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The development of RBL - STEM learning materials to improve students' computational thinking skills in solving convolutional neural network problems

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Abstract

In 21st century learning, computational thinking skills have become one of the essential competencies that need to be emphasised in the development of knowledge. To enhance computational thinking skills, research-based learning (RBL) with a science, technology, engineering and mathematics (STEM) approach, known as RBL-STEM, can be used. This study aims to explore RBL-STEM activities, describe the process and outcomes of developing RBL-STEM materials, and analyse data. In this research, the RBL-STEM framework is used to improve students' computational thinking skills in applying Convolutional Neural Network (CNN) to identify coffee plant diseases using a quadcopter drone and its flight path with resolving dominating set. The research method used is Research and Development (R&D). This research develops RBL-STEM materials and produces learning material products in the form of semester study plans, student assignment designs, student worksheets and learning outcome tests. The results of the development of the materials show validity with a validity criterion of 92%. Implementation using RBL-STEM materials was found to be practical with a practicality criterion of 96.25% and effective with an effectiveness criterion of 94.32%. In addition, students were highly engaged and provided very positive feedback on the learning experience. Pre-test and post-test analysis showed an improvement in students' computational thinking skills when solving CNN problems.

Keywords: Computational Thinking Skills; Research Based-Learning (RBL); Science, Technology, Engineering and Mathematics (STEM); Convolutional Neural Network (CNN)

1. Introduction

Education is a deliberate and planned effort to create a learning atmosphere that allows students to develop themselves actively, intelligently, critically, skilfully and nobly [15]. Self-development makes education play an important role in this era of globalisation, so in order to achieve educational goals, it is necessary to have national standards regulated by the government. Mathematics as one of the competencies in fulfilling national education standards is regulated in Government Regulation of the Republic of Indonesia No. 57 of 2021. This means that mathematics as a numeracy competence must be taught at all levels of education because mathematics is important for the development of science. Students who study mathematics, especially in higher education, are expected to be well adapted to the development of science [9].

Mathematics is a concept and principle that is widely used in everyday activities such as counting, measuring and other principles that play an important role in problem solving [6]. One of the applications of mathematics that has been widely used is digital image processing. Digital image processing is the process of modifying and manipulating images through computers using special algorithms. In image processing there is morphology to describe the shape of an object and image analysis to obtain image features [3]. The most dominant and successful technique in image processing today is the Convolutional Neural Network (CNN).

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CNNs are the most widely used class of artificial neural networks. CNNs use a mathematical operation called convolution instead of the usual matrix multiplication in at least one of their layers. CNNs are specifically designed to process pixel data used in image recognition and image processing. CNNs have superior representation capabilities because they consist of several to hundreds of feature layers connected by millions of parameters that can be learned to map input predictors to output class labels [17].

In agriculture, the novelty of this image processing technique is supported by the use of machine learning, which can be used to identify diseases in plants and classify different types of plants [7]. In its application, a sensor that can capture the appearance of the land is required to see the object as a whole. Quadcopter drones have been widely used in agriculture as sensors for real-time crop monitoring and surveillance [11]. The use of quadcopters is therefore a more feasible choice in smart agriculture. In addition, the application aspect that also needs to be considered is how to best capture images with a quadcopter drone. Optimal image capture requires an efficient trajectory that can capture all land views. The trajectory can be determined based on the resolving dominating set. The resolving dominating set is a concept for determining the minimum possible set of dominating points in a graph, provided that each member in the set of dominating points reaches or dominates other points outside the set [5].

Many studies have been conducted on the use of machine learning and CNN architecture. Researchers used deep learning with CNN techniques to differentiate between Robusta and Arabica coffee plants [12]. In addition, compared several CNN architectures in the classification of potato plant diseases [2].

Image processing problems, especially CNN and its application to plant disease detection, require skills in its operation. One of the skills that can be developed in this problem is computational thinking skills. In 21st century learning, especially in the Merdeka curriculum, computational thinking skills are one of the important competencies and need to be considered in the development of science. The definition of computational thinking skills is an analytical thinking process that is used as an approach to solve a problem and design a system so that it can be applied in the real world. The thinking concepts used are the same as those at the core of computer science [14].

Furthermore, in the context of education, learning models are also something that should be considered to change the mindset of students to reveal the unknown in order to improve aspects of learning [15]. One specific model and approach that can be used to improve computational thinking skills is the combination of the Research Based Learning (RBL) model with the STEM (Science, Technology, Engineering, and Mathematics) approach. RBL is a learning model that aims to increase students' knowledge by building knowledge starting from themselves by connecting theory and practice [13]. Therefore, it is necessary to combine RBL - STEM in order to improve computational thinking skills. In addition, RBL - STEM can also help institutions to develop learning programmes that are more relevant to the needs and challenges of the current digital era and help improve the quality of education in Indonesia. Some research related to the development of RBL - STEM in the classroom can be seen in the research [1, 4, 8, 10].

Based on the above problems, to support the success of learning improvement, the development of RBL - STEM-based learning tools will be carried out, which aims to improve students' computational thinking skills in digital image processing applications using CNN techniques. The tools to be developed are Semester Learning Plan (RPS), Student Assignment Design (RTM), Student Worksheet (LKM) and Learning Outcome Test (THB). The problems will be specialised in the identification of coffee plant diseases using CNN technique with data sources using quadcopter drones and their trajectories based on the resolving dominating set theory. To determine the effect of using RBL - STEM in improving students' computational thinking skills, statistical tests and analysis of students' responses to the results of the device development that has been carried out.

2. Method

The methodology of this study is based on Thiagarajan's 4D model, which consists of four stages: define, design, develop and disseminate. Figure 1 shows the 4D model. The statistical study, which was carried out using SPSS software, included the paired sample t-test in addition to the 4D model. The paired sample t-test is an alternative test that consists of two paired samples belonging to the same individual, but with two tests administered at different times and with different treatments. The study data must be examined using the assumptions test, specifically the normality test, before this analysis can be performed. In this study, the RBL-STEM approach was applied to the CNN application to see if students' computational thinking skills improved.

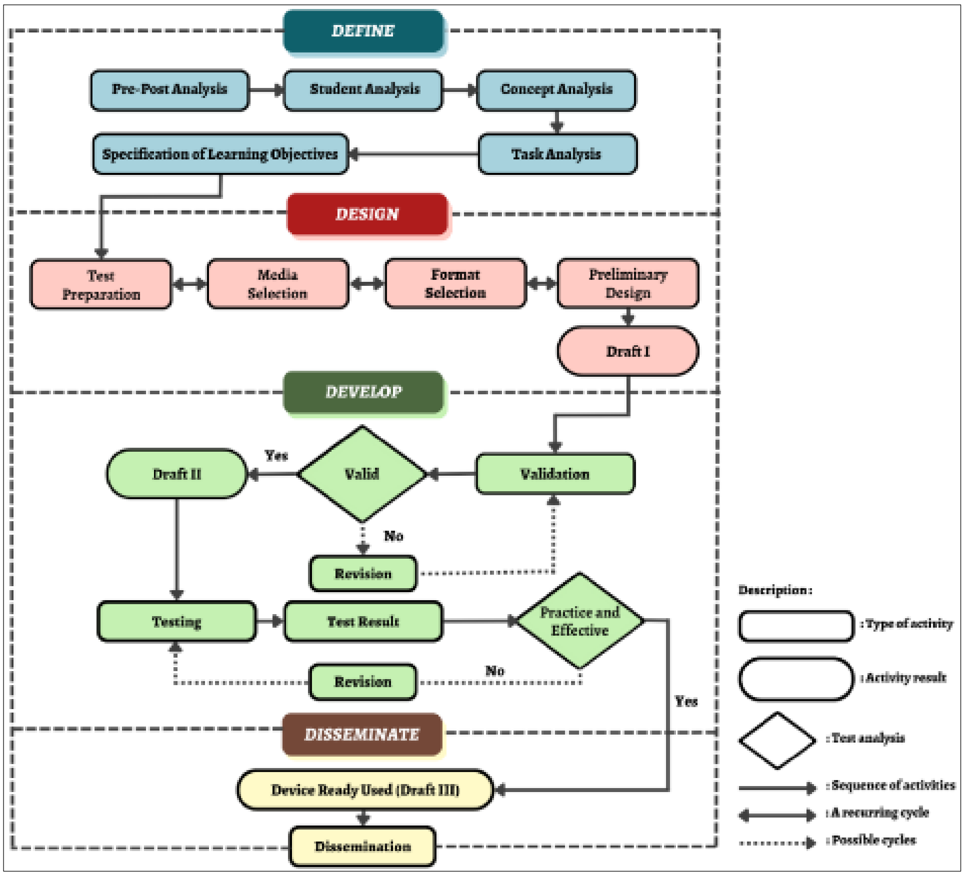

Figure 1 4-D Model Design

3. Results and discussion

This study uses RBL-STEM learning so that students can learn and develop skills in science, technology, engineering and mathematics. An explanation of the STEM aspects of this study can be found in Figure 2.

The expected outcomes are a CNN architecture to correctly identify coffee plant diseases and determine the most effective drone trajectory path based on the results of determining the dominating point in the resolving dominating set. This research approach includes the following stages: (a) Identification of coffee plant disease problems and how to monitor them; (b) Development of models using CNN techniques with data sources using quadcopter drones and drone trajectories based on the determination of dominator points on coffee plantation land using resolving dominating sets; (c) Collection of image data for CNN architecture modelling and analysis; (d) Implementing the model using CNN techniques to identify coffee plant diseases and determine drone trajectory paths using resolving dominating sets; (e) Proving the general formula of convolution, iteration, and evaluating and testing the model using image data of coffee leaves and other forms of coffee farmland; (f) Presenting results, writing research reports, and observing the required computational thinking skills.

The process of developing this tool is guided by Thiagarajan's 4D model, which consists of the stages of define, design, develop and disseminate. The criteria for the learning tools to be used are that the tools must be valid, practical and efficient.

Firstly, the purpose of the definition phase is to identify and define the learning needs by analysing the objectives and limitations of the material to be provided. This defining stage consists of five stages, early-late analysis to find out the basic problems that will be identified in the development of learning tools. Student analysis to examine the character of undergraduate students of Mathematics Education, University of Jember in accordance with the design and development of learning topics, students must be directly involved and have the ability to work together. Concept analysis to identify, detail and arrange CNN concepts to be taught to students. The following is based on the results of the initial-end analysis, which was obtained Figure 3 concept map as follows. Task analysis to determine the tasks in the LKM in the form of overlapping parts and THB to analyse students' computational thinking skills. Finally, specification of learning objectives, i.e. what learning objectives are to be achieved by students to identify computational thinking skills.

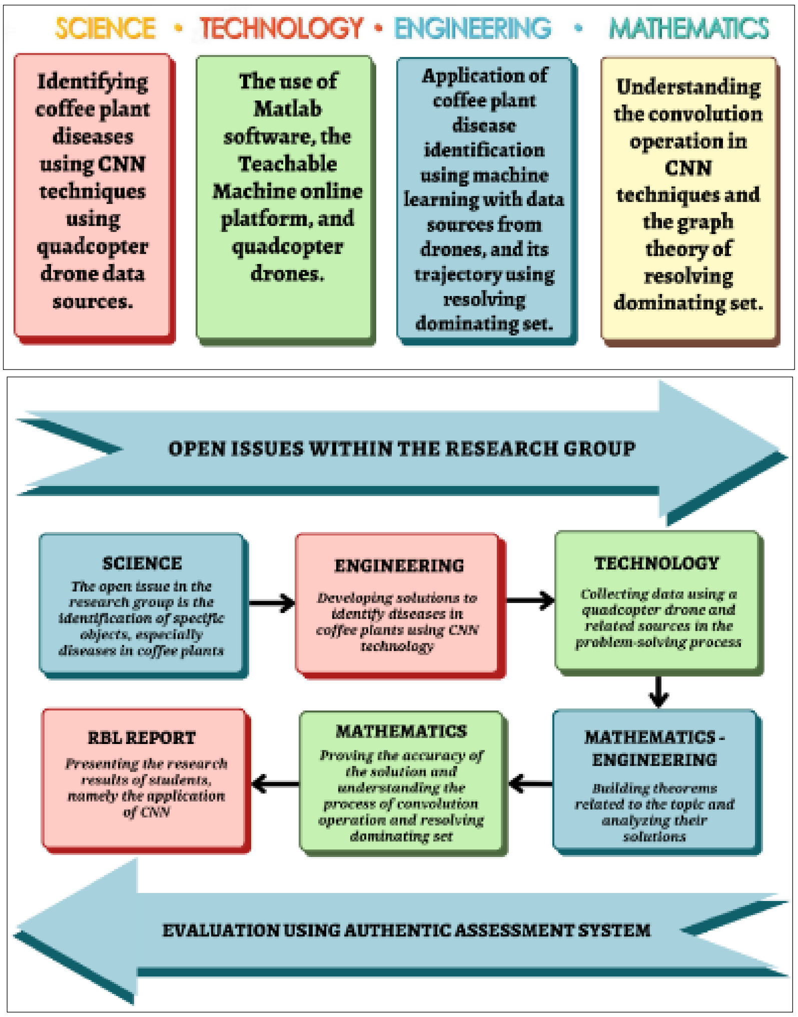

Figure 2 STEM aspects in research and RBL-STEM Syntax Framework

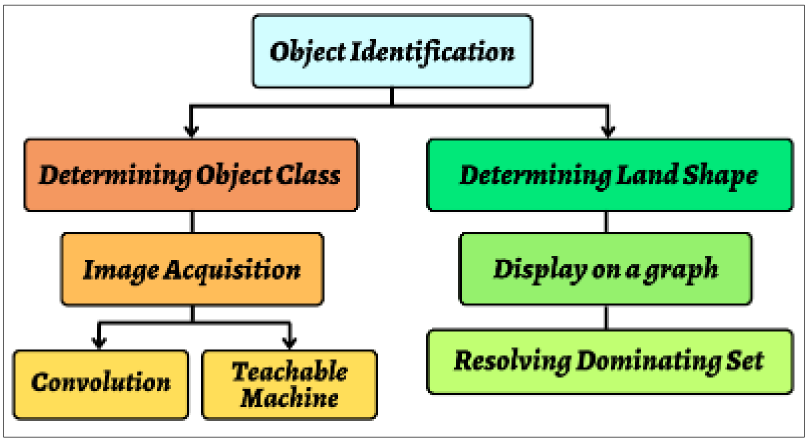

Figure 3 Concept Map

The second stage of the 4D model is design, this stage is to design an RBL-STEM device that is adapted to the results of the defining stage, namely to improve students' computational thinking skills in CNN application topics. This stage has the following steps: making tests in the form of pre-tests and post-tests, making learning media in the form of learning devices and power points to deliver material, making the whole design of learning devices must be made. The initial design of the learning device is shown in Figure 4 below.

Figure 4 Preliminary Design of Learning Materials

The third stage is development, the devices produced are validated by validators and improved according to their recommendations. The assessment is done by two validators, this validation process validators are given learning devices, assessment instruments and validation sheets.

Table 1 Validator Recapitulation Results

Validator results	Average	Percentage
Learning device	3.68	92%
Implementation Observation Sheet	3.64	91%
Student Activity Observation Sheet	3.78	94.5%
Student Response Questionnaire Sheet	3.75	93.75%
Student Questionnaire Sheet	3.67	91.75%

Based on Table 4.1 of the validation results for the learning device, the average score for all aspects is 3.68. In addition, based on the criteria for the validity of the device, the device is said to be valid if it receives a score of $3.25 \leq V_a \leq 4$. It can then be concluded that the device produced is valid.

The validated device is then tested on students. This trial was carried out in the Numerical Methods class, consisting of 18 students. The trial was supervised by several observers and teachers. At the first meeting of the trial class, the researcher gave a little insight into one of the techniques in machine learning, namely CNN, in the CNN application can be applied to object identification in the form of coffee plant disease. The students were then given a pre-test THB which was completed individually. In the second session, the students were divided into four groups, each with a group observer, the student observer. In the third session, the lecturer gave the post-test THB on the material presented in the second session.

Furthermore, the analysis of the learning implementation observation sheet shows whether the learning device meets the criteria of practicality. This includes the activities of the students and the teacher during the learning activities.

Table 2 Summary of the results of the implementation monitoring

Aspects Assessed	Average	Percentage
Syntax	3.88	96.88%
Social system	3.75	93.75%
Management Response Principle	3.9	97.5%
Overall average score of aspects	3.85	96.25%

On the basis of Table 2, the recapitulation of the results of the observation of the implementation obtained an average score of 3.85 and a percentage of 96.25%. Taking into account the criteria for the practicality of the device, it can be concluded that the learning device produced meets all the criteria very well, with a score of $90\% \leq SR \leq 100\%$.

The analysis of the effectiveness test of the device is based on the analysis of the students' completeness in the learning outcomes test based on computational thinking skills, the results of observing the students' activities during the learning activities, and the results of the students' response questionnaires. Based on the test results to measure students' computational thinking skills that 17 students or 94.44% of the students get scores above 60 and 1 student gets a score of 57, by considering the completeness criteria when ≥ 80% of the total number of students have been completed, it can be concluded that students in the Numerical Methods class have been classically completed. The data analysis of the observation of students' activities was obtained from the results of the observations made by four observers.

Table 3 Summary of the results of observation of student activities

Aspects Assessed	Average	Percentage
Introduction	4	100%
Core activity	3.78	94.53%
Conclusion	3.25	81.25%
Overall average score of aspects	3.78	94.32%

From Table 3 above, the recapitulation results obtained an average score of 3.78 and a percentage of 94.32% and it was concluded that the students were very active based on the activity criteria $90\% \leq P \leq 100\%$.

Table 4 Recapitulation of the result of the student questionnaire

Aspects Assessed	Percentage
Enjoyment of the learning component	97.22%
Novelty of learning components	77.78%
Students' interest in learning	100%
Clear understanding of the language used	94.44%
Understanding the meaning of each question/problem presented	66.67%
Interest in the design of the device	100%
Discussion with group members	94.44%
Overall average score	90.08%

Based on Table 4, the overall average positive percentage is 90.08% and it can be concluded that the students' response to the learning that has taken place is very positive. So all the requirements for testing the effectiveness of the device have been met.

Finally, the dissemination phase of the 4D model, this research will be delivered to mathematics teachers and disseminated through social media. The purpose of dissemination is to test the effectiveness of the learning devices and to receive input, corrections, suggestions and evaluations to improve the learning devices.

The following is a graph of the distribution of student pretest and posttest scores and the level of completeness scores can be seen in Figure 5. The percentage level of students' computational thinking skills can be seen in Figure 6.

Based on the pre-test results, all students are categorised as having low level computational thinking skills. Meanwhile, based on the post-test results, 72% of the students are categorised as having high level computational thinking skills, 22% as having medium level computational thinking skills and 6% as having low level computational thinking skills.

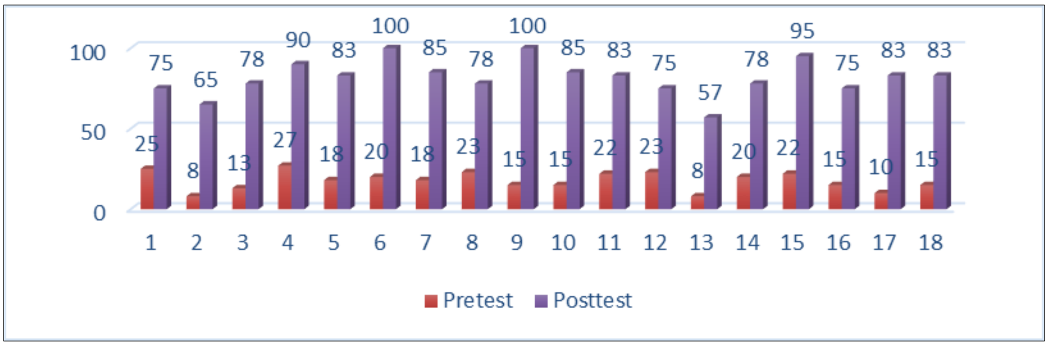

Figure 5 Distribution Chart of Pretest and Posttest Scores

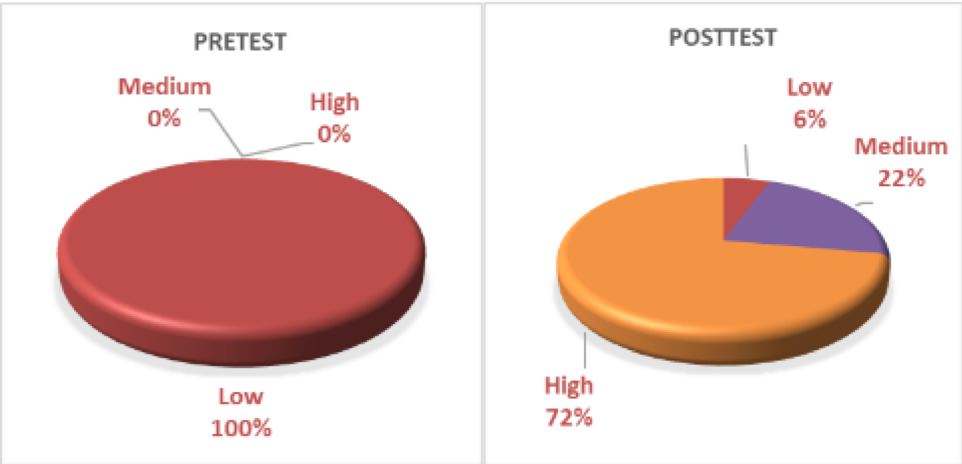

Figure 6 Persentase Level Keterampilan Berpikir Komputasional Mahasiswa

A quantitative analysis was also carried out to observe the improvement in students' computational thinking skills. Firstly, a normality test was carried out as a prerequisite for the paired samples t-test. This statistical test was carried out using SPSS. The results of the normality test are shown in Figure 7.

The normality test results indicate that the pretest scores are normally distributed, as the p-value is $0.535 > 0.05$. Similarly, the post-test scores are also normally distributed with a p-value of $0.394 > 0.05$. The next test performed is the paired samples t-test, shown in Figure 8 below.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
pretest	.123	18	.200*	.956	18	.535
posttest	.162	18	.200*	.948	18	.394

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Figure 7 Normality test results

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1 pretest - posttest	-63.94444	9.93788	2.34238	-68.88644	-59.00245	-27.299	17	.000

Figure 8 Paired Samples T-Test Results

Based on the above test results, a p-value of $0.000 < 0.05$ is obtained, indicating that the improvement in students' computational thinking skills between the two sets of pretest and posttest data is statistically significant. Therefore, it can be concluded that there is a significant improvement in the students' computational thinking skills.

4. Conclusion

The results of the analysis of this RBL-STEM material meet the criteria of validity, practicality and effectiveness. The validation score of the learning tool is 3.68 with a percentage of 92%. Based on the criteria of validity, the compiled learning materials meet the criteria of validity as they achieve a score of $3.25 \leq V_a \leq 4$. The average score from the overall observation of learning implementation is 3.85 with a percentage of 96.25%. On the basis of the practicality criteria, the learning materials produced meet the criteria of very high practicality, as they achieve a score of $90\% \leq SR \leq 100\%$. Furthermore, based on the post-test results, it was found that 17 out of 18 students scored above the minimum pass mark, indicating a classical pass. The average score from the overall observation of student activities is 3.78 with a percentage of 94.32%. Based on the students' responses in the questionnaire, the recapitulation of the overall scores of the students' responses shows an average positive percentage of 90.08%. This indicates that the learning material is effective as it meets the three criteria for effective learning material. Significantly, the students experienced an improvement in their computational thinking skills.

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 authors as a 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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