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)

The Development of RBL-STEAM Learning Materials to Enhance Undergraduate Students' Combinatorial Thinking Skills in Solving Zakat Distribution Problems Using Perfect Dominating Set

Imroatul Hasanah [1,*], Dafik [2], Arika Indah Kristiana [3] and dan Lela Nur Safrida [4]

[1] *Department of Postgraduate Mathematics Education, Faculty of Teacher Training and Education, University of Jember, Indonesia.*

[2] *Department of Postgraduate Mathematics Education, PUI-PT Combinatorics and Graphs, CGANT, Faculty of Teacher Training and Education, University of Jember, Indonesia.*

[3] *Department of Mathematics, Faculty of Mathematics and Natural Sciences, University of Jember, Indonesia.*

World Journal of Advanced Research and Reviews, 2026, 30(02), 1081-1093

Publication history: Received on 07 April 2026; revised on 12 May 2026; accepted on 14 May 2026

Article DOI: https://doi.org/10.30574/wjarr.2026.30.2.1335

Abstract

This study aims to develop and validate learning materials based on Research-Based Learning (RBL) integrated with the Science, Technology, Engineering, Arts, and Mathematics (STEAM) approach. The learning materials were designed to meet the criteria of validity, practicality, and effectiveness in enhancing undergraduate students' combinatorial thinking skills. The developed learning materials focus on optimizing zakat distribution through the use of blockchain technology with the perfect dominating set technique. This study employed the Research and Development (R&D) method by adopting the 4D development model, which consists of the Define, Design, Develop, and Disseminate stages. The products developed in this study included the Student Task Design (RTM), Student Worksheet (LKM), and Learning Outcome Test (THB). The validation results indicated that the developed learning tools obtained a validity percentage of 94.5%, which was categorized as highly valid. Furthermore, the trial involving 35 students showed that the RBL-STEAM learning tools achieved a practicality percentage of 96% and an effectiveness percentage of 91% in improving students' learning outcomes. During the learning process, students demonstrated positive responses and a high level of active engagement. The post-test results showed that 91% of students were classified as having a high level of combinatorial thinking skills, 9% were in the moderate category, and no students were in the low category. In addition, the statistical analysis using the paired sample t-test obtained a significance value of Sig. = 0.000 < 0.05, indicating a significant improvement between the pre-test and post-test scores. Therefore, the developed RBL-STEAM learning tools were proven to be effective in enhancing students' combinatorial thinking skills and their ability to apply mathematical reasoning to zakat distribution problems.

Keywords: RBL-STEAM; Combinatorial Thinking; Zakat Distribution; Blockchain Technology; Perfect Dominating Set.

1. Introduction

In the era of information and globalization, creative thinking skills are highly essential. These skills enable individuals to generate various ideas and innovations and subsequently transform them into products that are beneficial to society, the state, and the nation [1]. To address the challenges arising from continuous and dynamic changes, every individual needs to possess creative thinking skills [2]. NCTM states that combinatorial thinking is a highly important element compared to other types of logical thinking, and its existence is inseparable from mathematics learning [3]. Combinatorial thinking is a process of finding various solutions to solve discrete problems [4].

* Corresponding author: Imroatul Hasanah

However, empirical findings indicate that most students still encounter difficulties in developing higher-order thinking skills, particularly when they are required to analyze and decompose complex mathematical structures [5]. Conventional learning methods are often not yet optimal in connecting abstract mathematical concepts with their practical applications in digital contexts [6]. In the context of mathematics education, a learning model is needed that not only emphasizes conceptual understanding but also fosters mathematical curiosity and systematically develops students' combinatorial thinking patterns [1].

Research-Based Learning (RBL) is needed to effectively develop combinatorial thinking skills because this learning approach is challenging and focuses on real-world contexts [7]. Research-Based Learning (RBL) is a learning approach that positions students at the center of research activities [8]. In RBL, students are actively involved in various stages of research, such as problem exploration, data collection, analysis, and the preparation of research reports [9]. The main objective of this approach is to develop students' critical, analytical, and creative thinking skills, as well as to deepen their understanding of course materials by connecting them to real-world problems.

Furthermore, to enhance the effectiveness of the RBL model in developing students' combinatorial thinking skills, this study integrates Research-Based Learning with the STEAM approach, namely Science, Technology, Engineering, Arts, and Mathematics. This approach is an adaptation of STEM that emphasizes the interconnection between two or more fields of knowledge to facilitate learning through observation, inquiry, and problem-solving [10]. STEAM emerges as an innovation in learning that highlights the integration of various disciplines to develop 21st-century skills through an interdisciplinary and project-based approach. RBL requires the integration of STEAM to optimize the development of students' skills in solving problems that involve multiple disciplines [11].

In this study, the RBL-STEAM model is integrated into the context of zakat distribution problems as an effort to provide learning that is contextual, relevant, and based on real-world problem solving. Zakat distribution plays a crucial role in the Islamic economic system. Zakat is one of the state financial instruments that has existed since the time of Prophet Muhammad (peace be upon him) and constitutes one of the pillars of Islam [12]. In Islamic teachings, zakat is an obligation for individuals or institutions that have fulfilled the nisab requirements [13]. Zakat functions as a means of wealth redistribution and contributes to poverty alleviation. However, in practice, zakat distribution often faces various challenges, such as unequal distribution, limited transparency, and difficulties in accurately managing zakat recipient data [14]. To address these issues, solutions are needed that rely not only on economic approaches but also on the application of innovative technologies.

Blockchain, as a technology that enables decentralized and secure data storage and management, has emerged as a potential solution to address these problems in line with the rapid development of digital technology [15]. This technology connects data blocks cryptographically and is known as a distributed, transparent, secure, and tamper-resistant recording system [16]. The application of graph theory has become increasingly important in managing complex data. A graph is a mathematical structure that represents relationships among elements, known as nodes, which are interconnected through edges [17]. The use of graphs in blockchain enables a better understanding of how data are interconnected and interact with one another. One example of a graph concept that can be applied in blockchain is the perfect dominating set.

A perfect dominating set is a subset of vertices in a graph that satisfies two main conditions. First, every vertex that does not belong to the subset must have at least one neighbor within the subset, ensuring that the subset dominates the graph. Second, the set is considered perfect when every vertex outside the subset has exactly one neighbor in the subset, thereby ensuring unique domination while still covering the entire graph [18]. Blockchain that implements the perfect dominating set technique can be used to improve the efficiency of zakat distribution by ensuring that every zakat recipient can be reached and connected to the existing system, so that no recipient is overlooked.

Although these topics have significant potential, studies that comprehensively integrate RBL-STEAM, blockchain technology, and graph theory concepts into mathematics learning materials remain relatively limited. Therefore, this study aims to develop RBL-STEAM learning materials based on blockchain in the context of zakat distribution using the perfect dominating set technique, which meet the criteria of validity, practicality, and effectiveness. These learning materials are expected to contribute as a new paradigm in discrete mathematics learning. In addition, the development of these materials is also expected to enhance students' combinatorial thinking skills in solving complex problems that are relevant to global challenges in the digital era [19].

2. Material and Methods

2.1. RBL-STEAM

Research-Based Learning (RBL) was first introduced at Griffith University in 2008 and is grounded in the philosophy of constructivism. This philosophy requires students to take an active role in the learning process. RBL is a learning model that emphasizes students' active participation in the research process as part of their learning experience [20]. In the context of mathematics education, RBL offers significant potential to transform the learning paradigm from merely mastering procedures to strengthening mathematical thinking processes and developing deeper understanding [21]. Through students' engagement in the research process, RBL aims to facilitate deeper and more applicable learning, while also preparing them to address complex problems they may encounter in the professional world [22].

The main objective of *Research-Based Learning* (RBL) is to improve the quality of learning by providing students with opportunities to engage directly in research activities [23]. In this approach, students do not merely study theoretical concepts, but are also guided to apply the knowledge they have acquired in more realistic contexts. This approach enables students to connect academic learning with real-world challenges and provides them with direct experience in the process of knowledge development [24]. Through students' involvement in the research process, RBL aims to facilitate deeper and more applicable learning, as well as to prepare them to address complex problems they may encounter in the professional world [22].

In the continuously evolving field of education, there has been a paradigm shift toward more holistic and interdisciplinary learning approaches to prepare students with the skills required in the 21st century [25]. STEAM education, which integrates Science, Technology, Engineering, Arts, and Mathematics, has become increasingly popular globally as an innovative educational approach [26]. STEAM has been implemented across various disciplines, such as history, mathematics, and integrated curricula, to provide comprehensive insights into different fields while enriching students' knowledge and skills [27]. The STEAM approach strongly supports project- and research-based learning, as applied in Research-Based Learning 28.

This study applies the RBL model integrated with the STEAM approach to enhance students' combinatorial thinking skills in solving zakat distribution problems using the perfect dominating set technique in graph theory. The integration of these elements provides a learning framework that connects abstract mathematical reasoning with technological applications, thereby fostering analytical, research-oriented, and innovative abilities in mathematics education at the university level.

2.2. Combinatorial Thinking Skills

Combinatorial skills refer to the ability to understand and apply combinatorial principles in solving problems involving counting, arranging, and selecting elements from a given set [29]. These skills can also be applied in decision-making, planning, and experimental design. Furthermore, combinatorial thinking can develop students' ability to solve more complex problems and enhance their critical and creative thinking skills [1].

Combinatorial skills strengthen the ability to solve problems by evaluating various possibilities and alternatives. These skills also develop critical and creative thinking abilities to find innovative solutions to complex problems. In addition, combinatorial skills are highly useful in decision-making and have applications in everyday life, as well as in the fields of technology and computer science [1].

Various researchers have proposed different indicators of combinatorial thinking skills according to the context and objectives of learning. In general, these indicators emphasize the ability to identify patterns, generalize cases, construct algorithms, perform mathematical proofs, and apply concepts to new or open-ended problems. In the context of this study, combinatorial thinking serves as a foundation for connecting mathematical reasoning with zakat distribution through the *perfect dominating set* technique.

2.3. Methods

The development process was carried out systematically through the four stages of the 4D model, namely Define, Design, Develop, and Disseminate, as presented in Figure 1.

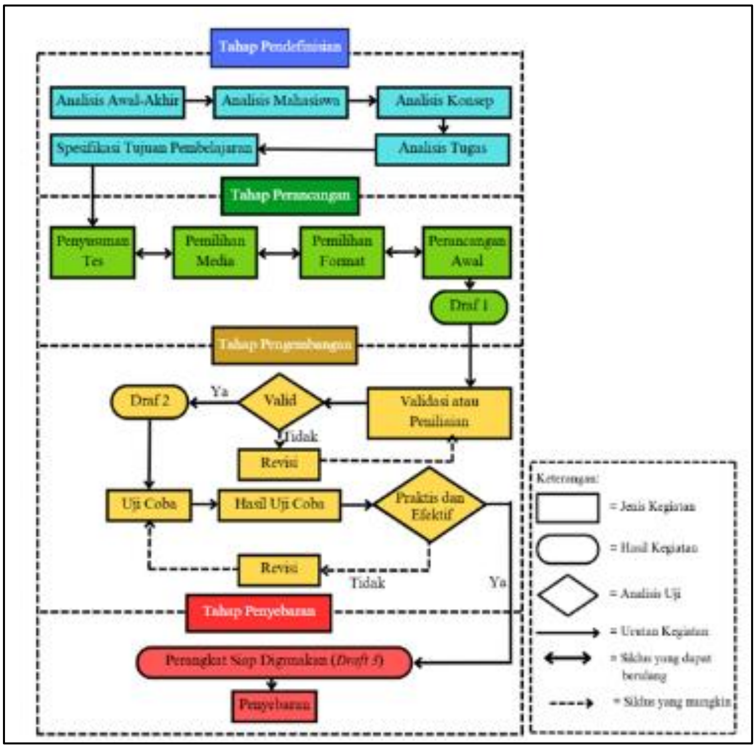

Figure 1 The flowchart of the 4D development model

The research procedure in this study refers to Thiagarajan's development model, commonly known as the 4D model. This model consists of four main stages, namely *Define*, *Design*, *Develop*, and *Disseminate*. The systematic flow of learning tool development based on the 4D model is presented in Figure 1. Data collection techniques in this study employed several research instruments, including learning tool validation sheets, learning implementation observation sheets, learning outcome tests, activity observation sheets, and response questionnaires. The collected data were analyzed quantitatively with the assistance of the SPSS application. The statistical analysis used was the *paired sample t-test* to determine the differences in learning outcomes before and after the implementation of the learning tools.

3. Results and Discussion

3.1. RBL-STEAM Implementation

The RBL-STEAM learning model encourages students to take a more active role in the learning process through direct engagement in research activities. In the initial stage of the RBL syntax, problems are formulated based on open-ended issues developed within research groups. In this study, the problem examined focuses on zakat distribution, as presented in Figure 2.

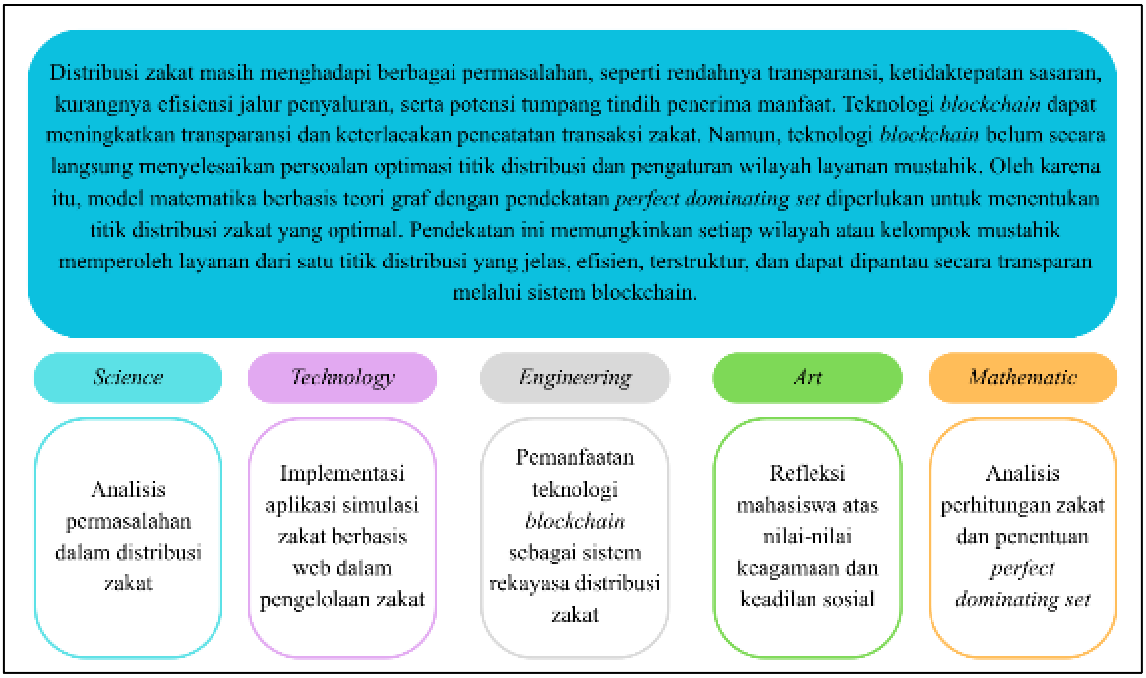

Figure 2 STEAM elements of Zakat Distribution

This study aims to address the problem of zakat distribution through the application of the *perfect dominating set* technique in graph theory using the RBL-STEAM learning model. Therefore, the RBL-STEAM activity framework in this study is designed through several stages: (1) students examine previous studies related to zakat distribution and the concept of *perfect dominating set*; (2) students design a conceptual solution by connecting the theory of *perfect dominating set* to the problem of zakat distribution; (3) students utilize web-based technology to systematically simulate the zakat distribution process; (4) students formulate and prove a *perfect dominating set* theorem, and subsequently apply it to analyze and solve a zakat distribution case study; (5) students generalize the obtained zakat distribution solution by relating it to religious and ethical values, particularly the Islamic principles of justice, trustworthiness, and social responsibility; and (6) students draw conclusions by presenting their findings on solving zakat distribution problems using the *perfect dominating set* technique integrated within the RBL-STEAM framework.

The sequence of the activities and their relationship to the STEAM domains are presented in figure 3. The figure illustrates the RBL-STEAM activity framework for solving zakat distribution problems through the application of the Perfect dominating set technique.

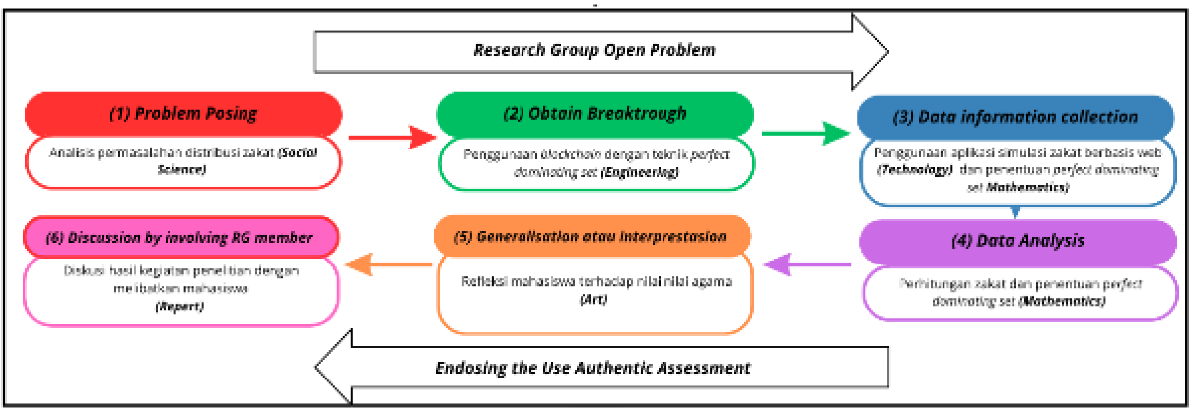

Figure 3 RBL-STEAM Activity Framework for the Perfect Dominating Set Problem

3.2. Validity, Practicality, and Effectiveness of RBL-STEAM Tools

The first stage in the 4D development model is the Define phase. This stage aims to identify learning needs through an analysis of learning objectives, student characteristics, the scope of the material, and the competencies to be developed.

In this phase, four main activities are conducted, namely front-end analysis, learner analysis, concept analysis, and task analysis. The front-end analysis is carried out to examine the problems and difficulties encountered by students in the learning process, particularly in understanding the concept of perfect dominating set and its application in solving zakat distribution problems. The results of this analysis serve as the basis for designing learning tools that are appropriate to students' needs. Learner analysis is conducted to obtain information about the characteristics of fourth-semester students in Class E of the Mathematics Education Study Program at the University of Jember, including their prior knowledge, learning motivation, and learning preferences. Furthermore, concept analysis aims to identify, elaborate, and systematically organize the key concepts related to graph theory, perfect dominating set, and blockchain-based zakat distribution, which are integrated into RBL-STEAM learning. Task analysis is conducted to determine the essential skills and expected learning outcomes in accordance with the mathematics education curriculum. This analysis focuses on developing students' combinatorial thinking skills as the final competency to be achieved through the developed learning tools.

The second stage in the 4D development model is the *Design* phase. This stage aims to design and develop the learning tools to be used in the study, resulting in an initial prototype of the developed tools. In this phase, the RBL-STEAM-based learning tools were designed to examine their potential in improving students' combinatorial thinking skills through the application of the *perfect dominating set* concept to zakat distribution problems. The design stage consists of four main activities: test preparation, media selection, format selection, and initial design development. Test preparation was carried out by developing essay questions that integrate STEAM elements and relate to the application of the *perfect dominating set* concept in the context of zakat distribution. Media selection involved the use of PowerPoint as a presentation medium to deliver materials related to graph theory, as well as the development of RBL-STEAM-based learning modules containing indicators of combinatorial thinking skills. The learning format adopted in this study refers to the RBL model integrated with the STEAM approach through systematic and structured learning stages. The initial design of the learning tools included the main components required in the study, namely the Student Worksheet (LKM) and the Learning Outcome Test (THB). A visualization of the developed learning tools is presented in Figure 4.

Figure 4 Initial Design of LKM and THB

The third stage in the 4D development model is the *Develop* phase. This stage consists of four main activities, namely validity testing, learning tool trials, practicality testing, and effectiveness testing. All learning tools developed at this stage were validated by expert validators and subsequently revised based on the feedback, suggestions, and recommendations provided. After the learning tools were declared valid, they were tested on fourth-semester students of Class E in the Mathematics Education Study Program at the University of Jember in the Discrete Mathematics course. Based on the assessments of the two validators, the developed learning tools were considered feasible for use with minor revisions. Therefore, improvements and refinements were made to enhance the quality of the tools before their implementation in the learning process. Based on the recapitulation of the validation results for the RBL-STEAM learning tools and instruments presented in Table 1, the average validation score was 3.79, with a percentage of 94.5%. Referring to the validity criteria, the developed learning tools met the validity requirements, as the score fell within the range of $3.26 \le Va < 4$. Thus, the RBL-STEAM learning tools were declared valid and feasible for use in the subsequent development stage.

Table 1 Recap of RBL-STEM Device Validation

Validattion Result	Average Score	Percentage
Learning Device	3.80	94,60%
Student Activity Observation sheet	3.80	94.40%
RBL-STEAM Implementation Sheet	3.76	94.00%
Student Response Questionnaire	3.80	95.00%
Overall average score	3.79	94.50%

The learning tools that had undergone revision and validation were subsequently tested on students to measure their practicality and effectiveness. The trial was conducted with 35 students enrolled in the Discrete Mathematics course in the Mathematics Education Study Program at the University of Jember. The implementation of the trial was assisted by eight observers, who were postgraduate students of Mathematics Education at the Faculty of Teacher Training and Education, University of Jember. Observation data and assessments of students' learning outcomes were used as the basis for evaluating the practicality and effectiveness of the developed RBL-STEAM learning tools.

The practicality test in this study consisted of two main indicators: the analysis of classroom learning implementation and the analysis of students' responses. The implementation of learning was observed using the RBL-STEAM implementation observation sheet, which was assessed by eight observers during the learning process. Based on the observation results, the average score for learning implementation was 3.81, with a percentage of 95.13%. Referring to the practicality criteria, the developed learning tools were categorized as highly practical because the score fell within the range of $90\% \leq SR \leq 100\%$.

Table 2 Observation Results of RBL-STEAM Model Implementation

Assessed Aspects	Average Score	Percentage
RBL-STEAM syntax	3.83	96.00%
Social system	3.75	93.75%
Reaction and management principles	3.83	95.65%
Overrall average score	3.81	95.13%

Based on the results of the student response questionnaire, the overall average percentage of positive responses was 92.05%. This percentage indicates that the developed learning tools were well received by students and were considered easy to use during the learning process. Based on the analysis of the two practicality indicators, namely learning implementation and student responses, it can be concluded that the developed RBL-STEAM learning tools meet the practicality criteria and are feasible to be implemented in mathematics learning activities.

Table 3 Summary of Data from Student Response Questionnaire Results

Assessed Aspects	Percentage
Enjoyment of the learning component	97.86%
Learning components are new	92.20%
Students are interested in learning	85.71%
Students clearly understand the language used	92.86%
Students understand the meaning of each problem presented	81.43%
Students are attracted by the appearance	97.15%
Students enjoy discussing with group members	97.14%
Overrall average score	92.05%

The effectiveness test of the developed learning tools included two main indicators, namely the analysis of students' learning outcomes and the analysis of students' activities during the learning process. The learning outcome data were obtained through the administration of a post-test on Monday, April 20, 2026, involving 35 students as the research subjects. Based on the post-test results, 32 students, or 91%, achieved scores above the minimum completeness criterion. This finding indicates that the learning process using the developed tools met the criterion for classical completeness.

Student activities were observed comprehensively throughout the learning process, including the introduction, core activities, and closing activities. The analysis of student activities was conducted based on the student activity observation sheets assessed by eight observers. As presented in Table 4, the results of student activity observations obtained an average score of 3.83, with a percentage of 96%. In addition, most of the comments provided by the observers indicated positive responses. This suggests that the developed RBL-STEAM learning tools were able to support an active, engaging, and meaningful learning process without requiring significant revisions. Based on the effectiveness criteria, the developed learning tools were categorized as highly effective because the score fell within the range of 90% ≤ P ≤ 100%. Therefore, the RBL-STEAM learning tools designed to improve students' combinatorial thinking skills in solving zakat distribution problems through the perfect dominating set technique can be declared effective for classroom implementation.

Table 4 Recapitulation of Student Activity Observation Results

Assessed Aspects	**Average Score**	**Percentage**
Introduction	4.00	100.00%
Core Activities	3.75	94.00%
Closing	3.75	93.75%
Overall average score	3.83	96.00%

The final stage of the development process is the Deployment stage. This stage is carried out by implementing the developed learning tools on a broader scale, such as in other classes or study programs that offer similar courses and have not previously been involved in the trial. The deployment stage aims to examine the extent to which the developed RBL-STEAM learning tools can be effectively implemented in various learning contexts. In addition, this stage is intended to ensure that the learning tools maintain good quality and consistency when applied to different groups of students.

3.3. Improvement of Combinatorial Thinking Skills

This section describes the improvement in students' combinatorial thinking skills after the implementation of the RBL-STEAM-based learning tools. The improvement was analyzed based on the results of the Learning Outcome Test (THB), which was administered before and after the learning process. The analysis of students' combinatorial thinking skills focused on five main indicators, namely identifying several cases, recognizing patterns across all cases, generalizing all cases, constructing mathematical proofs, and considering connections with other combinatorial problems. The distribution of students' pre-test and post-test scores is presented in Figure 5, while the percentage levels of students' combinatorial thinking improvement after the implementation of RBL-STEAM learning activities are shown in Figure 6.

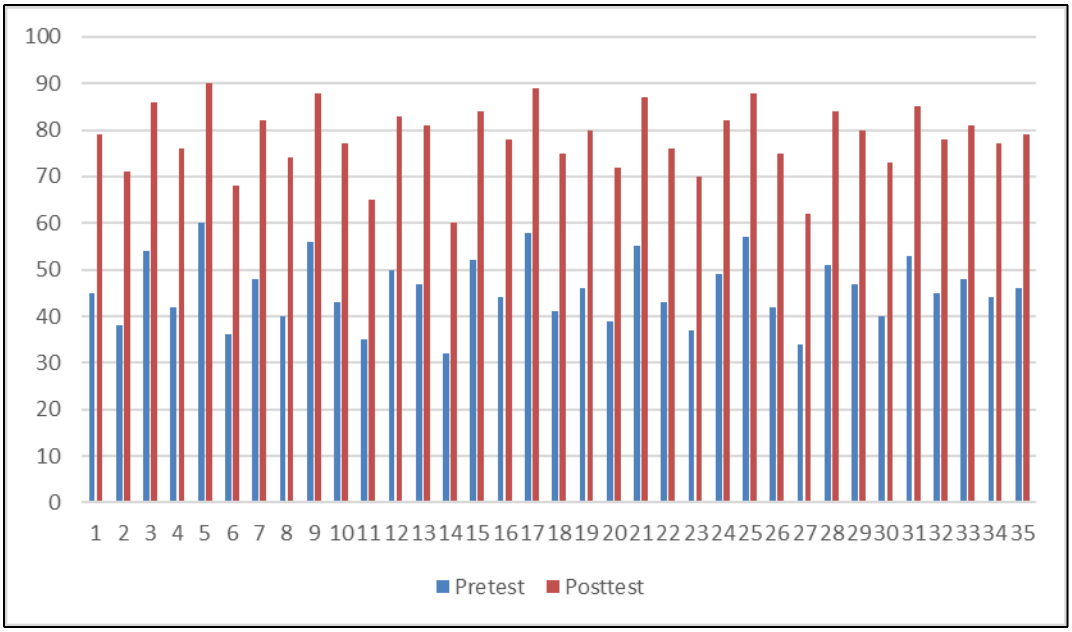

Figure 5 Graph of Distribution of Pretest and Posttest Scores

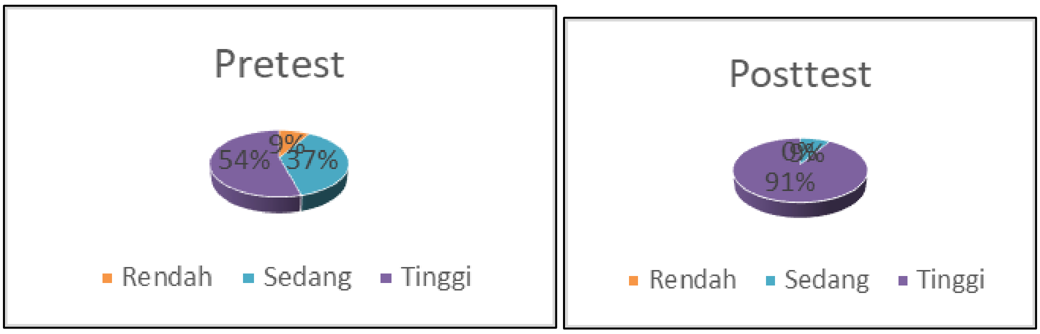

Figure 6 Percentage of Students' Combinatorial Thinking Skills Level

Based on the classification results in the pre-test stage, 9% of students were categorized as having a low level of combinatorial thinking skills, 37% were in the moderate category, and 54% were in the high category. After the implementation of the learning process and the administration of the post-test, an improvement in achievement was observed, with 91% of students reaching the high category of combinatorial thinking skills, 9% remaining in the moderate category, and no students classified in the low category. These findings indicate a significant improvement in students' combinatorial thinking skills after participating in RBL-STEAM learning focused on solving zakat distribution problems using the perfect dominating set technique. Furthermore, a normality test was conducted as a prerequisite before performing the paired samples t-test to ensure that the data were normally distributed. The statistical analysis, carried out with the assistance of SPSS software, confirmed that the implementation of the RBL-STEAM learning tools had a positive effect on improving students' combinatorial thinking skills.

Table 5 Normality Test Results

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	0.056	35	0.200*	0.985	35	0.892
Posttest	0.079	35	0.200*	0.966	35	0.351

Based on the normality test results presented in Table 5, the pre-test and post-test scores were found to be normally distributed, as the significance value (Sig.) > 0.05. After the normality assumption was fulfilled, the analysis was continued using the paired samples t-test, as shown in Table 6.

Table 6 Paired Sample Statistics

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pretest	45.6286	35	7.19103	1.21551
	Posttest	78.1429	35	7.44052	1.25768

The test results presented in Table 6 show that the average post-test score was higher than the average pre-test score. This indicates a significant improvement in students' learning outcomes after the implementation of the RBL-STEAM-based learning tools. The average pre-test score, which was initially 45.68, increased to 78.14 in the post-test. This improvement demonstrates a substantial development in students' combinatorial thinking skills after participating in RBL-STEAM learning activities involving zakat distribution problems through the application of the perfect dominating set technique. In addition, the number of data entries in both the pre-test and post-test was 35, corresponding to the number of students who participated in this study.

Table 7 Paired Sample Correlations

Paired Samples Correlations				
		N	Correlation	Sig.
Pair 1	Pretest & Posttest	35	0.978	0.000

The test results presented in Table 7, with a total of 35 data entries, show that the correlation value between the pre-test and post-test scores was 0.978 > 0.05. This value indicates a strong relationship between the two scores. In other words, students who obtained high scores in the pre-test tended to achieve higher scores in the post-test as well. These findings indicate that the implementation of the RBL-STEAM learning tools contributed consistently and measurably to the improvement of students' combinatorial thinking skills in solving zakat distribution problems through the application of the perfect dominating set technique.

Table 8 Paired Sample Test

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	-32.514	1.560	0.263	-33.050	-31.978	-123.305	34	0.000

The test results presented in Table 8 show that the probability value, or Sig. (2-tailed), was 0.000 < 0.05. This value indicates a statistically significant difference between the pre-test and post-test scores. Therefore, it can be stated that students' combinatorial thinking skills improved significantly after participating in learning activities using the RBL-STEAM learning tools. These findings further confirm that the implementation of RBL-STEAM-based learning tools is effective in enhancing students' ability to analyze, construct, and apply mathematical reasoning to solve zakat distribution problems through the perfect dominating set technique.

4. Conclusion

Based on the results of the study concerning the development of RBL-STEAM-based learning tools to improve students' combinatorial thinking skills, it was found that the developed tools met the criteria of validity, practicality, and effectiveness. Quantitative analysis was conducted by processing the pre-test and post-test data through normality testing and the paired samples t-test. The results of the normality test showed that the pre-test and post-test data were normally distributed, as indicated by the significance value (Sig.) greater than 0.05. Furthermore, the results of the paired samples t-test obtained a Sig. (2-tailed) value of 0.000 < 0.05. This indicates a significant difference between students' scores before and after participating in learning using the RBL-STEAM learning tools. These findings indicate that the implementation of RBL-STEAM learning tools significantly improves students' combinatorial thinking skills, particularly in solving zakat distribution problems through the perfect dominating set technique. Therefore, the results of this study can serve as a reference for the further development of RBL-STEAM learning tools, especially those oriented toward enhancing mathematical reasoning and higher-order thinking skills in mathematics education.

Compliance with ethical standards

Acknowledgments

The authors would like to express their sincere appreciation and gratitude to the University of Jember for the academic support and facilities provided, which enabled this research to be conducted and completed successfully. Special thanks are also extended to the expert validators for their valuable feedback, guidance, and constructive suggestions during the development and refinement of the learning tools. The authors also wish to thank the lecturers and students of the Mathematics Education Study Program who participated in the implementation of this research and provided the necessary data. Appreciation is likewise extended to the observers who assisted in collecting data through classroom learning observations.

This research was funded by the PUI-PT Combinatorics and Graph (CGANT), University of Jember, in 2026. The authors also extend their gratitude to LP2M, University of Jember, for their invaluable support in facilitating this project.

Disclosure of Conflict of interest

The authors declare that they have no conflict of interest.

Statement of Ethical Approval

This research was approved by the Research Ethics Committee of Universitas Jember.

Statement of Informed Consent

All participants gave their informed consent before participating in this study.

References

[1] Putra, E. D., Slamin, Kristiana, A. I., & Suwito, A. (2025). Development of Educational Research on Integrated Combinatorial-Thinking learning model: Combinatorial thinking skills. International Journal of Innovative Research and Scientific Studies, 8(2), 1821–1832. https://doi.org/10.53894/ijirss.v8i2.5552

[2] Najichah, Z., Mukaromah, S. U., & Jariyah, I. A. (2025). The role of creative thinking in educational development in the Society 5.0 era. Jurnal Citra Pendidikan, 5(2), 32–45. https://doi.org/10.38048/jcp.v5i2.4630

[3] Ferrini-Mundy, J. (2000). Principles and standards for school mathematics: A guide for mathematicians. Notices of the American Mathematical Society, 47(8), 868–876.

[4] Naghme, Hasan, F. (2020). Toward a model for students' combinatorial thinking. The Journal of Mathematical Behavior.

[5] Maylisa, I. N., Dafik, Hadi, A. F., Wangguway, Y., & Harjito, L. O. (2020). The influence of research-based learning implementation in improving students' combinatorial thinking skills in solving local irregularity vertex r-dynamic coloring. Journal of Physics: Conference Series, 1538(1), 012090. https://doi.org/10.1088/1742-6596/1538/1/012090

[6] Cirneanu, A. L., & Moldoveanu, C. E. (2024). Use of digital technology in integrated mathematics education. Applied System Innovation, 7(4), 66. https://doi.org/10.3390/asi7040066

[7] Marsidi. (2025). The Development of RBL- STEM Learning Materials to improve Students ' Combinatorial Thinking Skills in Solving DNA Protection Problems. 18(3), 409–434.

[8] Adawiyah, R., Kristiana, A. I., & Lutfi, M. (2023). Enhancing Students ' Combinatorial Thinking for Graceful Coloring Problem : A STEM-Based , Research-Informed Approach in ATM Placement. 8(1), 77–93. https://doi.org/10.24042/tadris.v8i1.15176

[9] Kristiana, A. I., Ridlo, Z. R., Prihandini, R. M., & Adawiyah, R. (2022). Research Based Learning and STEM Learning Activities : The Use of R-Dynamic Coloring to Improve the Students Meta-literacy in Solving a Tessellation Decoration Problem. 3(4), 52–60.

[10] Octavianingrum, D. (2022). Design of a Research-Based Learning model to improve research culture. Jurnal Pendidikan dan Konseling (JPDK), 4(6), 7769–7776.(https://doi.org/10.31004/jpdk.v4i6.9542)

[11] Jamil, D. O., & Kristiana, A. I. (2025). The Development of RBL-STEAM Learning Materials to Enhance Undergraduate Students ' Computational Thinking Skills in Solving Zakat Distribution Problems Using Local Irregular Labeling.

[12] Irkhami, N. (2019). Zakat , Kharāj , ' Ushr , And Jizya As The Instruments Of Islamic Public Finance : A Contemporary Study. 8(1), 90–113. https://doi.org/10.22373/share.v8i1.3804

[13] Mukhlishin, Wahab, A., Setiaji, B., & Tazhdinov, M. (2024). Zakat Maal Management and Regulation Practices: Evidence from Malaysia, Turki and Indonesia. Journal of Human Rights, Culture and Legal System, 4(2), 569–592. https://doi.org/10.53955/jhcls.v4i2.204

[14] Musnaeni, M., & Khasanah, A. M. (2025). Zakat distribution as an instrument for poverty alleviation in the practice of Zakat Management Institutions in Indonesia. Jurnal Miftahul Ilmi: Jurnal Pendidikan Agama Islam, 2(2), 89–100. (https://doi.org/10.59841/miftahulilmi.v2i2.88)

[15] Mokodenseho, S., Syafri, M., & Judijanto, L. (2023). Utilizing Blockchain Technology to Increase Transparency in Zakat Management. 1(01), 1–9.

[16] [16] Nadia Puspita Sari, F. A. (2025). Optimization of blockchain technology in zakat accounting: A literature study in accounting, Faculty of Economics and Business. 2(4), 419–426.

[17] Phule, S. E. (2024). Graph Theory Applications in Database Management. 3(3), 13–17.

[18] Livingston, M., & Ý, Q. F. S. (1990). PERFECT DOMINATING SETS. 79.

[19] Sandefur, J., Lockwood, E., & Greefrath, G. (2022). Teaching and learning discrete mathematics. ZDM – Mathematics Education, 54, 753–775. https://doi.org/10.1007/s11858-022-01399-7

[20] Estuhono. (2022). Research-Based Learning Models in Physics for 21st Century Students. 14, 1803–1814. https://doi.org/10.35445/alishlah.v14i1.1268

[21] Prahmana, R. C. I. (2017). The role of research-based learning to enhance students' research and academic writing skills. Journal of Education and Learning, 11(3), 351–366.

[22] Hasan, M. (2022). Research-based learning: Theoretical foundations, planning, implementation, and evaluation. Tahta Media Group.

[23] Charitas, R., & Prahmana, I. (2017). The Role of Research-Based Learning to Enhance Students ' Research and Academic Writing Skills. 11, 351–366.

[24] Yanti, F. A., Yunitasari, Thohir, M. A., & Kinasih, A. (2024). Implementation Process of Research-Based Learning (RBL) in Science Learning. Formatif: Jurnal Ilmiah Pendidikan MIPA.

[25] Barkah, E. S., Awaludin, D., Iqbal, M., & Asykuri, E. (2024). Implementation of the STEAM learning model (Science, Technology, Engineering, Arts, and Mathematics): A strategy for improving 21st-century skills. *5*(9), 3501–3511.

[26] Naim, S., & Mokodenseho, S. (2022). Implementation of the Virtual Learning Models during the Covid-19 Pandemic: Students' Perspectives and Its Lessons. Jurnal Kependidikan: Jurnal Hasil Penelitian Dan Kajian Kepustakaan Di Bidang Pendidikan, Pengajaran Dan Pembelajaran, 8(3), 617. https://doi.org/10.33394/jk.v8i3.5570

[27] Smerda-Mason, D. L. (2023). Integration of STEAM education supports the future of cybersecurity. Handbook of Research on Current Trends in Cybersecurity and Educational Technology, 140–155. https://doi.org/10.4018/978-1-6684-6092-4.ch008

[28] Kavitha, R. N., & Kareem, J. (2025). Mediating Role of Mathematics and Science Engagement in the Relationship between Attitude toward STEM Education and Subjective Well-being of Adolescents. Science Education International, 36(1), 48–56. https://doi.org/10.33828/sei.v36.i1.5

[29] Khunaifi, M. H., & Susanah, S. (2023). High school students' combinatorial thinking in solving combinatoric problems based on mathematical ability. MATHEdunesa, 12(2), 450–468. https://doi.org/10.26740/mathedunesa.v12n2.p450-468