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(RESEARCH ARTICLE)

The Development of RBL-STEAM Learning Materials to Enhance Undergraduate Students' Computational Thinking Skills in Solving Zakat Distribution Problems Using Local Irregular Labeling

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Abstract

This study aims to develop and validate Research-Based Learning (RBL) instructional materials integrated with the Science, Technology, Engineering, Arts, and Mathematics (STEAM) framework that are valid, practical, and effective in enhancing undergraduate students' computational thinking skills. The instructional materials address the optimization of zakat distribution through blockchain technology, grounded in the concept of local distance irregular labeling. This research adopted a Research and Development (R&D) methodology using the 4D model. The participants consisted of undergraduate students enrolled in the Mathematics Education program at Nurul Jadid University. Research instruments included expert validation sheets, student response questionnaires, and a computational thinking skills test encompassing the indicators of decomposition, pattern recognition, abstraction, and algorithmic thinking. The findings indicate that the developed instructional materials satisfy the criteria of validity, as evidenced by expert judgment; practicality, based on implementation observations and student responses; and effectiveness, demonstrated by a statistically significant improvement in students' computational thinking skills following the implementation of the learning intervention. The integration of Islamic philanthropy (zakat) with emerging technologies and graph-theoretical concepts within these instructional materials provides meaningful learning experiences while strengthening students' capacity to solve complex problems in the digital era

Keywords: RBL-STEAM; Computational Thinking; Zakat Distribution; Blockchain Technology; Local Distance Irregular Labeling

1. Introduction

The rapid advancement of digital technology in the era of Society 5.0 has significantly transformed the landscape of higher education. Mathematics education is no longer just about calculating formulas but is now focused on equipping students with 21st-century skills to solve complex real-world problems. One of the most vital cognitive skills in this context is computational thinking [1]. Computational thinking allows students to approach problems logically and algorithmically, which is the foundation for understanding modern technologies like artificial intelligence and data science [2].

However, empirical evidence suggests that many students still struggle with high-order thinking skills, particularly in decomposing complex mathematical structures. Traditional learning meth-ods often fail to bridge the gap between abstract mathematical theories and their practical applications in the digital world [3]. In the context of mathematics

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education, there is an urgent need for a learning model that can stimulate students' curiosity and research-oriented mindset to improve their computational thinking skills [4].

One of the most promising solutions is the Research-Based Learning (RBL) model. RBL empowers students to act as researchers, where they undergo the process of identifying problems, collecting data, and finding solutions through scientific inquiry [5]. Studies have shown that RBL can significantly increase student engagement and independence in learning complex mathematical concepts [6]. By integrating research into the curriculum, students can understand how a theory is constructed and applied.

To make RBL more relevant to current industry needs, it is integrated with the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach. STEAM provides a transdisciplinary framework that encourages students to see a problem from multiple perspectives [7]. The inclusion of "Arts" in mathematics education helps in visualizing abstract concepts, while "Engineering" and "Technology" provide the tools for practical implementation. The synergy between RBL and STEAM creates a robust environment for fostering computational thinking [8].

In this study, the RBL-STEAM model is applied to a contemporary and socially relevant context: the management of zakat (Islamic philanthropy). Indonesia, as a country with a large Muslim population, faces significant challenges in the transparency and accountability of zakat distribution [9]. Conventional zakat management systems often lack real-time data tracking, leading to potential mismanagement. This social issue provides a rich context for students to apply mathematical logic in creating a better system [10].

Blockchain technology is introduced as a digital solution to these zakat distribution problems. Blockchain's decentralized and immutable nature ensures that every transaction is recorded transparently and cannot be tampered with [11]. For mathematics students, blockchain is not just a financial tool but a manifestation of complex graph structures and cryptographic algorithms. Understanding how blockchain works requires strong computational thinking, specifically in designing secure and efficient data flow [12].

From a mathematical standpoint, the optimization of these distribution networks can be modeled using graph theory, specifically through local distance irregular labeling. This type of labeling focuses on assigning unique weights to vertices based on their local distances, ensuring no two adjacent nodes have the same properties [13,14]. This concept is crucial in modeling a fair and non-overlapping zakat distribution network where each recipient (mustahik) is uniquely identified within the blockchain system [15].

Despite the potential of these topics, there is limited research that integrates RBL-STEAM, blockchain technology, and graph labeling into a single learning tool for mathematics education. Therefore, this research aims to develop a valid, practical, and effective RBL-STEAM learning tool based on blockchain-zakat and local distance irregular labeling. This tool is expected to provide a new paradigm in teaching discrete mathematics while simultaneously enhancing students' computational thinking skills in facing global challenges [16].

2. Material and methods

This section describes the systematic approach and the specific components utilized in developing the research-based learning tools. The study employed a Research and Development (R&D) methodology, specifically following the 4D development model—Define, Design, Develop, and Disseminate—to ensure the creation of high-quality instructional materials [17]. The following subsections detail the essential materials involved, including the research subjects, the instructional framework, and the procedural stages of the development process.

2.1. Material

The research subjects involved in this study were undergraduate students enrolled in the Mathematics Education program at Universitas Nurul Jadid, Probolinggo, Indonesia. These subjects were strategically selected because they were undertaking the Discrete Mathematics course, which serves as the foundational knowledge for understanding graph theory and its modern applications. The involvement of these students was crucial to evaluate how a specialized pedagogical approach, such as RBL-STEAM, could be implemented in a real-world higher education setting, particularly when dealing with complex topics like blockchain-based digital philanthropy.

The core of this research is the development of instructional materials designed within the Research-Based Learning (RBL) framework integrated with Science, Technology, Engineering, Arts, and Mathematics (STEAM). These materials comprise a Student Task Plan (RTM), Student Worksheets (LKM), and a Learning Outcomes Test (THB). The RTM was structured to guide students through the systematic phases of research, while the LKM provided contextual problems regarding zakat distribution through the lens of local distance irregular labeling. All materials were meticulously oriented toward stimulating the four pillars of computational thinking: decomposition, pattern recognition, abstraction, and algorithmic design. This integration ensures that students are not merely passive recipients of information but active researchers who utilize mathematical concepts to solve contemporary digital issues.

Furthermore, several research instruments and supporting digital tools were employed to ensure the validity and functionality of the developed materials. The research instruments included expert validation sheets to assess content and construct accuracy, observation sheets to monitor the pedagogical implementation, and student response questionnaires to evaluate the practicality of the tools. A key supporting component of this study was the Digital Zakat Web Platform, which functioned as a simulation environment. This platform allowed students to visualize the decentralized nature of blockchain technology and apply graph labeling theories to solve zakat distribution bottlenecks. By utilizing this digital context, the learning environment became more immersive, bridging the gap between abstract mathematical modeling and tangible technological solutions.

2.2. Methods

The development process was conducted through the four stages of the 4D model: define, design, develop, and disseminate, as illustrated in Figure 1.

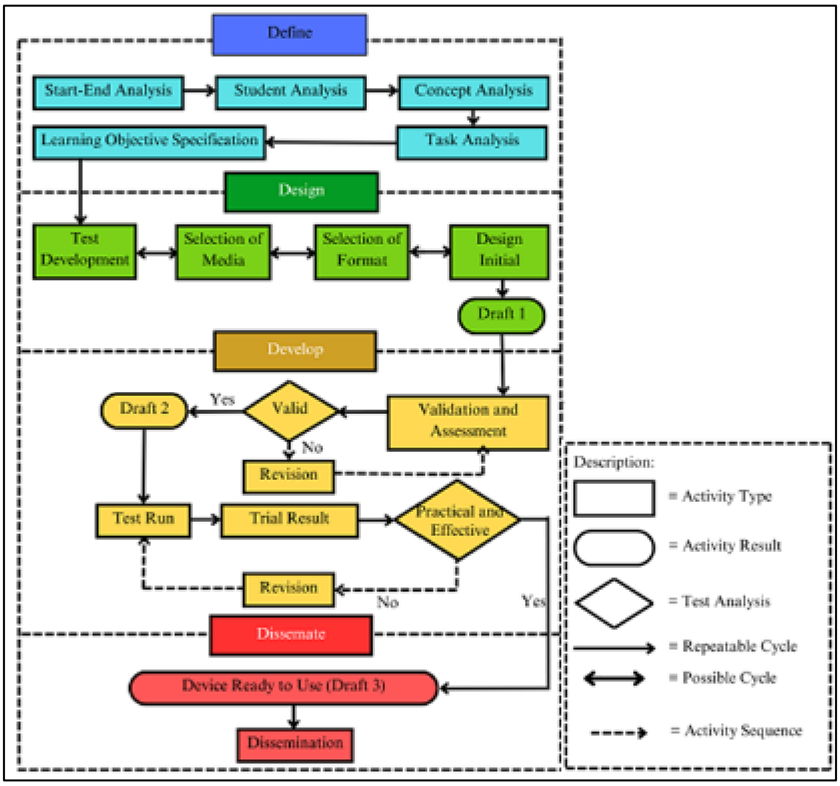

Figure 1 The flowchart of the 4D development model

In the define stage, a fundamental analysis was performed, including front-end analysis, student analysis, concept analysis, and task analysis to specify the learning objectives. This stage aimed to identify the core problems in computational thinking and the necessity of integrating blockchain-based zakat distribution into the curriculum. This was followed by the design stage, where the initial prototypes (Draft 1) of the RBL-STEAM learning tools were constructed. This phase included test development, selection of media, and selection of format to ensure alignment with the research objectives.

The develop stage involved two main activities: expert validation and developmental testing. The initial drafts (Draft 1) of the learning materials underwent validation and assessment by experts. If the materials were declared valid, they proceeded to a test run (Draft 2); otherwise, a revision process was required. The trial results were then analyzed to determine the practicality and effectiveness of the tools. If the criteria were not met, further revisions were performed until the device was ready to use (Draft 3). Finally, the disseminate stage was carried out through the dissemination of the finalized RBL-STEAM learning tools to lecturers and the academic community at Universitas Nurul Jadid, aiming to promote their use in broader educational contexts.

3. Results and discussion

This section presents and discusses the results obtained from the implementation and evaluation of the RBL-STEAM learning tools. The findings are organized into three main parts: (1) the implementation of the RBL-STEAM model in the context of blockchain-based zakat distribution, (2) the development and validation of the learning tools, and (3) the improvement of students' computational thinking skills. The discussion focuses on how the integration of Research-Based Learning, STEAM, and graph-theoretical concepts contributes to students' learning outcomes and supports the effectiveness, practicality, and validity of the developed instructional materials.

3.1. RBL-STEAM Implementation

The development of instructional materials in this study integrates five core components of STEAM into the context of digital zakat distribution management. Before detailing the procedural steps of the learning process, the conceptual framework of how Science, Technology, Engineering, Art, and Mathematics are embedded within the zakat distribution problem is illustrated in Figure 2.

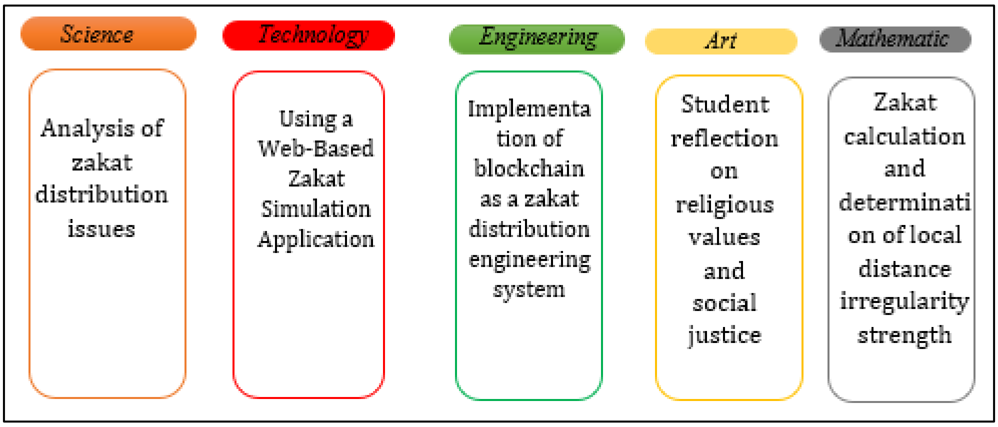

Figure 2 STEAM Elements in Zakat Issues

The implementation of RBL-STEAM framework in this study was conducted through six structured phases designed to facilitate the development of students' computational thinking in the context of blockchain-based zakat distribution. In the Science phase, learning activities began with the presentation of real-world problems related to zakat distribution. Students were guided to analyze key concepts and identify essential components of zakat, along with existing challenges in its distribution. This was followed by the Engineering phase, in which students designed alternative zakat distribution strategies supported by blockchain technology. At this stage, students decomposed the problem into logical components and developed preliminary algorithmic solutions aimed at ensuring transparency and decentralization.

The Technology phase emphasized the implementation of digital solutions through the use of a web-based zakat platform. Students explored relevant technological tools and simulated the distribution process, enabling them to translate conceptual models into operational procedures. In the Mathematics phase, graph-theoretical concepts were applied to represent the zakat distribution network. Students constructed mathematical models and formulated theorems related to local distance irregularity strength to evaluate the efficiency and structure of the distribution system. To support holistic learning, the Arts phase encouraged students to interpret their mathematical and technological solutions within the framework of Islamic ethical values and social responsibility. Through this phase, students connected their models to principles such as justice (*'adl*) and trust (*amanah*), reinforcing the ethical dimension of digital zakat management. Finally, in the Reporting phase, students compiled their analyses, mathematical models, and reflections into structured scientific reports. This phase emphasized systematic communication of results and critical reflection on the problem-solving process.

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

The development of the RBL-STEAM learning tools began with the **define** stage, which aimed to identify instructional needs through an analysis of learning objectives, content, and contextual constraints. At this stage, several analyses were conducted, including the identification of students' difficulties in understanding local distance irregular labeling, the examination of learner characteristics in the Mathematics Education program at Universitas Nurul Jadid, the systematic organization of relevant theoretical concepts, and the identification of key skills required by the curriculum, particularly students' computational thinking skills.

Based on the results of the define stage, the process continued to the **design** stage, in which the initial prototypes of the Semester Lesson Plan (RPS), Student Task Plan (RTM), Student Worksheets (LKM), and Learning Outcomes Test (THB) were developed. These learning tools were designed to integrate the concept of local distance irregularity strength within the context of blockchain-based zakat distribution in order to support the development of students' computational thinking skills. To illustrate the outcomes of the Design stage, the initial layouts and structures of the RTM, LKM, THB are presented in 3. These preliminary designs represent the conceptual framework of the RBL-STEAM approach embedded in the learning tools, including the alignment between learning objectives, computational thinking indicators, and the zakat distribution context.

Figure 3 Initial Design of the RBL-STEAM Learning Tools (RTM, LKM, and THB)

The **develop** stage focused on validating, revising, and testing the RBL-STEAM learning tools to ensure their quality and feasibility. At this stage, the developed instructional materials, including RTM, LKM, and THB, were evaluated by subject-matter and instructional design experts. The validation process examined content accuracy, alignment with the RBL-STEAM framework, clarity of presentation, and suitability for developing students' computational thinking skills. Based on the experts' suggestions, revisions were made to improve the structure, clarity, and coherence of the learning tools. Revisions and refinements of the learning tools were made based on the evaluations and feedback provided by three experts. The results indicated that the developed RBL-STEAM learning tools were feasible for use with minor revisions. All recommendations were incorporated to ensure that the materials met the required quality standards and were ready for implementation. As shown in Table 1, the average validation score was 3.68 (92%), which meets the validity criteria. According to Hobri [18], scores in the range of 3.26–4.00 indicate valid learning tools; therefore, the developed materials were considered valid and suitable for practicality testing.

Table 1 Recapitulation of RBL-STEAM Learning Tools Validation

Validation Result	Avarage Score	Percentage
Learning tools	3,74	93,50%
Student Activity Observation Sheet	3,58	89,50%
RBL-STEAM Implementation Sheet	3,77	94,25%
Student Response Questionnaire	3,63	90,75%
Overall average score	3,68	92%

After being revised and validated, the RBL-STEAM learning tools were implemented in a limited trial involving 33 undergraduate students. The classroom implementation was observed by seven observers, and the observation data, together with students' work, were used to evaluate the practicality of the learning tools. The results showed an average implementation score of 3.83 (95.75%), which falls into the very high practicality category [18]. In addition, most observer feedback was positive and did not require further revision, indicating that the developed learning tools were highly practical for classroom use. These findings confirm that the instructional design, learning activities, and supporting materials were implemented consistently in accordance with the RBL-STEAM framework. Furthermore, the observation results provide empirical evidence that the learning process was well managed and actively engaged students throughout the learning activities. The summarized of observation results of RBL-STEAM model implementation are presented in detail in Table 2.

Table 2 Observation Results of RBL-STEAM Model Implementation

Assessed Aspects	**Avarage Score**	**Percentage**
RBL-STEAM syntax	3,75	93,75%
Social system	3,81	95,25%
Reaction and management principles	3,92	98,00%
Overall average score	3,83	95,75%

The effectiveness of the developed RBL-STEAM learning tools was evaluated using three indicators: students' learning outcomes, classroom activity, and student responses. The learning outcomes was evaluated using a posttest (THB) administered to 33 undergraduate students. The results showed that 31 students (93.9%) achieved scores above the minimum mastery criterion, indicating that classical learning mastery was attained. This finding demonstrates that the developed learning tools were effective in supporting students' understanding of local distance irregularity strength in the Discrete Mathematics course.

Students' learning activities were evaluated through classroom observations conducted by seven observers across three learning phases: introduction, core activities, and closing. The observation results showed an overall average score of 3.83 (95.75%), which reflects a very high level of student engagement during the learning process. These results indicate that the RBL-STEAM learning tools successfully facilitated active and meaningful student participation throughout the instructional activities. The summarized results of the students' activity scores are presented in detail in Table 3.

Table 3 Recapitulation of Student Activity Observation Results

Assessed Aspects	**Avarage Score**	**Percentage**
Introduction	3,86	96,50%
Core activities	3,78	94,50%
Closing	3,86	96,50%
Overall average score	3,83	95,75%

Student responses toward the developed learning tools were collected through a questionnaire completed by all 33 participants. The results revealed an overall positive response rate of 94.26%, indicating that students perceived the learning tools as useful, engaging, and supportive of their learning. The summarized results of the student response scores are presented in detail in Table 4.

Table 4 Summary of Data from Student Response Questionnaire Results

Assessed Aspects	**Percentage**
Enjoyment of the learning component	96,97%
Learning components are new	90,15%
Students are interested in learning	87,87%
Students clearly understand the language used	95,45%
Students understand the meaning of each problem presented	95,45%
Students are attracted by the appearance	96,97%
Students enjoy discussing with group members	96,97%
Overall average score	94,26%

Taken together, the high level of learning achievement, strong classroom engagement, and highly positive student responses provide clear evidence that the developed RBL-STEAM learning tools are effective for teaching the topic of local distance irregularity strength. The final stage was the disseminate stage, which involved implementing the developed learning tools on a broader scale. This stage may be conducted in classes that were not included in the initial trial or in study programs offering related courses. The main purpose of this stage was to verify whether the learning tools could function effectively and consistently when applied in more diverse instructional contexts.

3.3. Improvement of Computational Thinking Skills

This section presents the improvement in students' computational thinking skills after the implementation of the RBL-STEAM learning tools. The improvement was analyzed based on the results of the Learning Outcomes Test (THB), which was administered before and after the learning intervention. The analysis focused on four indicators of computational thinking, namely decomposition, pattern recognition, abstraction, and algorithmic thinking.

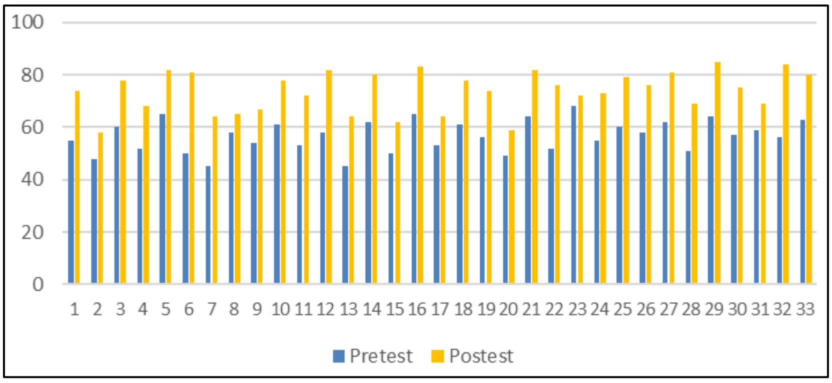

Figure 4 Graph of Distribution of Pretest and Posttest Scores

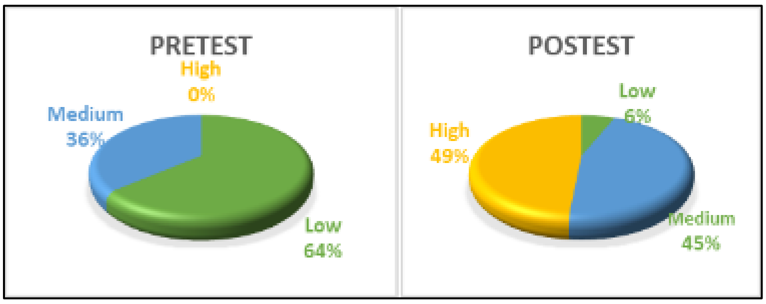

Figure 5 Percentage of Students' Computational Thinking Skill

Figures 4 and 5 present a graphical overview of students' computational thinking scores before and after the implementation of the RBL-STEAM learning tools. Figure 4 shows the distribution of individual pretest and posttest scores for all 33 students. A consistent increase from pretest to posttest can be observed across all participants, with no student experiencing a decline in score. This pattern indicates that the learning intervention had a positive effect on students' computational thinking performance. Figure 5 illustrates the distribution of students across three proficiency levels—low, medium, and high—before and after the intervention. At the pretest stage, most students were in the low and medium categories, whereas after the intervention, a substantial shift toward the high category is evident. This shift demonstrates a meaningful improvement in students' computational thinking skills at the group level.

Although the graphical results indicate a clear improvement in students' computational thinking performance, statistical analysis is required to determine whether this improvement is significant. Therefore, a series of inferential statistical tests, including the normality test and paired-sample t-test, were conducted to examine the significance of the difference between pretest and posttest scores.

Prior to conducting hypothesis testing, the normality of the pretest and posttest data was examined using the Shapiro–Wilk test. As shown in Table 5, the significance values for the pretest ($p = 0.738$) and posttest ($p = 0.080$) were both greater than 0.05, indicating that the data were normally distributed. Therefore, a parametric paired-sample t-test was appropriate for further analysis.

Table 5 Normality Test Results

Tests of Normality						
	Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
THB Pretest	0.076	33	0.068	0.200	33	0.738
THB Postest	0.134	33	0.160	0.143	33	0.080

Descriptive statistics in Table 6 indicate a substantial increase in students' computational thinking scores, with the mean score rising from 56.64 in the pretest to 73.76 in the posttest, representing an average gain of 17.12 points. This improvement suggests a strong positive effect of the RBL-STEAM learning intervention on students' performance.

Table 6 Paired Sample Statistic

Paired Samples Statistics					
		Mean	**N**	**Std. Deviation**	**Std. Error Mean**
Pair 1	THB Pretest	56.6364	33	6.00426	1.04521
	THB Postest	73.7576	33	7.69346	1.33929

In addition, the paired-sample correlation between pretest and posttest scores was high ($r = 0.707$, $p < 0.001$), as presented in Table 7, indicating a strong relationship between the two sets of scores.

Table 7 Paired Sample Correlations

Paired Samples Correlations				
		N	**Correlation**	**Sig.**
Pair 1	THB Pretest & THB Postest	33	0.707	0.000

The results of the paired-sample t-test (Table 8) revealed a statistically significant difference between the pretest and posttest scores ($t = -17.98$, $df = 32$, $p < 0.001$). This finding confirms that the improvement in students' computational thinking skills after the implementation of the RBL-STEAM learning tools was not due to chance, but rather reflects a significant learning effect.

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	THB Pretest - THB Postest	-17.12121	5.47013	0.95223	-19.06084	-15.18159	-17.980	32	0.000

The results of the statistical analysis provide robust evidence of the effectiveness of the RBL-STEAM learning tools in enhancing students' computational thinking skills. The Shapiro–Wilk test confirmed that both pretest and posttest scores followed a normal distribution, justifying the use of parametric procedures. A strong positive correlation between pretest and posttest scores ($r = 0.707$, $p < 0.001$) indicates consistent learning gains across students. Moreover, the paired-sample t-test revealed a statistically significant improvement in performance ($t = -17.980$, $p < 0.001$), with the mean score increasing substantially from 56.64 to 73.76. This significant gain demonstrates that the instructional design grounded in the RBL-STEAM framework effectively facilitated students' development of computational thinking skills in solving local distance irregularity strength problems.

The observed improvement is not merely a statistical effect but reflects a meaningful shift in how students approached complex mathematical problems. Through the RBL-STEAM framework, students were required to decompose the zakat distribution problem into graph-based structures, identify patterns in vertex labeling, and construct algorithmic procedures to ensure local distance irregularity strength. These activities directly align with the core components of computational thinking, namely decomposition, pattern recognition, abstraction, and algorithmic thinking, which explains the substantial increase in posttest scores.

Furthermore, embedding the learning tasks within a blockchain-based zakat distribution context provided an authentic and socially relevant problem environment. This real-world grounding encouraged students to engage more deeply with the mathematical modeling process, as they were not merely manipulating abstract graphs but solving a realistic optimization problem. Such contextualization has been shown to enhance cognitive engagement and transfer of learning, which likely contributed to the strong and consistent learning gains observed across students.

From a pedagogical perspective, the RBL-STEAM approach enabled students to function as novice researchers rather than passive learners. They were guided to explore, formulate, test, and refine mathematical ideas through technology-supported simulations and theoretical graph analysis. This inquiry-oriented learning process fostered higher-order thinking and supported sustained cognitive effort, which is essential for developing computational thinking in advanced mathematical topics such as local distance irregularity strength.

The findings of this study are consistent with previous research indicating that Research-Based Learning integrated with STEM or STEAM frameworks can significantly enhance students' computational thinking and analytical skills. For example, Lestari and Kurniati [19] reported that RBL–STEM learning materials effectively improved students' abilities in problem decomposition, pattern recognition, and algorithmic reasoning. Similarly, the present study demonstrates that engaging students in inquiry-driven mathematical activities leads to meaningful gains in computational thinking. However, while previous studies have employed various authentic and contemporary STEM problem contexts, this research introduces a blockchain-based zakat distribution problem combined with graph-theoretical modeling. This novel integration provides a culturally grounded and socially relevant learning environment, thereby extending the existing literature by showing that computational thinking can be strengthened through mathematically rigorous and ethically meaningful digital philanthropy contexts.

4. Conclusion

The present study aimed to develop and evaluate RBL-STEAM–based learning tools to enhance students' computational thinking skills in solving zakat distribution problems using the concept of local distance irregularity strength. The developed learning tools, including the Student Task Plan (RTM), Student Worksheets (LKM), and Learning Outcomes Test (THB), were systematically designed and validated through expert review and classroom implementation. The validation results indicated that the learning tools met the criteria of content and construct validity, confirming that they were appropriate for instructional use in discrete mathematics courses.

The practicality of the learning tools was demonstrated through classroom observations during the limited trial involving 33 undergraduate students. The high implementation score and positive observer feedback showed that the RBL-STEAM learning tools were easy to use, well-structured, and effectively supported classroom activities. In addition, the integration of blockchain-based zakat distribution as a contextual problem increased student engagement and facilitated meaningful learning, particularly in modeling, algorithmic thinking, and abstraction.

Furthermore, the effectiveness analysis confirmed that the RBL-STEAM learning tools significantly improved students' computational thinking skills. This was evidenced by high classical learning mastery, very active student participation, and highly positive student responses. The statistical results supported these findings, indicating a significant difference between pretest and posttest scores. Overall, the study demonstrates that RBL-STEAM–based learning tools provide a powerful instructional approach for enhancing computational thinking in discrete mathematics, particularly when mathematical theory is connected to authentic and socially relevant contexts such as zakat distribution.

Compliance with ethical standards

Acknowledgements

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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 Nurul Jadid.

Statement of Informed Consent

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

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