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The development of RBL-stem learning materials to improve student's computational thinking skills in solving *b*-coloring problems for intercropping farming

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Abstract

Research-Based Learning can be studied with a STEM approach, in RBL students will find a problem that requires solving, problem solving skills are very important in learning. One of these mathematical thinking skills is computational thinking skills. b-coloring is one of the concepts of graph theory. b-Coloring is widely applied in various fields, one of which we can apply to intercropping agriculture. The development of RBL-STEM learning materials to improve students' computational thinking skills in this research meets the criteria of being valid, practical and effective. The validity score is 3.87. The results of observing learning implementation were 3.71 with a percentage of 92.75%, and student responses were 91.62% positive, thus meeting practical criteria. Based on the test results, researchers found that 97.50% of students completed the test so they met the effective criteria. Quantitative analysis includes pretest and posttest data processing, where normality tests and paired sample t tests are carried out. Based on the normality test, it can be concluded that the pretest and posttest scores are normally distributed, because the p-value is greater than 0.05, namely 0.051 and 0.17. Next, a paired sample difference test (paired sample t-test) was carried out which showed a p-value of 0.000. These results show that there is a significant increase in students' computational thinking abilities after taking part in the learning.

Keywords: Research Based Learning; Science Technology Engineering Mathematics; Computational Thinking Skills

1. Introduction

As time progresses and human interests meet their needs, humans try to find ways to produce new theories and even new knowledge that can be applied in everyday life in order to obtain effectiveness and time efficiency. One way is to create tools that can lighten the workload. In the discovery of this tool, everything cannot be separated from the role of mathematics which of course cannot be separated from other sciences [1].

One of the thinking skills in mathematics that can help mathematics researchers in developing knowledge is computational thinking skills. The concept of computational thinking was first proposed in 1980 by Seymour Papert, a mathematician, educator, and researcher in the field of computers from the Massachusetts Institute of Technology (MIT). In 2006, Jeannette Wing, a computer scientist from Carnegie Mellon University, popularized the term "Computational thinking" in an article published in Communications of the ACM. Wing defines computational thinking as involving problem solving using a logical and systematic mindset involving the selection and use of algorithms, data representation, problem decomposition, use of abstractions, and hypothesis testing. Computational thinking also helps one to develop skills in designing and implementing effective and efficient solutions using technology. With

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computational thinking, one can also develop the ability to identify errors or weaknesses in a solution and correct them quickly. Computational thinking is not only important for those who want to pursue a career in technology or computing. In education, computational thinking can help solve math or science problems more easily [2].

One learning model that gives students the opportunity to think with computational skills, learn and build knowledge from research steps such as searching for information, formulating hypotheses, collecting data, analyzing, making conclusions and compiling reports is the Research Based Learning (RBL) model. The implementation of the Research Based Learning (RBL) model is seen as making study time more efficient and effective because it is integrated into the research process and students discover the knowledge they learn for themselves. The Research Based Learning (RBL) model creates a more democratic learning atmosphere and gives students the opportunity to be more active in strengthening their understanding and mastering course theory, by collaborating either with fellow students or with lecturers to make observations in the field regarding the implementation of theory in professional work. Students make observations about how the theory works in professional work, then collect relevant data, then analyze the data obtained, and formulate conclusions to produce new knowledge [3].

Entering the third decade, the 21st century is marked by several phenomenal and momentous human achievements, such as progress in the field of science and technology. This also has an impact on changes, especially in the field of education. The implementation of the Independent Campus curriculum is the government's effort to develop education in Indonesia, considering that competition in the 21st century demands competitive human resources in the fields of science, technology, engineering design, and mathematics. Integrated STEM is one way to make learning more connected and relevant. STEM-based learning will support Industry 4.0 goals with the required 21st century skills. STEM directs educators to package project-based learning involving five fields of knowledge, namely science, technology, engineering, art, and mathematics [4].

Technology in the era of the industrial revolution 4.0 has also been widely adapted to various industrial and production sectors, one of which is in the agricultural sector, which is better known as Smart Agriculture. Smart agriculture is a mechanism that changes agricultural land management patterns that were previously carried out conventionally to be much more productive and efficient through an automated control and monitoring system that can be carried out using technology. An intelligent system that can be used in the agricultural sector is a development of a generalized mathematical model, namely a Neural Network. Scientists create mathematical algorithms that work like the working patterns of neurons. Graph Neural Network was first proposed by Scarselli in 2009. Graph Neural Network is a type of neural network that directly uses graph structure data in the dataset and its output. This of course supports the productivity of agricultural products to be more optimal, as well as managing and predicting harvest results and problems faced by agricultural land managers [5]. Other efforts that can be made to optimize land productivity are intercropping patterns and providing nutrients to the soil.

Intercropping is planting two or more types of plants on a plot of land at the same time. The aim of the intercropping cropping pattern is to optimally utilize the production factors owned by farmers (including limitations: land, labor, working capital), use fertilizers and pesticides more efficiently, reduce erosion, conserve land, biologically stabilize the soil, and obtain greater total production compared to monoculture planting [6]. Meanwhile, providing nutrients to the soil in this research is one of the techniques that determines the growth rate of a plant. Soil contains nutrients available in limited quantities. Most nutrient needs must be met through fertilization. Fertilization aims to maintain and increase the availability of substances containing one or more nutrient elements in the soil which is intended to replace nutrients that have been absorbed from the soil so that plants will grow well and will be able to have maximum potential. NPK fertilizer contains nutrients, nitrogen, phosphorus and potassium. This fertilizer is very good for supporting plant growth. Apart from that, the advantage is that the nutrients contributed can meet the plant's nutritional needs [7]. Apart from neural networks, intercropping and soil nutrients, of course a theory in mathematics will also help maximize research.

One of the graph theory concepts in mathematics that can be applied in this research is b-coloring. b-coloring graph G is vertex coloring with each color class containing at least one vertex that neighbors all other color classes [8]. The usefulness of the b-coloring concept in this research can be used as a layout for planting the desired plants.

2. Material and methods

2.1. Research Based Learning

RBL (research-based learning or research-based learning) is a learning model that is associated with various activities such as analyzing, synthesizing and evaluating, and allows students and educators to increase the assimilation and application of knowledge [9]. RBL adheres to student-centered learning which provides opportunities for students to learn by doing, so that learning is more meaningful. The Research Based Learning (RBL) model is a new learning model that gives students the opportunity to learn and build knowledge from research steps such as searching for information, formulating hypotheses, collecting data, analyzing, making conclusions and compiling reports. In general, RBL has the aim of creating a learning process that leads to analysis, synthesis and evaluation. Apart from that, it can improve the ability of students and teachers to apply knowledge. Another statement from Maylisa defines research-based learning as a learning method that uses contextual learning, authentic learning, problem solving, cooperative learning, direct learning, and inquiry approaches [10].

2.2. Science, Technology, Engineering, and Mathematics

STEM is a learning approach that motivates students to generate mind-on and hands-on-learning through the process of problem solving [11]. STEM integration is defined as a combination of science, technology, engineering, and mathematics with the hope of: (1) relying on students' understanding of each discipline in a contextual manner, (2) expanding students' understanding of each discipline in a culturally relevant STEM context and (3) increase student interest in each discipline by presenting several ways that students can take to explore each STEM field [12]. From the definition above, it can be concluded that the STEM approach is an approach that combines four scientific disciplines, namely Science, Technology, Engineering and Mathematics which focuses on solving problems in everyday life. STEM education also has the aim of building an understanding of STEM literacy which refers to an individual's ability to apply four interrelated domains [13].

2.3. Computasional Thinking Skills

Wing defines computational thinking as involving problem solving using logical and systematic thinking patterns involving the selection and use of algorithms, data representation, problem decomposition, use of abstractions, and hypothesis testing. The ability to think computationally is very important in the world of computing, because it can help someone develop critical, creative and analytical thinking skills in solving complex problems, both in the context of computing and everyday life. Computational thinking also helps one to develop skills in designing and implementing effective and efficient solutions using technology. With computational thinking, one can also develop the ability to identify errors or weaknesses in a solution and correct them quickly. Computational thinking is not only important for those who want to pursue a career in technology or computing, but can also help someone in a variety of other fields. Several studies have found that computational thinking is useful for improving mathematical abilities, reasoning abilities, and creative thinking [2].

2.4. Methods

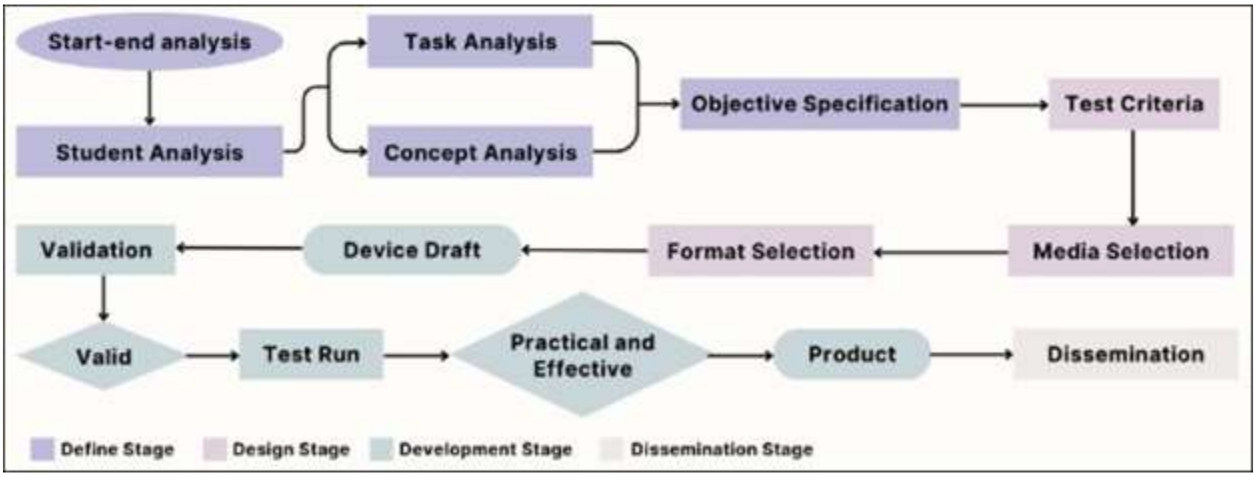

Figure 1 4-D model learning device development scheme

The stages that are used in this study refer to the development of the Thiagarajan 4-D Model which consists of the defining stage, the design stage, the development stage, and the dissemination stage. The data that was obtained from the observation of student activities during the learning process were statistically tested using parametric statistical tests. The statistical test in this study used SPSS. There are two variables in this study, namely the free variable and the bound variable. The free variables tested are research-based learning materials with STEM approach, while the bound variables are students' computational skills. Furthermore, paired sample t test was carried out on pre-test and post-test results [14]. The Thiagarajan 4-D model learning device development scheme can be seen in Figure 1.

3. Results and discussion

To increase students' computational understanding of the precision farming problems that accompany agriculture, the steps taken to integrate the RBL-STEM model described below. Especially the b-coloring concept to determine how many plants species in the companion farming system. This RBL model requires students to participate actively. Students must start by understanding the problem at hand and finding the best way to solve it. Next, students will read literature to obtain relevant information. In this case the problem faced is how to determine the number of plant types with the concept of b-coloring and knowing the condition of the soil.

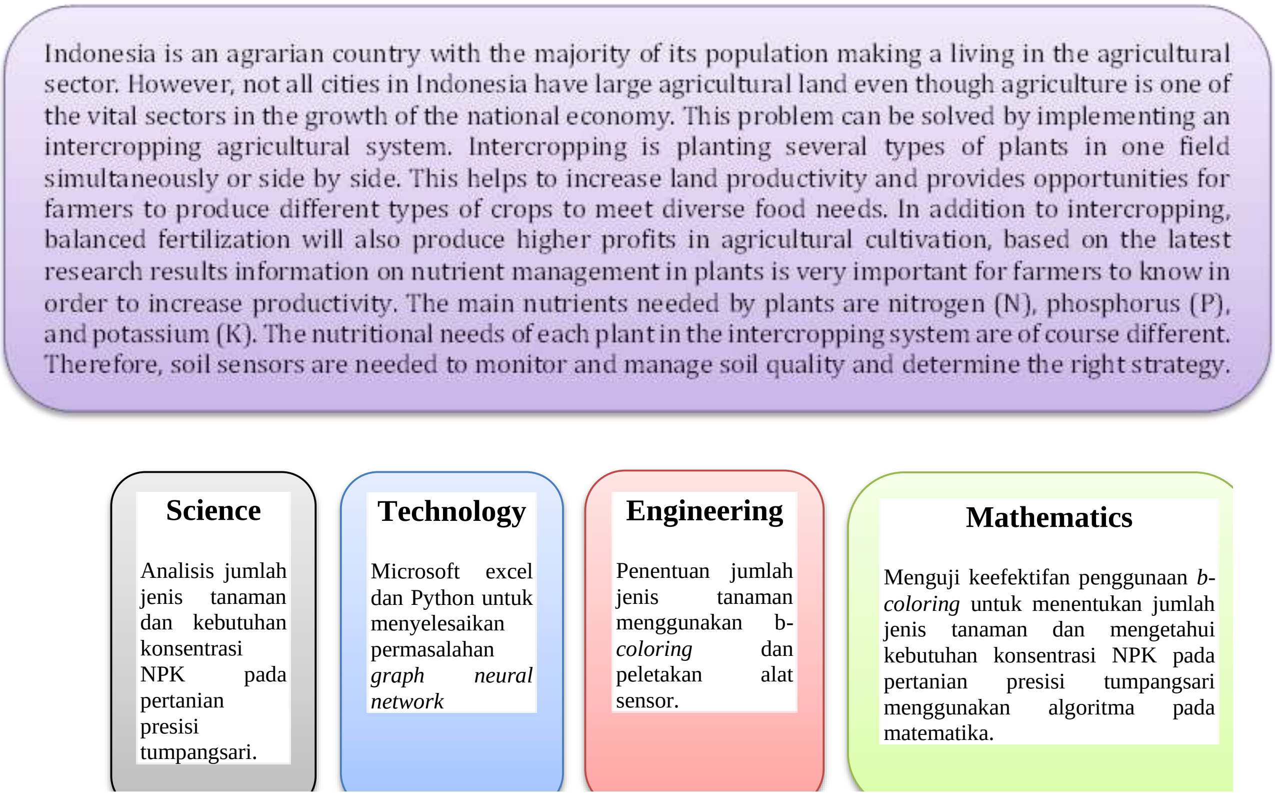

Figure 2 STEM aspect in research

This research solves the problem of companion agriculture to precision agriculture by using the b-coloring concept. The expected result is determining the number of types of plants that can be planted in companion farming and placement of sensors including Sodium, Phosphor and Potassium to determine soil conditions. The RBL-STEM model in this research includes stages (a) Identification of the determination problem number of plant types and placement sensors to determine soil requirements; (b) Get a breakthrough using the b-coloring concept; (c) Collect data that will be used in solving the determination problem. The number of plant types is determined as much as possible using the b-coloring concept and placement sensors determine soil conditions; (d) Development of the number of plant types and their placement sensors on companion farms based on the b-coloring concept; (e) Test the number of plant species owned have been found; (f) Preparation of research reports and observations of students' computational thinking skills.

The instruments included Student Assignment Designs, Student Worksheets, and Learning Outcome Tests that were used as pretests and posttests. As part of the Thiagarajan (4D) model, this development process consists of defining, designing, developing, and disseminating stages. The purpose of this defining stage is to establish and define learning needs by analyzing the objectives and limitations of the material to be provided. This stage consists of five stages, namely: (a) Beginning-end analysis is conducted to determine the problems that occur in learning activities and the development of learning devices. It is expected that this device will help students who are hampered in classroom learning because they find it difficult to understand the concept of b-coloring. (b) Student analysis, data on the characteristics of Mathematics Education students at FKIP University of Jember were collected through student analysis.

Students must have the ability to work together in groups and be directly involved in the learning process. (c) Concept analysis, this process is carried out to identify, detail, and arrange the concept of b-coloring that will be learned by students. (d) Task analysis, researchers set tasks in the MFI in the form of overlapping parts and in the computational thinking skills test in the form of questions about b-coloring in the real world (e) Specification of learning objectives, the purpose of this activity is to identify students' computational skills according to the expected final ability.

Table 1 RBL-STEM activity framework

Phase	Description
Science	Providing problems about companion farming precision agriculture whose solutions are related to the concept of b-coloring and graph neural network
Engineering	Planning solutions to problems related to b-coloring
Technology	Gathering information related to the problem and things that will form the solution
Mathematics-Engineering	Generate theorems about *b*-coloring of some graphs and analyze the solution of the given problem
Mathematics	Proving that the theorem is reliable to solve the problem of companion farming precision agriculture
RBL Report	Presenting the results obtained regarding the solution of the problem and the *b*-coloring theorem obtained

At the design stage, RBL-STEM tools are being carried out to find out how learning tools affect students' computational abilities in b-coloring material. The initial design of the learning device as in Figure 3. Student Worksheet is made with the concept of b-coloring using the RBL-STEM learning model. In accordance with the learning indicators to be achieved, this Student Worksheet focuses on solving b-coloring problems in companion farming precision agriculture that has been adapted to the RBL-STEM syntax. The Learning Outcome Test was used to measure students' computational thinking skills. This test was used for both pretest and posttest which consisted of b-coloring. Pretest and posttest were conducted individually to determine the ability before and after student learning. Validation was conducted before the tests were tested.

Figure 3 The initial design of the learning materials

Next is the development stage. Each device made at the development stage was validated by validators and changed according to recommendations. Two validators, both of whom are lecturers of the Mathematics Education study program at FKIP University of Jember, began the validation process, the validators were given learning devices, assessment instruments, and validation sheets. In addition to providing an assessment, the validators also provided comments and recommendations on the learning devices made. According to the evaluation of both validators, the device can be used with minor changes. All suggestions from validators are used to revise learning devices to ensure that the developed devices are feasible to use in learning. Based on the results of the validation of learning devices that can be seen in Table 2, the average score of all aspects is 3.61. The device is considered valid if it receives a score of 3.25 ≤ Va ≤ 4. Thus it can be concluded that the learning device made is valid.

Table 2 Learning materials validation recapitulation result

Assessed aspect	Average Score	Average percentage
Format	3.75	93.75%
Content	3.50	87.50%
Language and Writing	3.63	90.63%
Overall aspect average score	3.61	90.28%

The validated and modified device was tested on students. The trial was conducted in the discrete mathematics class of the Mathematics Education Study Program, FKIP, University of Jember. This trial was conducted on a class of 40 students. The researcher started the learning by giving a pretest with a duration of forty minutes. After that, the researcher gave a little incentive about the idea of b-coloring and its application to companion farming precision agriculture. The second meeting, students were divided into seven groups each with one observer. Each student discussed with their group. The observer helped guide the group if there were problems in working on the Student Worksheet. Each group was given the opportunity to make a presentation on what they had learned during the discussion. In the third meeting, the researcher gave a posttest to be answered, and a response questionnaire given until the end of the lecture time.

Data collected from the test included student activity data, implementation observation data, student response questionnaire, and pretest and posttest results. The analysis of the learning enactment sheet shows whether the learning device is practical. The recapitulation results of the device practicality test are presented in the appendix, which shows that the learning implementation observation sheet received an average score of 3.9 with a percentage of 97.5%. By considering the criteria for device practicality, it can be concluded that the learning devices that have been made meet the criteria very well. Analysis of student completeness in the combinatorial thinking skills test, the results of observations of student activities during learning activities, and the results of student response questionnaires about learning are all indicators that can determine whether the learning device is effective or not.

Based on the response of students' answers in the computational thinking skills test, we can conclude that there are 40 students who get scores above 70. In addition, considering the criteria for passing the learning test, it can be said that all students have achieved overall completeness. In this case, one of the three requirements to assess the effectiveness of a learning tool has been met. Analysis of student activity observation data was obtained from the results of observations made. The recapitulation of the student activity observation sheet showed that the sheet received an average score of 3.90 with a percentage of 97.5%. This shows that two of the three criteria needed to consider a learning tool effective have been met. Student response data was obtained from student response questionnaires distributed through printouts. The recapitulation of the student response questionnaire shows that the average positive percentage is about 91.62%, indicating that the learning tool has been considered effective because the three requirements have been met.

For the dissemination stage, this research will be delivered to Mathematics Education lecturers and on the internet, including social media. The aim is to find out whether the tools that have been developed work well for learning activities. In addition, it also wants to get input, corrections, suggestions, and assessments to improve this learning tool.

The following is a graph of the distribution of students' pretest and posttest scores and the percentage of students' computational skill levels can be seen in Figure 4. In the pretest results, students who were categorized as students with computational thinking skills at the medium level were 30% and low level were 35%. Meanwhile, in the posttest results, students who were categorized as students with computational skills at a high level reached 100%.

Figure 4 The percentage of students' computational skill levels

Furthermore, a normality test was carried out as a condition for the paired sample t test to be carried out. This statistical test was carried out using SPSS. The results of the data normality test are presented in table 2. Based on the results of the data normality test, it shows that the pretest and posttest values are normally distributed because the p-value on the pretest is 0.053> 0.05 and on the posttest is 0.059> 0.05. The last test is the paired sample t test which is presented in Figure 6,

Table 2 Normality test results

Tests of Normality						
	Kolmogorov-Smirnova			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	0.113	40	0.200*	0.945	40	0.051
Posttest	0.150	40	0.024	0.960	40	0.172

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	-36.62500	14.09071	2.22794	-41.13143	-32.11857	-16.439	39	.000

Figure 6 Paired sample t test results

The results of the paired sample t test yielded a p-value of less than 0.05 which is 0.000 < 0.05, indicating that the improvement in computational thinking skills between the two data groups is not random, but a statistically significant improvement. There is strong enough evidence to suggest that the observed improvement between the two groups of data is not caused by random variables but the improvement may have significant meaning. Thus, it can be concluded that there is an increase in students' computational thinking skills.

4. Conclusion

Based on the research that has been carried out in the development of RBL-STEM learning tools to improve students' computational thinking skills, it can be concluded that the tools meet the criteria of valid, practical, and effective. Quantitative analysis involves processing pretest and posttest data, where normality test and paired sample t-test are conducted. Based on the normality test, it can be concluded that the pretest and posttest scores have a normal distribution, because the p-value is greater than 0.05, they are 0.051 and 0.17. Furthermore, a paired sample t-test was conducted which showed a p-value of 0.000. These results show that there is a significant increase in students' computational thinking skills after participating in the learning.

Compliance with ethical standards

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Disclosure of conflict of interest

I would like to disclose that I am the author responsible for this research, collaborating with other author as team. Although I will strive to remain objective throughout the article preparation process, I feel it is important to disclose my relationship with the other authors.

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