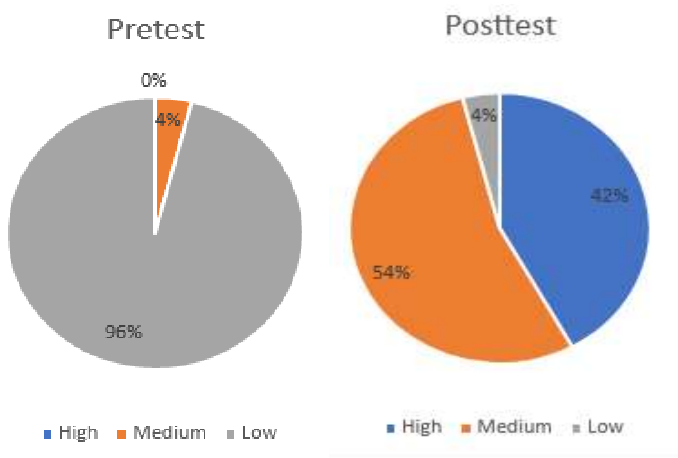

Fig. 7. Percentage of Students' Computational Thinking Skills Level

Based on Fig. 7., it can be known that there are two levels of computational thinking skills when students do pretests, namely medium level with a percentage of 4% and low level with a percentage of 96%. In addition, there are three levels of computational thinking skills when students take the posttest, namely high level with a percentage of 42%, medium level with a percentage of 54%, and low level with a percentage of 4%.

The next step is to test the normality on the pretest value and the posttest value. Test normality using the R application available online. After the normality test, a p-value of 0.35 was obtained, which indicates that the data is distributed normally. Normality test results can be seen on Fig. 8.

statistic	p.value	method	data.name
0.96	0.35	Shapiro-Wilk normality test	datasetInput()[, input$var.y]
0.96	0.35	Shapiro-Wilk normality test	datasetInput()[, input$var.y]

Fig. 8. Normality Test Results

Fig. 9. Paired Sample t-Test Result

After the data is declared normal, the next statistical test carried out is a paired sample t test using the application R. Results of the paired sample t test on Fig. 9. indicates that the p-value obtained is $2{,}2 \times 10^{-16}$. *p-value* $< 0{,}05$ indicates that there is a significant difference between the pretest value and the posttest value. Therefore, it can be concluded that there is an influence on the application of research-based learning tools with the application of STEM.

DISCUSSION

Research-based learning tools with a developed STEM approach must meet valid criteria, practical, and effective criteria. Furthermore, the device was validated by two validators of mathematics education lecturers FKIP Jember University. The validation results show that this learning tool 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 Suntusia (2019) who explained that learning carried out in conventional classes causes students to tend to be passive and lack the drive to develop their potential. The results of the application of learning tools have been proven to significantly improve students' computational thinking skills. This can be seen from the results of the paired sample t test between the pretest value and the posttest value which shows an influence in the form of increasing student learning outcomes.

CONCLUSION

Devices that have been developed meet valid criteria, practical and effective. The validity results on each learning device were 3.5 for the face-to-face plan, 3.41 for the student worksheet, and 3.56 for the learning outcomes test. The observation result of the learning implementation score was 3.8 with a percentage of 95%. There were 23 students who completed or around 82%, the percentage of the average score of student activities was 94.17%, and as many as 94.47% of students gave a positive response.

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