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The development of RBL-STEM learning tools to improve students' computational thinking skills in solving plant disease classification problems using convolutional neural network segmentation

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Abstract

This research aims to develop Research Based Learning (RBL) and Science, Technology, Engineering and Mathematics (STEM) based learning tools to improve students' computational thinking skills. The tools include a student task design (RTM), a student worksheet (LKM) and a learning outcome test (THB). Using Thiagarajan's 4D development model (define, design, develop, disseminate), the device was tested on students using a Convolutional Neural Network (CNN) approach for citrus plant disease classification using data from quadcopter drones. The validation results showed that the device was valid with an average score of 3.85 (96.42%). The practicality of the device is very high with an implementation score of 3.85 (96.36%) and a positive student response of 90.08%. The effectiveness of the device was demonstrated by 90% of students achieving classical completeness on the post-test and an increase in computational thinking skills from 0% (high) on the pre-test to 92% on the post-test. The paired sample t-test results also confirmed the statistically significant increase. This learning tool proved to be valid, practical and effective, contributing to technology-based learning innovation in modern agriculture.

Keywords: RBL-STEM; Computational thinking skills; CNN; Quadcopter drone; Citrus plant disease classification

1. Introduction

Education is an essential foundation for building character and providing the knowledge and skills necessary to realise one's potential. Through education, individuals not only develop critical thinking, creative and problem-solving skills, but also gain a broader understanding of the world, increase empathy and promote active participation in society. Education is also a driving force for sustainable development, individual empowerment and improving the overall quality of life [11]. Investing in education is therefore a strategic investment in the future, both for individuals and for society.

In education, the learning model plays an important role in shaping students' mindsets. One approach considered effective in developing students' cognitive skills is the combination of Research Based Learning (RBL) and the Science, Technology, Engineering and Mathematics (STEM) approach. RBL is a learning model that enables students to build knowledge independently by combining theory and practice. This approach aims to improve deep understanding and critical thinking skills [10]. On the other hand, STEM is an approach that combines four disciplines in an integrated learning framework. This approach focuses not only on theoretical understanding but also on practical application, which allows students to develop innovation and problem-solving skills [9].

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The combination of RBL and STEM (RBL-STEM) has great potential to improve computational thinking skills, namely the analytical ability to solve complex problems, design systems and apply solutions in the real world. Computational thinking skills are very important in the modern era, especially when dealing with problems that involve sophisticated technology, such as visual data processing for disease classification of plantation crops [12].

The Convolutional Neural Network (CNN) technique has become one of the most dominant and successful methods in the field of visual data processing. CNN is an artificial neural network specifically designed for image recognition and processing. This method utilises deep data representation capabilities through multiple feature layers, enabling accurate analysis for image segmentation and classification tasks [5]. This technology is supported by modern devices such as quadcopter drones, which are capable of capturing images of land in real time. These drones are often used in plantations to monitor crop conditions, detect diseases, and classify crop types with high efficiency [4].

Developing students' computational thinking skills for CNN-based digital image processing is highly relevant to solving modern agricultural problems, such as citrus disease classification. This technique not only helps students understand cutting-edge technology applications, but also prepares them for the challenges of the technology-based workforce [3]

A number of studies support the effectiveness of the RBL-STEM approach in developing students' skills. Gita [12] found that the use of RBL-STEM can improve critical thinking and problem solving skills. Other studies by Komaria and Alpian [8,2] showed similar results, namely an increase in students' ability to understand complex concepts and apply them in real life. Based on these results, there is a need to develop RBL-STEM-based learning tools to support students' computational thinking skills, especially in digital image processing using CNN [1].

This research focuses on the development of a learning tool to support students in identifying citrus plant diseases using data from quadcopter drones. The tool will train students to analyse visual data, design algorithms and apply CNN-based solutions for disease segmentation and classification. This research is expected to make a significant contribution to technology-based learning innovation in modern agriculture [7].

Based on this problem, in order to support the success of learning improvement, the development of RBL-STEM-based learning tools will be carried out, which aim to improve students' computational thinking skills in digital image processing applications using CNN techniques. The tools to be developed are Semester Learning Plan (SSP), Student Assignment Design (RTM), Student Worksheet (LKM) and Learning Outcome Test (THB). The problems will be specialised in the classification of plant diseases in citrus plantations using Convolutional Neural Network (CNN) techniques with data sources using quadcopter drones. 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. Methods

The research methodology is based on Thiagarajan's 4D model, which consists of four stages: define, design, develop and disseminate. Figure 1 illustrates the 4D model. The statistical study, which was conducted using SPSS software, included a 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 from the same individuals, but with two tests administered at different times and with different treatments. The research data must be examined using assumption tests, particularly normality tests, 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.

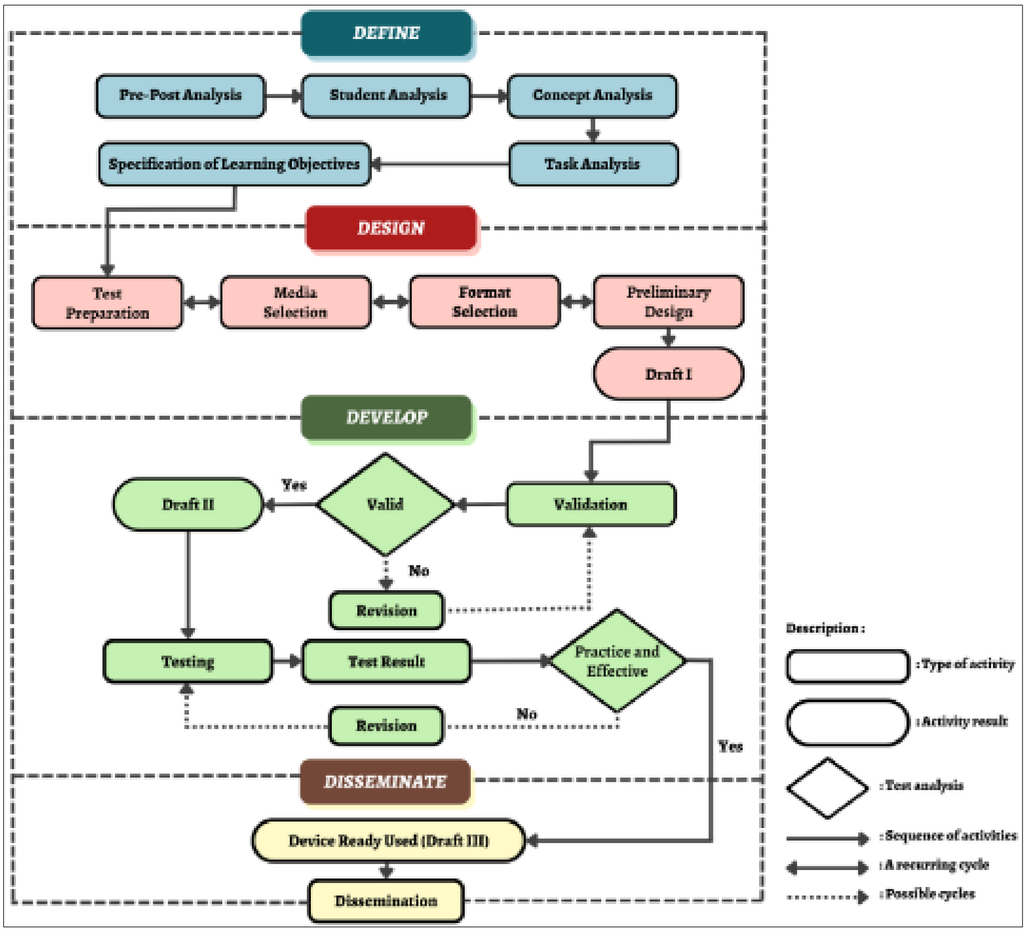

Figure 1 Stages of learning device development 4D model

3. Results and discussion

This research uses RBL STEM learning to enable students to learn and develop skills in science, technology, engineering and maths. An explanation of the STEM aspects of this research can be found in Figure 2.

The expected result is a CNN architecture to correctly identify citrus plant diseases. This research approach includes the following stages: (a) Identification of citrus plant disease problems and how to monitor them; (b) Development of models using CNN techniques with data sources using quadcopter drones; (c) Collection of image data for modelling and analysis of the CNN architecture; (d) Implementation of models using CNN techniques in the identification of citrus plantation diseases; (e) proving the general formula of convolution, iteration, evaluation and testing of models using citrus fruit image data; (f) presenting results, preparing research reports and observations; (f) presenting results, preparing research reports and observations.

Using the CNN application, the process and results of this RBL-STEM device were used to determine the effect of this device on the classification of citrus fruit plantation diseases. The instruments developed include a Student Task Design (RTM), a Student Worksheet (LKM), and a Computational Thinking Skills Test (TKBK) in the form of a pre- and post-test. The development process is based on Thiagarajan's 4D model, which consists of definition, design, development and dissemination stages. The criteria for the learning tools to be used are that they must be valid, practical and efficient.

Firstly, the purpose of the definition stage 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, namely the beginning-end 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 at Jember University 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 organise CNN concepts to be taught to students. The following is based on the results of the initial-end analysis obtained concept map Figure 3 as follows. Task analysis to determine the tasks in the MFI in the form of overlapping parts and THB to analyse students' computational thinking skills. Finally, the specification of learning objectives, namely what learning objectives students want to achieve to identify computational thinking skills with several categories, namely high, medium and low.

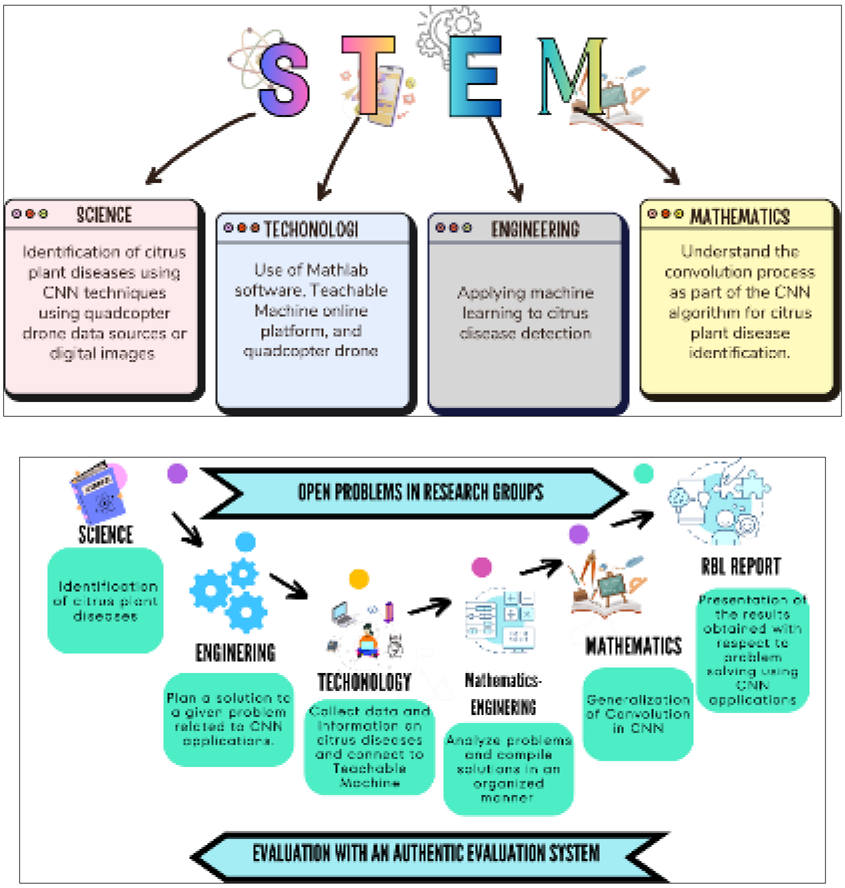

Figure 2 STEM aspects in research and RBL-STEM Syntax Framework

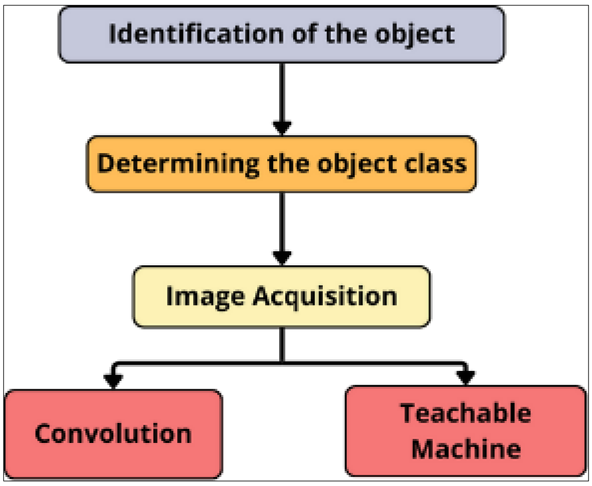

Figure 3 Concept Map

The second stage of the 4D model is design, this stage involves designing an RBL-STEM device tailored to the results of the defining stage, namely to improve students' computational thinking skills on the topic of CNN applications. This phase includes the following steps Making tests in the form of pre-test and post-test, making learning media in the form of learning devices and powerpoints to deliver the material. The whole design of the learning tools has to be done before conducting the test. The learning tools include the Semester Learning Plan (SSP), the Design of Student Assignments (RTM), the Test of Analytical Thinking Skills (TKBA) and the Student Worksheet (LKM). The design of the learning tools is shown in Figure 4. The initial design of the learning tool is shown in Figure 4 below.

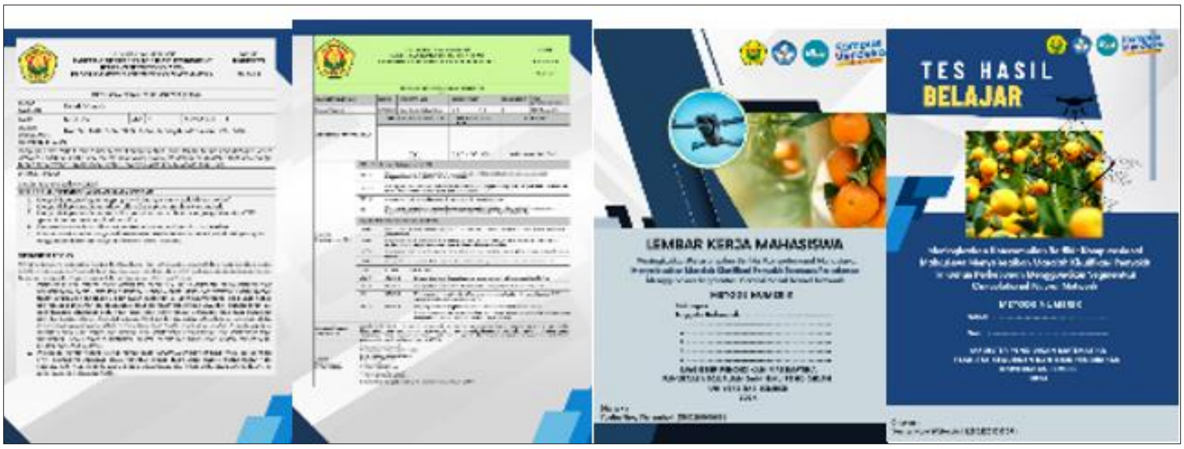

Figure 4 Design of RTM, RPS, LKM and THB

The third stage is development, the resulting device is validated by the validators and improved according to their recommendations. The assessment was carried out by two validators, who were provided with learning devices, assessment tools and validation sheets.

Table 1 Recapitulation of RBL-STEM Device Validation Results

Validation Result	Average	Percentage
Student Assignment Draft Sheet (RTM)	3.86	96.50 %
Student worksheet (LKM)	3.86	96.50%
Learning Outcomes Test Sheet (THB)	3.84	96.16 %
Student activity observation sheet	3.84	96.08 %
RBL-STEM Implementation Observation Sheet	3.88	97.16 %
Student Response Questionnaire	3.86	96.50 %
The overall average score	3.85	96.42 %

Based on Table 1, the results of the validation of learning devices and RBL-STEM instruments, the average score for all aspects is 3.85 with a percentage of 96.42%. Based on the validity criteria, the prepared learning device meets the validity criteria because it meets the score $3,85 \leq V_a \leq 4$.

The validated device was tested on students. This trial was conducted in the Numerical Methods class consisting of 36 students. Evaluation results, consisting of observer ratings and student work, were used to assess the practicality and effectiveness of the learning devices.

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 the classification of objects in the form of citrus plant diseases. The second session, students were divided into nine groups with each group there was a group observer, namely the student observer. Each student has to discuss with his group. Observers help guide the group if there are problems in working on the LKM. Each group was given the opportunity to practice and use props and objects in the form of quadcopter drones and healthy and diseased citrus fruit plants (black spot, greening, canker, and healthy) to directly analyze. Then, each group presented the results of their work and the instructor reinforced the conclusions of what they had learned. By using the RBL-STEM model, this trial class learned in an orderly and smooth manner. In the third session, the instructor gave a THB post-test on the material presented in the second session. Students were then asked to fill out answer sheets and questionnaires until the end of the lecture period.

Data collected during the study were student activity data, implementation observation data, response questionnaire, student questionnaire, and pretest-posttest THB results. The data were used to evaluate the practicality and effectiveness of the learning devices. The results of the analysis will be used to consider revisions to the device until the prototype is ready for use in the classroom.

The test of the practicality of the learning devices consists of 2 indicators, namely by analyzing the results of the implementation of learning in the classroom and the results of the questionnaires of the students' responses. The results and analysis of learning implementation are based on the RBL-STEM implementation observation sheet evaluated by 9 observers. Based on the average score of the overall learning implementation observation results is 3.85 with a percentage of 96.36%. In addition, the observers' comments were mostly positive, so they did not change the overall learning device. Based on the criteria of practicality, the prepared learning device meets the criteria of very high practicality because it meets the score of $90\% \leq SR \leq 100\%$. Results and student response questionnaires distributed to students after conducting the post-test. Overall, the average positive percentage is 90.08% and it is concluded that the students' response is very positive to the learning that has been given. Thus, all the requirements for testing the practicality of the device have been met.

Table 2 Summary of Data from Student Response Questionnaires

Assessed Aspect	Persentase
Enjoy the learning components	98.15%
Students feel trained in computational thinking skills	86.46%
Learning components are new	77.78%
Understand the language clearly	86.44%
Understand the significance of each problem or issue presented	76.39%
Interest in device design	93.06%
Interested in learning	97.22%
Discuss with other members	100%
Average score across all aspects	90.08%

The results of the learning implementation analysis based on the RBL-STEM implementation observation sheet met the practical criteria and received a positive score. The results of the analysis of the student response questionnaire sheet also received a positive response from the students. Based on the results of the analysis of the 2 indicators of the practicality of the learning device, this device is practical to use.

The effectiveness test of learning devices consists of 2 indicators, namely by analyzing student learning outcomes and student activity observation results. Student learning outcomes were obtained through a post-test conducted on Friday, December 5, 2024. Based on the test results to measure students' computational thinking ability that 36 students with an overall average score of 90% by considering the completeness criteria when ≥ 80 % of the total number of students have completed it can be concluded that students in the Numerical Methods class have completed classically. The results of observation of student activity are observation of introduction, core activities and conclusion. The analysis of student activity was based on the student activity observation sheet, which was evaluated by 9 observers. The results of scoring can be seen in Table 3.

Table 3 Summary of Student Activity Observation Results

Assessed aspect	Average	Percentage
Introduction	3.88	97.12 %
Core Activities	3.72	93.05 %
Closure	4	100 %
Average score across all aspects	3.86	96.66 %

Based on Table 4.3, the overall average score of the student activity observation results is 3.86 with a percentage of 96.66%. In addition, the observers' comments were mostly positive, so they did not change the overall score of the learning tools. Based on the effectiveness criteria, the learning tools meet the criteria of effective very active because they meet the score of $90\% \leq P \leq 100\%$.

The last stage is the dissemination stage, this research will be conveyed to mathematics education lecturers 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 students' pretest and posttest scores, and the level of completeness scores can be seen in Figure 5 and the percentage level of students' computational thinking skills can be seen in Figure 6.

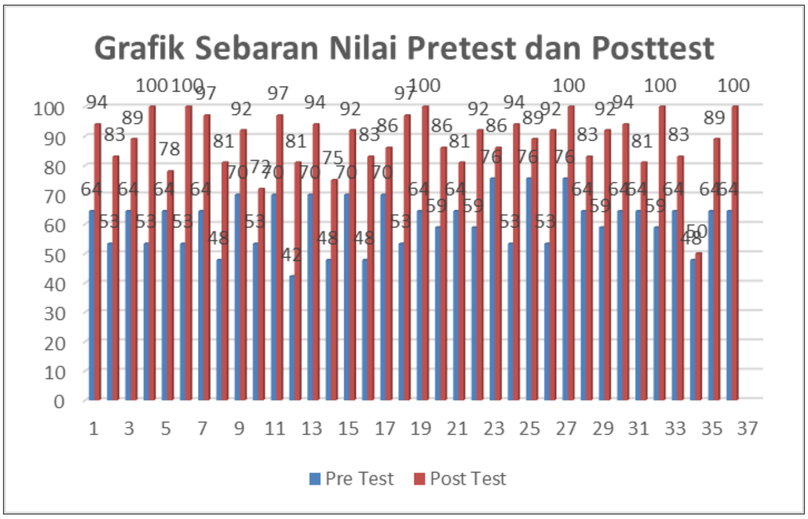

Figure 5 Distribution Chart of Pretest and Posttest Scores

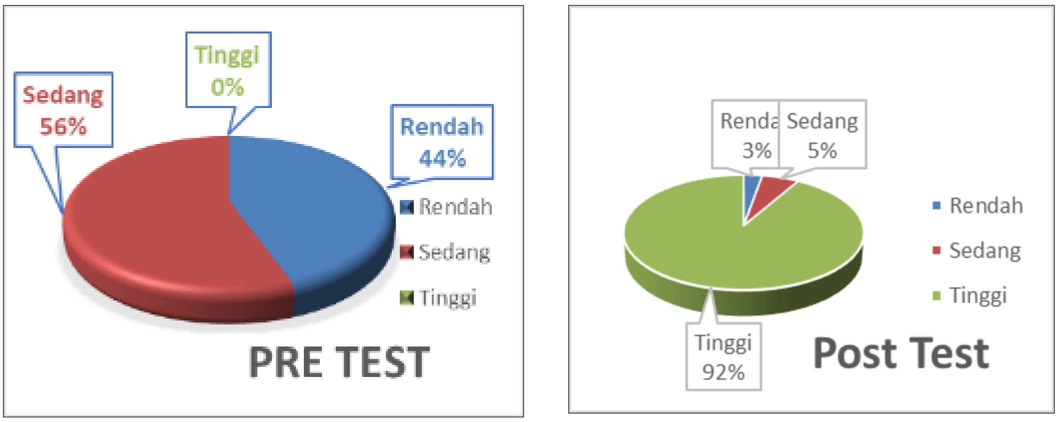

Figure 6 Persentase Level Keterampilan Berpikir Komputasional Mahasiswa

Based on the pretest results, 44% of the students were categorized as students with low level computational thinking skills and 56% of the students were categorized as students with moderate level computational thinking skills. Meanwhile, based on the post-test results, 92% of the students are classified as students with high level computational thinking skills, 5% of the students are classified as students with moderate level computational thinking skills, and 3% of the students are classified as students with low level computational thinking skills.

In addition, a normality test was performed as a condition for performing the paired samples t-test. This statistical test was performed using SPSS. The results of the data normality test are shown in Table 4.

Table 4 Normality Test Results

Tests of Normality						
	Kolmogorov-Smirnova			**Shapiro-Wilk**		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
PreTest	0.200	36	0.001	0.940	36	0.052
PostTest	0.150	36	0.038	0.943	36	0.063
a. Lilliefors Significance Correction						

Based on the results of the data normality test, it shows that the pre-test value is normally distributed because the p-value is 0.52>0.05 and the post-test value is normally distributed because the p-value is 0.63>0.05. The next test is the paired samples t-test, which is shown in Table 5 below.

Table 5 Paired Samples T-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	-28.833	10.109	1.685	-32.254	-25.413	-17.113	35	0.000

Based on the above test results, the p-value obtained is less than 0.05, namely 0.000 <0.05, which shows that the increase in students' computational thinking skills between the two groups of pretest and posttest data has increased very significantly statistically. Therefore, it can be concluded that there is an increase in students' computational thinking skills.

4. Conclusion

The results showed that the developed RBL-STEM-based learning tools met the criteria of validity, practicality, and effectiveness. In terms of validity, the tool, which includes Student Task Design (RTM), Student Worksheet (LKM), Learning Outcome Test (THB), as well as observation instruments and questionnaires, obtained an average score of 3.85 with a percentage of 96.42%, which is classified as valid. The practicality of the learning tools is also very high, as indicated by the learning implementation score of 3.85 (96.36%) and the positive student response questionnaire with an average percentage of 90.08%. In terms of effectiveness, 90% of the students achieved the minimum classical completeness on the post-test, while student activity observations showed an average score of 3.86 (96.66%), which meets the criteria of very high effectiveness. In addition, this tool was also able to significantly improve the students' computational thinking skills, where 92% of the students achieved high skills after the implementation of learning, compared to none before. These results prove that RBL-STEM learning tools are effective, valid, and practical in supporting technology-enhanced learning.

Compliance with ethical standards

Acknowledgements

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Disclosure of Conflict of interest

I would like to disclose that I am the responsible author for this study, working as a team with the other authors. While 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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