World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

Check for updates

The development of RBL-STEM learning materials to promote the students analytical thinking skills in solving convolutional neural network problems

Utami WW [1 *], Slamin [2] and Dafik [1]

[1] *Department of Postgraduate Mathematics Education, University of Jember, Jember, Indonesia.*
[2] *Department of Computer Science, University of Jember, Jember, Indonesia.*

World Journal of Advanced Research and Reviews, 2024, 21(01), 2204–2212

Publication history: Received on 07 November 2023; revised on 22 January 2024; accepted on 24 January 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.21.1.0099

Abstract

Analytical thinking is a crucial cognitive skill that involves organizing, connecting, and understanding information to formulate solutions to problems. Analytical thinking skill consist of three indicators, namely the ability to distinguish, organize, and connect. To enhance higher-order thinking skills, we utilize RBL learning integrated with a STEM approach. Developing the learning materials to support the success of learning activity is important to improve student analytical thinking skill. The learning materials that have been developed reach the criteria of valid, practical, and effective. The validity of material component reach 3.79 or 94.75%. The post-test results show that 31 students (82%) have scores above the minimum completeness. The observation result of material learning implementation achieved an average score of 3.95, equivalent to a 98.75% percentage. Student response data reaches the average positive percentage 90.64%. Based on data analysis, it can be conclude that the RBL-STEM learning materials is ready for use.

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

1. Introduction

Analytical thinking is a high-level cognitive skill that involves organizing, connecting, and determining the purpose of information. Individuals with strong analytical thinking skills will have better ability to understand information[3]. Therefore, it is crucial to develop analytical thinking skills from an early age. This is especially important in the era of Industry 4.0, where humans are constantly surrounded by digital technologies such as IoT (Internet of Things), Big Data, and AI, which enable the dissemination of massive amounts of information.

The quality of education in Indonesia is greatly impacted by the establishment of clear educational goals. According to Law No.20 of 2003, the government aims to empower students through knowledge and skills. Improving the curriculum is one way to enhance learners' knowledge and skills. The government aims to enhance students' mindsets by promoting a student-centered curriculum, as outlined in Permendikbud No. 81A of 2013. This learning model involves active student participation in creating a learning center, maximizing their potential and promoting self-directed learning.

To promote student potential, various learning models can be employed, including the research-based learning (RBL) model. RBL integrates research findings and activities into the learning process [6]. The RBL model is used in college to facilitate the learning process by enabling students to build knowledge, thinking skills, and practical connections between research and their learning boundaries. This research integrates the RBL model with the STEM approach.

STEM is an interdisciplinary approach that combines Science, Technology, Engineering, and Mathematics. This approach encourages students to develop their ability to reason, solve problems, think critically, learn independently,

* Corresponding author: Wachyu Wiji Utami

and make connections with the real world [18]. The aim of STEM integration is to help students comprehend all fields and view each one in a physical, intellectual, and cultural context, and participate in the examination of STEM topics [5].

Developing materials that support the success of the learning process can improve students' thinking skills in higher education. Student Task Design (RTM), Student Worksheets (LKM), and Learning Outcome Tests (THB) are examples of materials that can support the success of RBL-STEM-based learning activities.It is important to ensure that the learning materials used align with the learning objectives.Therefore, the development of learning materials is crucial to ensure that the available material aligns with the curriculum, its characteristics, objectives, and problem-solving demands [11].

Mathematics involve a wide range of topics, including image processing. Image processing involves using computational techniques and algorithms to analyze, manipulate, and interpret digital images in order to obtain useful information or make decisions based on the processed visual images [1]. Mathematical concepts such as calculus, numerical methods, geometry, and information theory are frequently employed in various image processing techniques and algorithms. Convolutional Neural Network (CNN) algorithms are an innovative form of image processing used for image recognition [7].

CNNs have been applied in the transportation industry to detect damage on railway sleepers. Trains are a crucial mode of mass transportation, and infrastructure maintenance is necessary to prevent accidents [10]. Digital technology can be utilized in railway safety through the detection and classification of railway sleepers based on the characteristics of the data set processed in the CNN application. Drone technology can be a breakthrough for image capture and monitoring [9].

2. Material and methods

2.1. Research Based Learning (RBL)

RBL is a student-centered system that provides opportunities for hands-on learning, making it more meaningful [15]. RBL by [17] described as consisting of three stages: exposure, experience, and problem identification. In the exposure stage, students gather information and literature related to their research. In the experience stage, they identify and formulate problems based on their literature study and experience. The final stage is the capstone stage, during which students conduct experiments based on ideas or plans to provide solutions. The stages of RBL according to [17], are illustrated as follows.

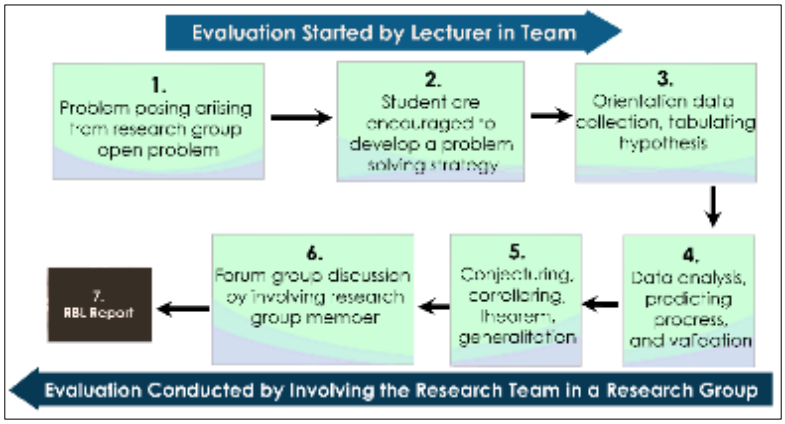

Figure 1 RBL Stages

2.2. STEM

STEM is an interdisciplinary approach that integrates Science, Technology, Engineering, and Mathematics. integrates the four components of science, technology, engineering, and mathematics into one learning experience, helping students use technology and assemble it into experiments that can prove scientific concepts supported by mathematically managed data. The STEM approach can make the learning process more innovative and more varied in relation to everyday life[4]

According to [5], the objectives of STEM education are as follows: (i) Possessing the ability to identify problems, explain natural phenomena, and draw conclusions based on evidence related to STEM issues; (ii) Understanding the specific characteristics of STEM as a form of human-initiated knowledge, inquiry, and design; (iii) Recognizing how STEM

disciplines shape material, intellectual, and cultural aspects; (iv) Demonstrating an interest in studying STEM issues by utilizing the principles of science, technology, engineering, and mathematics. An explanation of STEM by [13] are science is the ability to use scientific knowledge and processes to understand the world and nature and the ability to participate in making decisions to influence it; technology is knowledge of how to use new technologies, understand how new technologies are developed, and have the ability to analyze how new technologies affect individuals, and society; Engineering is Application of science and technology through the design process using a project-based learning theme by integrating several different disciplines; and mathematics is The ability to analyze, reason, and communicate ideas effectively and from the way of behaving, formulating, solving, and interpreting solutions to mathematical problems in their application.

2.3. Analytical Thinking Skill

Analytic thinking skills are part of the higher order thinking skills used by students to solve problems in education and everyday life [12]. Analytic thinking skills involve breaking down information into smaller parts and determining the relationships between them to provide a more in-depth explanation [16]. According to [14] suggest that to develop analytical thinking skills, students should be trained to focus on the learning process, evaluate the process taken, and comment on the results obtained. So that students can benefit and can develop better analytical thinking skills to solve problems in the future [2].

According to [3], analytical thinking skills can be measured through indicators such as the ability to analyze and break down information, recognize cause and effect factors, and formulate questions or answer the purpose of the information. Analytical thinking indicators comprise the ability to distinguish, organize, and connect. Distinguishing involves grouping problems and presenting them in discussions. Organizing includes compiling and arranging parts of the problem to form an orderly whole. Connecting involves linking interrelated concepts to form a complete understanding. This indicator also has sub-indicators that support deeper understanding [8].

2.4. Method

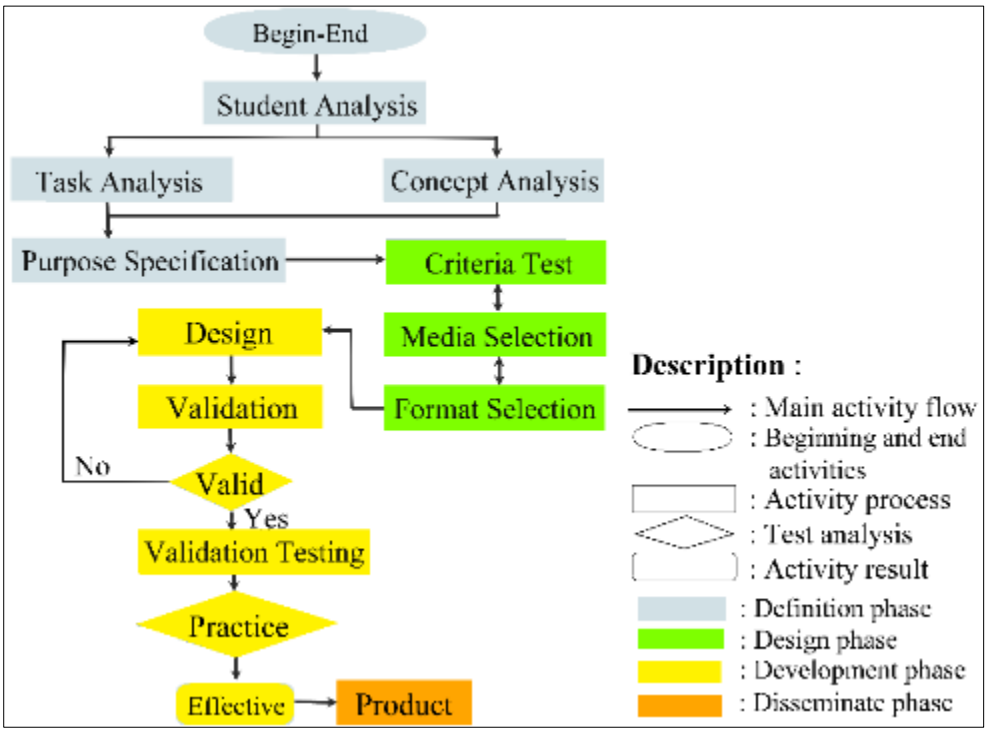

Figure 2 4D model design

The stage in this study are based on the Thiagarajan 4D Model, which includes defining, design, development, and dissemination stages. Figure 2 displays the 4D model design. In addition to the 4D model, the SPSS application is used for paired sample t-test statistical analysis.

3. Results and discussion

This research uses research-based learning with STEM approach so students can learn and develop skills in the fields of Science, Technology, Engineering, and Mathematics. The problem presented using the RBL-STEM learning model is about CNN applications for detecting rail sleeper damage using drones as a data source. An explanation of the STEM aspects of the study can be seen in Fig. 3. The problems used are described in more detail as follows.

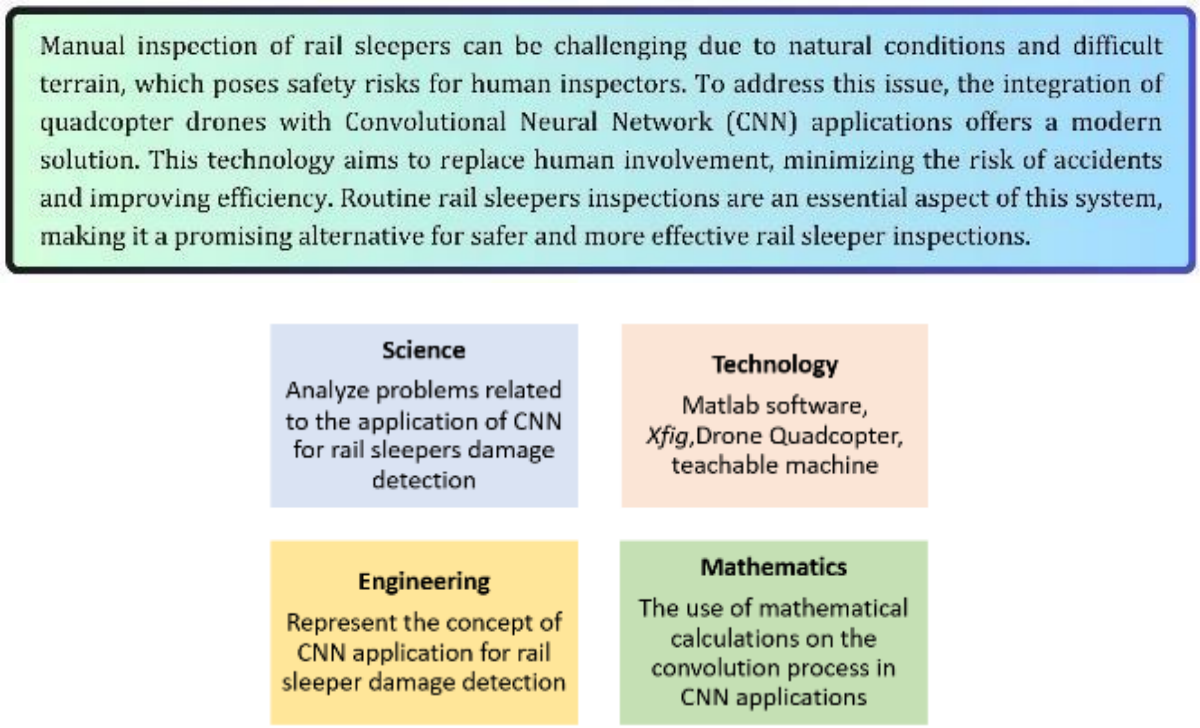

Figure 3 STEM aspect in this research

This research aims to address the issue of using CNN for railway sleeper damage detection through quadcopter drones. The goal is to understand the concept of applying CNN as a breakthrough in sleeper damage inspection and to independently perform image processing for sleeper detection using a prototype. The RBL model in the research uses the stages of (a) Identifying problems regarding the detection of rail bearing damage, inspection processes, and obstacles; (b) Getting a breakthrough using CNN applications using quadcopter drones as a data source; (c) Data collection and development of rail bearing damage detection solutions in CNN applications; (d) Analysis of mathematical calculations and solution steps; (e) Test the rail bearing damage detection model that has been produced; (f) Report on research results and observation of student analytical skills.

Table 1 RBL-STEM activities framework

SN	Phase	Description
1	*Science*	Identification of rail sleeper damage detection problems and utilization of CNN applications
2	*Engineering*	Plan a solution to the given problem related to CNN application using drones as a tool to collect data
3	*Technology*	Gathering information related to problems and things that will be solutions to problems
4	*Mathematics-Engineering*	Build knowledge of the relationship between the given problem and image processing using CNN application.
5	*Mathematics*	Performed an organized solution and generalized the convolution process in the CNN application.

6	*RBL-Report*	Present the results obtained regarding problem solving by utilizing CNN applications and quadcopter drones.

The instruments in this study include Semester Learning Plan (RPS), Student Task Plan (RTM), Student Worksheet (LKM), and Learning Outcome Test (THB). THB in this case is used as a test of students' analytical thinking skills. The device development in this study used the Thiagarajan (4D) model, so that the development process used the following stages namely stages of defining, designing, developing, and disseminating. The defining stage aims to establish and define the learning needs, analyze the objectives, and consider the limitations of the provided material. The defining stage consists of five stages: (1) Initial analysis is carried out to determine the problems that occur in learning activities and develop learning tools, learning tools are expected to help students who have difficulty in understanding the concept of CNN application in object identification; (2) Student analysis, characteristics data of undergraduate students majoring in Mathematics Education at the Faculty of Teacher Training and Education (FKIP), Jember University, were collected through student analysis. At this stage, students are required to possess teamwork skills within a group and actively participate in the learning process; (3) Concept analysis, The process of concept analysis is carried out to identify, elaborate, and organize the concepts of the Convolutional Neural Network application that will be studied by students; (4) Analyzing task, the task analysis process is conducted by the researcher through assigning tasks in the learning module in the form of incomplete sections and in the analytical thinking skills test in the form of the application of CNN, including its application to the problem of detecting railway sleepers damage. These tasks are expected to enhance the analytical thinking skills of students; (5) Learning objectives specification, this activity aims to identify the analytical skills of students in accordance with the expected final abilities.

Learning materials planning is carried out to determine the effect of learning materials on student analytical skills in CNN applications. the initial design of the materials can be seen in Figure 4. The learning materials in this study consists of 4 components, namely Semester Learning Plan (RPS), Student Task Design (RTM), Student Worksheet (LKM), (4) Learning Outcome Tests (THB). Before the learning materials is taught to students, the learning materials needs to be validated first.

Figure 4 Design of RPS, RTM, LKM, and THB

The next stage is the development stage. Each material is validated by a validator and then developed based on the recommendations of the validator. After the learning materials is declared valid, a trial of the learning materials is carried out in the Numerical Methods Mathematics class of the Mathematics Education Study Program, FKIP, University of Jember. The results of the validation of learning materials show that the average score for all aspects is 3,79. Based on the criteria for the validity of learning materialss ,the device is considered valid if it gets a score of $3{,}25 \leq V_a \leq 4$. Based on the validation results, it can be concluded that the learning materials made are valid and suitable for use in learning. The result of learning materials validation is shown in Table 2.

Table 2 Learning materials validation result

No.	Assessed Aspect	Average Score	Average Percentage
1	Format	4.00	100%
2	Content	3.71	92.75%
3	Language and writing	3.67	91.75%
Overall aspect average score		**3.79**	**94.75%**

The validated and revised material was tested on a class of 39 students under the supervision of observer and a lecturer. During the first meeting, the researcher provided the LKM and some background information on CNN applications, the problem of railway sleeper damage detection, and the use of drones as a technology that can help in the detection process. In the second meeting, each group is given the opportunity to make a presentation about the things they learned as a result of the discussion. In the third meeting, the lecturer gave THB to be answered, then the lecturer gave a response questionnaire at the end of lecture time.

The data collected from the trial were student activity data, implementation observation data, student response questionnaire, LKM, pre-test results, and post-test results. The data was then used to evaluate the practicality and effectiveness of the learning materials. The learning implementation observation received an average score of 3.95 with a percentage of 98.75%. Based on the criteria for the practicality of the device, it can be concluded that the learning materials that has been made meets very high practical criteria, because it meets the score of $90\% \leq SR \leq 100\%$.

Table 3 The learning implementation observation result

No.	Assessed Aspect	Average Score	Average Precentage
1	Syntax	3.96	99.25%
2	Social system	3.95	98.25%
3	reaction and management principles	3.95	98.75%
Overall aspect average score		**3.95**	**98.75%**

The effectiveness of learning tools is determined based on the analytical thinking skills test, the results of observations of student activities during learning activities, and the results of student response questionnaires. The response of students' answers in the analytical skills test shows that 82% get scores above the standard of completeness which indicates that students have high analytical skills because they meet the criteria for completeness of effective learning materialss $75\% \leq A_n \leq 100\%$. It indicate one of three requirements to assess the effectiveness of a learning materials have been fulfilled. Student activity observation sheets show an average score percentage of student activity of 3,77 with a percentage of 94,25%. It indicate that students are very active in the learning process because they meet the activity criteria $90\% \leq P \leq 100\%$. It's shown in Table 4.

Table 4 The recapitulation of student activity observation

No.	Assessed Aspect	Average Score	Average Precentage
1	Introduction	3.93	98.25%
2	Main Activities	3.74	93.50%
3	Closing	3,65	91.25%
Overall aspect average score		**3.77**	**94.25%**

Student response data obtained from student response survey that distributed via hardfile. the average positive percentage is 90.64%. This number is based on the criteria for student responses included in a very positive response of $\mathbf{80\%} \leq \boldsymbol{P_r} \leq \mathbf{100\%}$. Then it can be concluded that the learning device has been considered effective because the three criteria needed to consider an effective learning materials have been reach. It's shown in Table 5.

Table 5 The recapitulation of student response survey result

No.	Assessed Aspect	Precentage
1	Enjoyment of learning component	96.78%
2	Students' information literacy skills feel trained	88.90%
3	Leraning component are new	87.20%
4	Students clearly understand the language	92.30%
5	Students understand the meaning of each presented problem	84.60%
6	Students are attracted by the appearance (text and images)	89.75%
7	Students are interested in learning	100%
8	Students enjoy discussing with group members	92.30%
Overall aspect average score		**91.48%**

The final stage of the 4D model is the dissemination stage. The dissemination stage aims to find out whether the developed device works well for learning activities. In this research, we will use quantitative data analysis to analyze the improvement of students' analytical thinking skills. The distribution of students' pretest and posttest scores is visualized using a graph that can be seen in Figure 5. The percentage of students' analytical thinking skills level is visualized in Figure 6.

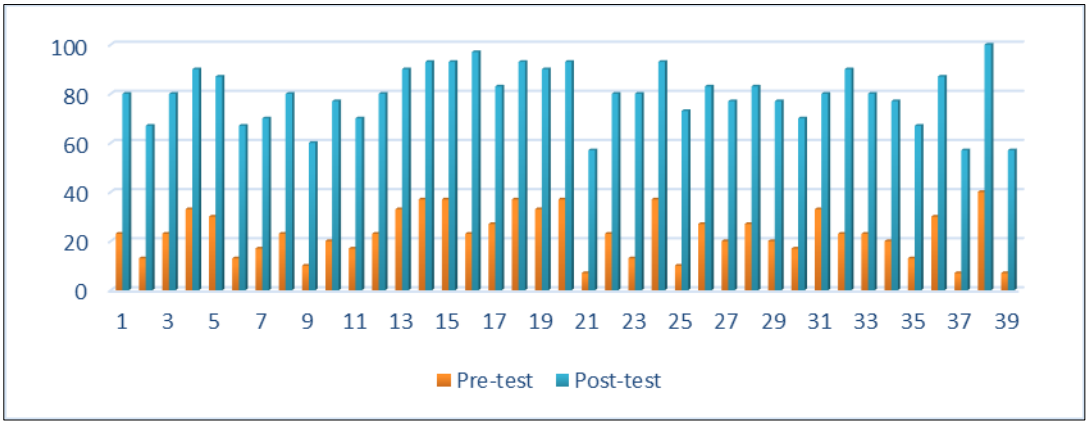

Figure 4 The distribution of students' pre-test and post-test

According to Figure 6, in the pre-test results, students categorized as students with high analytical skills were 0%, students with moderate analytical skills were 0%, and students with low analytical skills were 100%. Whereas in the post-test results, students who were categorized as students with high analytical skills were 72%, students with moderate analytical skills were 20%, and students with low analytical skills were 8%.

The 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 software. The results of the data normality test are presented in Figure 7.

Based on the results of the data normality test in Figure 7, it shows that the pre-test and post-test scores are normally distributed with a pre-test significance value of $0.093 > 0.05$ and a post-test significance value of $0.10 > 0.05$. The last test is the paired sample t-test presented in Figure 8.

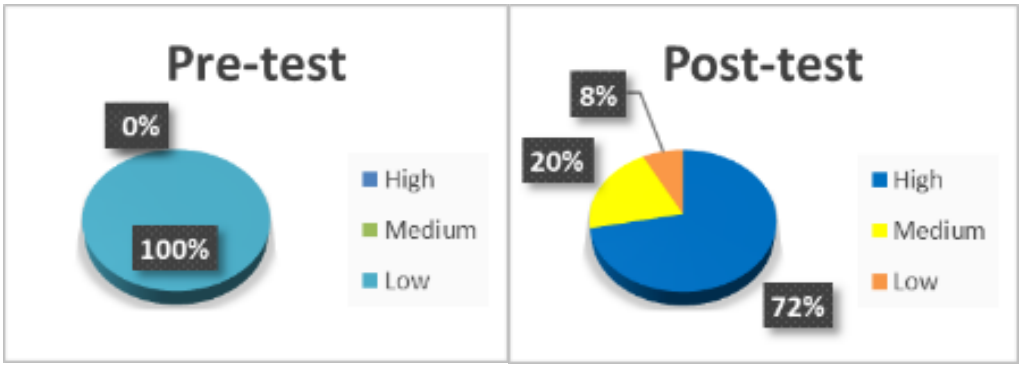

Figure 5 Percentage level of students' analytical thinking skills

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
pretest	.125	39	.128	.952	39	.093
posttest	.126	39	.120	.953	39	.100

Figure 6 Normality test result

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	-56.46154	4.87122	.78002	-58.04060	-54.88247	-72.385	38	.000

Figure 7 Paired sample t-test result

The paired sample t-test results yielded a significance value of 0.00<0.05, indicating that the improvement in analytical thinking skills before and after learning with RBL-STEM learning materials was a statistically significant improvement

4. Conclusion

The results of the analysis of this RBL-STEM material meet the criteria of validity, practical and effective. The average of validation process is 3.79 with presentage 94.75%. According to validation criteria, the material learning are valid because it reaches score $3.25 \leq V_a \leq 4$. Based on the post-test results, it is known that as many as 31 students (82%) have scores above the minimum completeness which means classically complete. The learning implementation achieved an average score of 3.95, equivalent to a 98.75% percentage. Student response data reaches the average positive percentage 90.64%. This shows that the teaching materials developed are effective because the three requirements for effective teaching materials are met.

Compliance with ethical standards

Acknowledgement

We gratefully acknowledge the support from department of Postgraduate Mathematics Education and Combinatorial Education and Research-Based Learning (CEREBEL) of the year 2024.

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.

References

[1] Aditya, M. R. V., Husni, N. L., Pratama, D. A., & Handayani, A. S. Application of Color Detection Digital Image Processing System on Starbot. 2020; 14(02): 185–191.

[2] Aksu, G., & Eser, M. T. Development of analytical thinking tendency scale: Validity and reliability study. Elementary Education Online. 2020; 19(4): 2307–2321.

[3] Anggraini, A. The Effectiveness of E-Learning as a Substitute for Conventional Lectures to Improve Students' Analytical Skills. Jurnal Sosial Humaniora. 2018; 9(2): 95.

[4] Banila, L., Lestari, H., & Siskandar, R. Application of blended learning with a STEM approach to improve students' science literacy skills in biology learning during the covid-19 pandemic. Journal of Biology Learning. 2021; 3(1): 25.

[5] Bybee, R. W. The Case for STEM Education Challenges and Opportunities. NSTA Press; 2013.

[6] Dafik, Sucianto, B., Irvan, M., & Rohim, M. A. The analysis of student metacognition skill in solving rainbow connection problem under the implementation of research-based learning model. International Journal of Instruction. 2019; 12(4): 593–610.

[7] Efrian, M. R., & Latifa, U. Image Recognition Based on Convolutional Neural Network (Cnn) to Detect Skin Diseases in Humans. Power Elektronik : Jurnal Orang Elektro. 2022; 11(2): 276.

[8] Fitriani, F., Wirawan Fadly, & Ulinnuha Nur Faizah. Analysis of Students' Analytical Thinking Skills on the Theme of Inheritance of Traits. Jurnal Tadris IPA Indonesia. 2021; 1(1): 55–67.

[9] Lesiak, P. Inspection and Maintenance of Railway Infrastructure with the Use of Unmanned Aerial Vehicles. Problemy Kolejnictwa - Railway Reports. 2020; 64(188): 115–127.

[10] Mardiana, S., Hamdani, D. Railway Track Inspection Information System Using Drones and Image Processing Techniques. Journal of …, 2020; 02(01): 9–12.

[11] Mursyidah, I. L., Dafik, Kristiana, A. I., & Izza ,R. 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. International Journal of Current Science Research and Review. 2023; 06(01): 634–644.

[12] Prawita, W., Prayitno, B. A., & Sugiyarto. Effectiveness of a generative learning-based biology module to improve the analytical thinking skills of the students with high and low reading motivation. International Journal of Instruction. 2019; 12(1): 1459–1476

[13] Pujiati, A. Improving Science Literacy with STEM Learning in the Era of Industrial Revolution 4.0. Universitas Indraprasta PGRI Jakarta INFO. 2019; 0812(80): 547–554.

[14] Qomariya, Y., Muharrami, L. K., & Hadi, W. P. Bangkalan Using the Pictorial Method. Journal of Natural Science Education Reseach. 2018; 1(1): 10.

[15] Rahim, F. R. Implementation of Research Based Learning (RBL) in Integrated Science Courses in Physics Education Study Program. Jurnal Eksakta Pendidikan (Jep). 2019; 3(1): 82.

[16] Ramadani, A. S., Supardi, Z. A. I., Tukiran, & Hariyono, E. Profile of Analytical Thinking Skills Through Inquiry-Based Learning in Science Subjects. Studies in Learning and Teaching. 2021; 2(3): 45–60.

[17] Suntusia, Dafik, & Hobri. The effectiveness of Research Based Learning in improving students' achievement in solving two-dimensional arithmetic sequence problems. International Journal of Instruction, 2019; 12(1): 17–32.

[18] Zubaidah, S. STEAM (science, technology, engineering, arts, and mathematics): Learning to empower 21st century skills [STEAM (Science, Technology, Engineering, Arts, and Mathematics): Learning to Empower 21st Century Skills]. Seminar Nasional Matematika Dan Sains, September: 2019; 1–18.