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The Development of RBL-STEM Learning Materials to Improve Students' Conjecturing Thinking Skills in Solving Resolving Efficient Domination Number and it's Application on Nutrition Supply of Hydroponic Plants using STGNN

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Abstract
Conjecturing thinking skills are prediction skills obtained from recognizing patterns of mathematical phenomena or real-life problems. Indicators of conjecturing skills, namely: observing cases, organizing cases, finding and predicting patterns, formulating conjectures, validating conjectures, generalizing conjectures, and justifying conjectures. This research aims to develop RBL learning materials with STEM approach. Learning materials that can support the success of learning activities in improving conjecturing skills must be developed by meeting several criteria, namely valid, practical, and effective. The validity score obtained for each device is 3.53 for the student assignment design with a percentage of 88.33%, 3.46 for the student worksheet with a percentage of 86.54%, and 3.5 for the learning outcomes test with a percentage of 87.5%. The average score of the overall learning implementation observation was 3.78 with a percentage of 94.42%. There were 24 completed students or about 80%, the average score percentage of student activity was 94.42%, and 94.47% of students gave positive responses.

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Keywords: Conjecturing Thinking, RBL-STEM, Resolving Efficient Domination Number

Introduction

Government Regulation No. 19 of 2005 has regulated the national standard of education which indicates that every higher education must include mathematics as one of the subjects or courses. Mathematics is a science that discusses patterns or regularities (pattern) and levels (order) (Supriyani, *et.al*, 2019) [10]. The important role of mathematics is recognized as so difficult that it is impossible for someone to live a normal life in the world in the 20th century without using mathematics (Siagian, 2016) [9]. Mathematics is closely related to problem solving. Many researchers have suggested that problem solving and conjecture are important parts of mathematical activities. Problem solving is one part of the school mathematics standards (María C. C., *et.al*). He further explained that mathematical thinking and reasoning skills including making conjectures are important because they serve as the basis for developing new insights and improving further studies. Conjecturing plays a role in learning mathematics, namely: (1) Conjecturing as a way of solving problems (2) Conjecturing as a process that helps students understand the material, and (3) Conjecturing as a process that trains students in reasoning. According to Shadiq in mathematics teaching, the skill of formulating mathematical conjecture is a necessity that must be applied in learning so that students can have skills and apply them in everyday life and improve learning outcomes. (Shadiq, 2014) [8].

The rapid development of science and technology has a major impact on human life. Many conveniences and innovations are obtained with the support of digital technology. Therefore, to take advantage of opportunities and answer the challenges of the industrial revolution 4.0, research-based learning (RBL) is needed in higher education. Research Based Learning is learning that requires students to be able to find, explore (develop knowledge) to solve the problems at hand, and then test the truth of that knowledge. The learning interaction between students and educators is an active interaction. Educators act as facilitators and mediators in order to bring students to achieve the expected competencies (Sariada, 2021) [7].

Therefore, to shape students in the learning process, lecturers can use approaches to support the learning process, one of which is the STEM approach. The STEM approach is an approach that refers to the four components of science, namely science, technology, engineering, and mathematics (Davidi, dkk, 2021) [2]. STEM-based learning can be packaged in several learning models, one of which is the research-based learning model. According to Salimi, *et al*, research-based learning is one of the student-centered learning (SCL) methods that integrate research in the learning process (Salimi, *et.al*, 2017) [6].

To improve students' conjecturing thinking skills, it is necessary to develop materials that support the success of learning activities. Learning materials that need to be developed to support the success of a research-based learning activity are student assignment plans (RTM), student worksheets (LKM), and learning outcomes tests (THB). The learning materials used must be in accordance with the learning objectives. Therefore, the development of learning materials is very necessary to fulfill the availability of materials according to the demands of the curriculum, characteristics, objectives, and demands for problem solving (Depdiknas, 2008). Mathematics consists of many topics, one of which is graph theory. In graph theory, we assume objects as vertices and edges as relationships between objects. Graph $G = (V(G), E(G))$ consists of two finite sets, namely $V(G)$ and $E(G)$. $V(G)$ is the set of vertices which is usually denoted by V only. While $E(G)$ is the set of edges which is usually denoted by E only. Each element e in $E(G)$ is an unordered pair of vertices in $V(G)$ (Daniel and Taneo, 2019). Graph theory originated from a Konigsberg bridge problem solved by Leonhard Euler in 1736. One of the topics contained in this graph theory is resolving efficient domination number. In graph theory, of course, it is inseparable from the problem of proof. In solving problems about the set of distinguishing efficient domination, students will be trained to find ideas, strategize from what is known to be able to formulate and develop mathematical proofs of the problems given. Therefore, the ability to prove students is needed in developing graphs and solving the problem of distinguishing efficient domination sets or what is known as resolving efficient domination number.

Method

The stages used in this study refer to the development of Thiagarajan's 4D model which consists of defining, designing, developing, and disseminating stages (Hobri, 2021) which can be seen in Figure 1. Quantitative data analysis using paired sample t test statistical test with R-Shiny application.

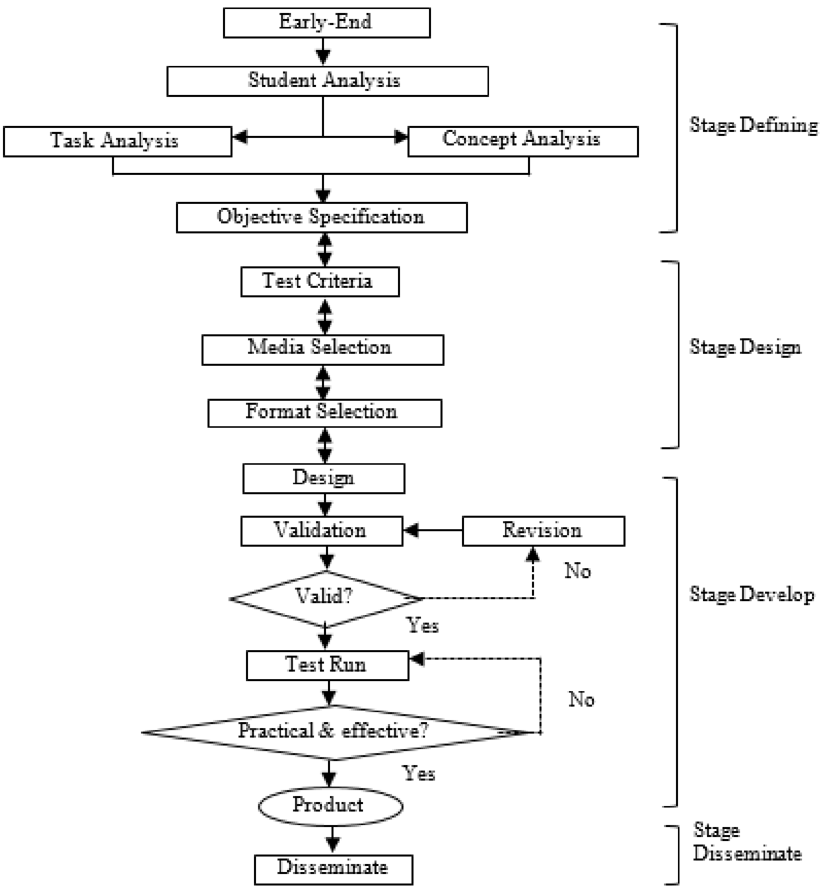


Fig 1: Design of 4D model

Research Findings

This study uses research-based learning with a STEM approach so that students can learn and develop skills in Science, Technology, Engineering, and Mathematics. An explanation of the STEM aspects of the research can be seen in Figure 2. The RBL-STEM stages in this study can be seen in Figure 3.

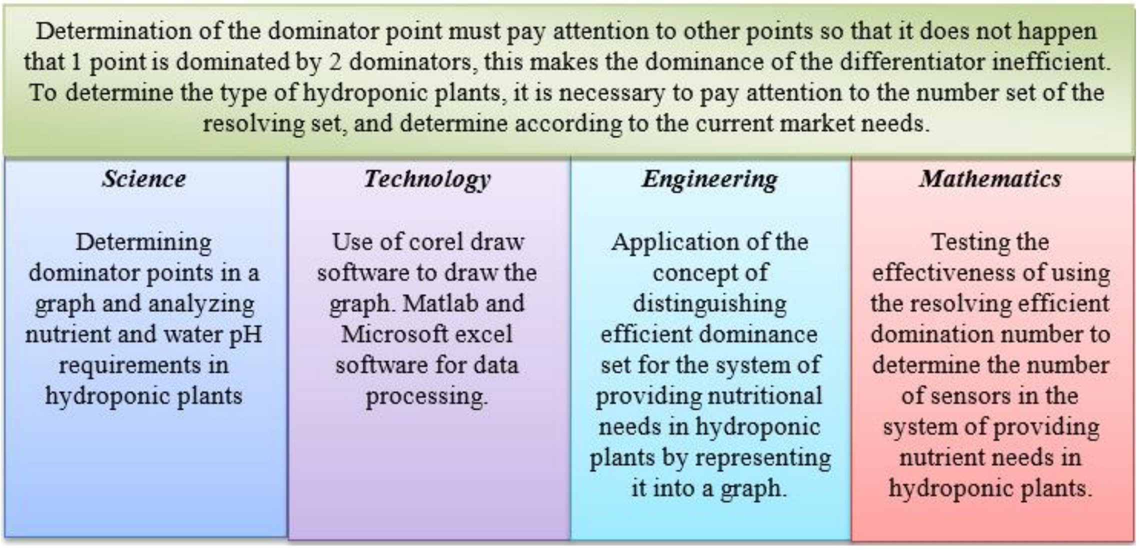


Fig 2: Aspects of STEM

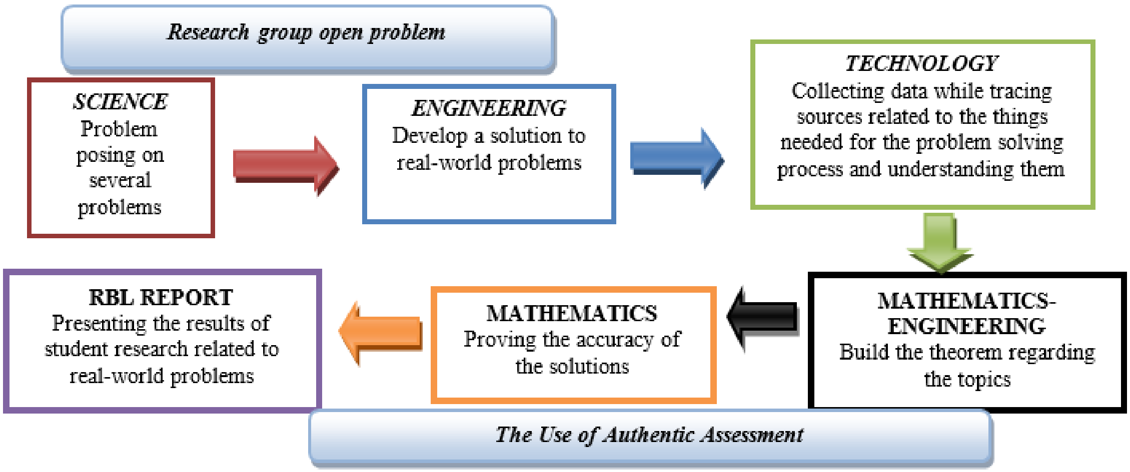


Fig 3: Stages of RBL-STEM according to Izza, *et al*, 2023

The expected results in this study based on the problems presented are the determination and placement of TDS meter and pH water sensors based on the results of forecasting the level of nutritional needs of hydroponic plants using spatial temporal graph neural network. Determination of the number of sensors laying TDS meter and pH water sensors is determined as a minimum using a combination of the concept of resolving efficient dominating set and based on the results of nutritional needs forecasting using spatial temporal graph neural network. The research-based learning model with a STEM approach in this study uses the stages of (a) problems regarding the provision of nutritional needs in hydroponic plants whose solutions use graph neural networks and resolving efficient dominating sets; (b) Arranging problem solving related to resolving efficient dominating sets; (c) Searching for and collecting information about problems and things that will be problem solving; (d) Finding theorems on the topic of resolving efficient dominating sets from several graphs and analyzing the solution of the given problem; (e) Proving the theorems found on the topic of resolving efficient dominating sets the solution of the given problem. (f) Present the result obtained about the problem solving and the theorem obtained about the topic of resolving efficient dominating set. The first stage in this research is the defining stage, which consists of the beginning-end analysis stage, student analysis, concept analysis, and task analysis. At this stage of the preliminary-end analysis, resolving efficient dominating sets was chosen as the topic of study because this topic belongs to a new topic that combines two topics, namely the dominating set and the efficient dominating set. The existence of learning on this topic is expected to add insight to students and be used as a reference for preparing the final project. Solving this problem requires students who are active and creative so that they can find the expected efficient dominating set. A suitable learning model used in research-based learning to train students' conjecturing skills. In this study, student analysis was used to obtain data on the characteristics of undergraduate students of Mathematics Education, FKIP, University of Jember graph application class. Students must be directly involved in the learning process and be able to work together in groups. Students find it a little difficult to understand the topic of resolving efficient dominating sets and its applications, one of which is big data processing in machine learning using Matlab software. Furthermore, based on the results of the initial-end analysis that has been carried out, the concept analysis carried out produces a concept map which can be seen in Figure 4.

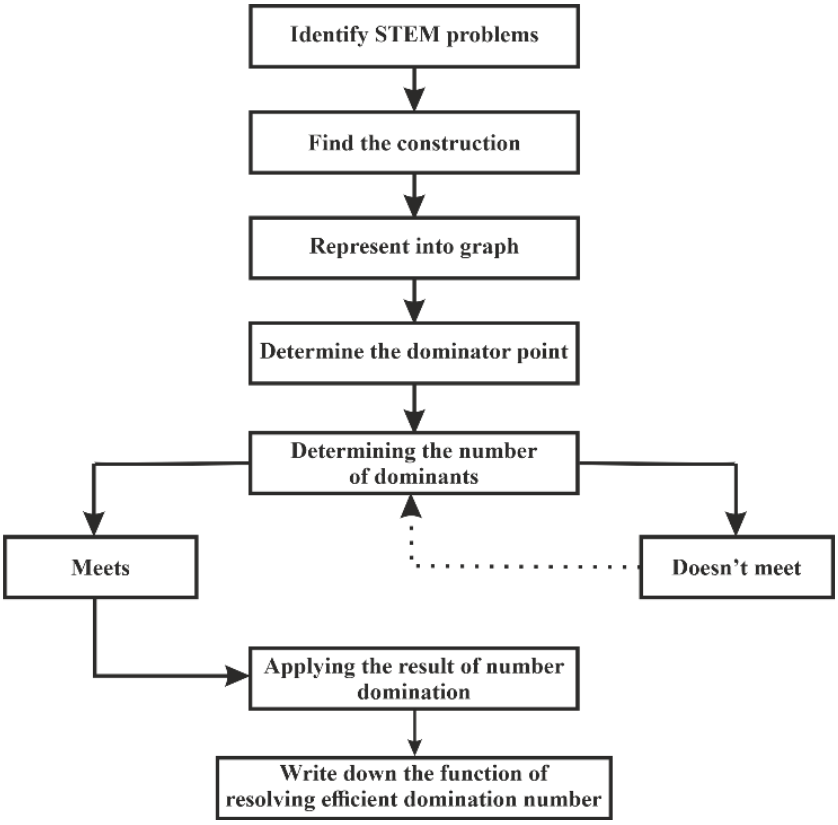


Fig 4: Analyze the concept of resolving efficient domination number

The task analysis conducted refers to the beginning-end analysis, student analysis and concept analysis. Based on the basic problems that occur in the learning process, the characteristics of students and the conceptual framework created, researchers set tasks in the MFI in the form of overlapping sections and in the thinking skills test in the form of questions about the set of distinguishing efficient dominance and its application in the real world. The assignment is expected to improve students' conjecturing skills. The final abilities that must be achieved by students after learning include being able to understand the concept of resolving efficient domination number and their applications in the real world.

The second stage in this research is the design stage which consists of four steps, namely the preparation of tests and instruments, media selection, format selection, and initial design. The initial step at this stage is the preparation of tests and instruments based on the task and concept analysis that has been described in the formulation of learning objectives. This test is in the form of a description that contains STEM, in this case the problem raised is the problem of anomalies in the nutritional needs of hydroponic plants and the classification of hydroponic plants related to the topic of resolving efficient domination number of distinguishing and determining hydroponic plants that will occur nutritional needs anomalies and do not occur nutritional needs anomalies related to graph neural networks. The next step is the media selection process adjusted to student analysis, concept analysis, and previous task analysis. The media chosen include power point as a presentation medium for delivering material that can support understanding to students, as well as the development of Student Worksheets (LKM) which contain indicators of conjecturing. The third step at this stage is the selection of formats in the development of learning devices which aims to formulate and determine the design of learning media, selection of strategies, approaches, methods, and learning resources that will be used during teaching and learning activities. In this study, the learning model used is research-based learning with a STEM approach on the topic of resolving efficient domination number with the learning stages in it chosen as a learning format. This was done because this research aims to develop a research-based learning material with a STEM approach on the topic of resolving efficient domination number and contains several things that can measure students' conjecturing skills based on these ability indicators. The last step in this stage is the initial design. Initial design is carried out based on the entire design of learning devices that must be done before the trial. The learning materials are in the form of Student Task Design (RTM), Student Worksheet (LKM), and Learning Outcome Test (THB). Cover of the LKM and THB can be seen in Figure 5.

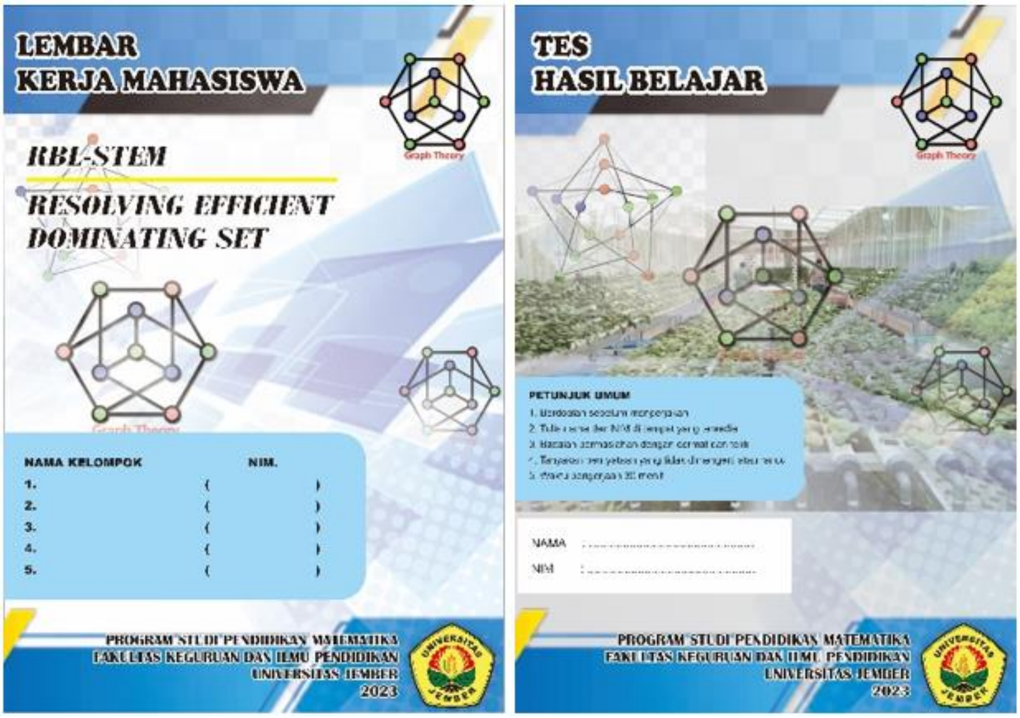


Fig 5: Cover of the LKM and THB

The next stage is the development stage. At the development stage, all devices developed were validated by validators and revised according to the suggestions given. The learning device was validated by two validators, the first validator was a lecturer in the PGSD study program, Faculty of Teacher Training and Education, University of Jember who was an expert in the field of graphs and the second validator was a lecturer in the mathematics education study program, Faculty of Teacher Training and Education, University of Jember who was an expert in the field of education. The results of validation of learning devices from both validators can be seen in Table 1, Table 2, and Table 3.

Table 1: The results of the validation recapitulation of the student assignment design (RTM)

Aspects assessed	Average	Percentage
Format	3,5	87,50%
Content	3,6	90,00%
Language and writing	3,5	87,50%
Average score of all aspects	3,53	88,33%

Table 2: The results of validation recapitulation student worksheet (LKM)

Aspects assessed	Average	Percentage
Format	3,50	87,50%
Content	3,40	85,00%
Language and writing	3,49	87,13%
Average score of all aspects	3,46	86,54%

Table 3: The results of the validation recapitulation of the learning outcomes test (THB)

Aspects assessed	Average	Percentage
Format	3,50	87,50%
Content	3,50	87,50%
Language and writing	3,50	87,50%
Average score of all aspects	3,50	87,50%

After the device is declared valid, the next step is to test the device to test the practicality and effectiveness of the device. The practicality test of learning devices is carried out by analyzing student learning activities and lecturer activities during learning. Analysis of student and lecturer activities based on observation sheets of the implementation of the learning process assessed by five observers taken from Master of Mathematics Education students. The results of the score recapitulation can be seen in Table 4. Based on Table 4, the average score of the overall learning implementation observation is 3.78 with a percentage of 94.42%. Therefore, it can be concluded that the learning material meets the practicality category.

Table 4: Rekapitulasi hasil observasi keterlaksanaan proses pembelajaran

Aspects assessed	Average	Percentage
Syntax	3,67	91,63%
Social system	3,83	95,83%
Principles of reaction and management	3,83	95,8%
Average score of all aspects	3,78	94,42%

After the device is declared practical, the device will be tested for effectiveness. The effectiveness test can be determined based on three criteria, namely the completeness of the student learning outcomes test, student activity analysis, and student response results. The first criterion is the completeness of learning outcomes. The results of the answers collected by students were obtained by 24 students getting scores above 60. Therefore, there are 80% of students completed and have met one of the criteria for a device to be called effective. The second criterion is the analysis of student activity obtained based on the student activity observation sheet. The score recapitulation results can be seen in Table 5Based on Table 5, it was found that the average percentage score of student activity was 94.42%. Based on the criteria of activeness, students are classified as very active. This means that two of the three requirements for an effective learning material have been met.

Table 5: The results of recapitulation of student activity observation

Aspects assessed	Average	Percentage
Intoduction	3,92	97,88%
Core acitivities	3,74	93,43%
Closing	3,67	91,67%
Average score of all aspects	3,78	94,42%

The third criterion is the student response results. The results of student responses were obtained by distributing student questionnaires in hardfile form. There were 30 students who filled out the questionnaire. Based on student responses in the questionnaire sheet, the recapitulation of student response scores is presented in Table 6. The recapitulation of student questionnaire data in Table 6 shows that the lowest positive answer with a percentage of 84.62% lies in the statement about understanding the questions contained in the LKM and THB. This is because the materials provided has not been studied. Furthermore, the highest positive response is on the item of the novelty of the LKM. This is because the topics discussed in the MFI are relatively new for students of the FETT Mathematics Education Study Program at Jember University, namely about resolving efficient domination number and spatial temporal graph neural networks. Overall, the average positive percentage of the statements was 94.47%, while the negative percentage was 5.53%. This indicates that the majority of students gave a positive response to the learning and learning materials presented. This means that all three requirements for an effective learning materials have been met.

Table 6: Recapitulation of student response data

Aspects assessed	Percentage of responses	
	Yes	No
Student enjoyment of the learning component	98,08%	1,92%
Novelty of the learning component	93,27%	6,73%
Students' interest in learning	100%	0%
Students' level of understanding of the language used	90,39%	9,61%
Students' level of understanding of the questions presented	84,62%	15,38%
Students' level of interest in learning materials	100%	0%
Students' enjoyment during problem discussion	100%	0%
Average score of all aspects	95,19%	4,81%

The last stage is the dissemination stage. The materials that are distributed are RTM, LKM, and THB using a research-based learning model with a STEM approach. The dissemination in this study will be carried out online, namely uploading on social media by providing a google drive link.
The data analysis of this study used paired sample t-test which is comparing the results of pretest and posttest to determine the improvement of students' conjecturing skills after the implementation of learning devices in the classroom. Graphs of the value and percentage of pre-test and post-test results of students in the research class can be seen in Figure 6 and Figure 7.

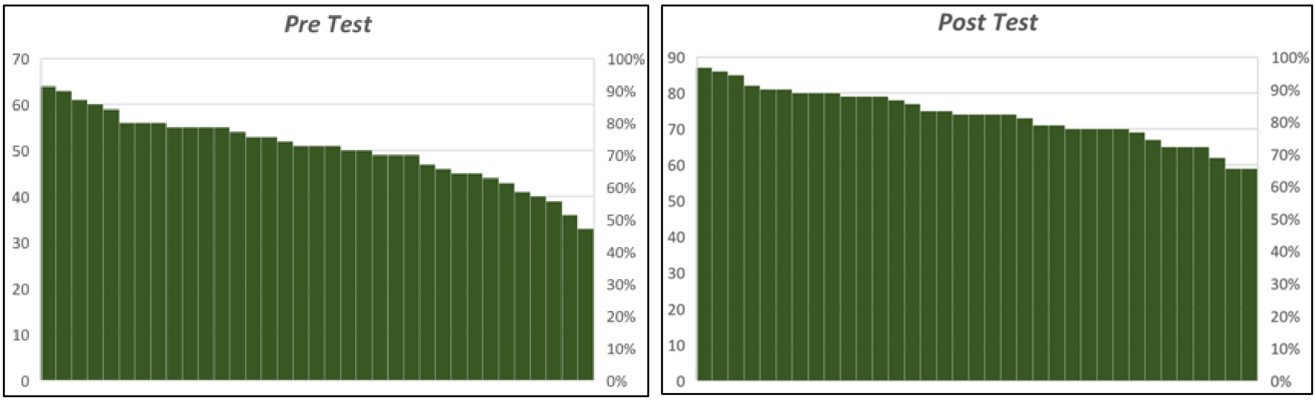


Fig 6: Graph of pre-test and post-test scores

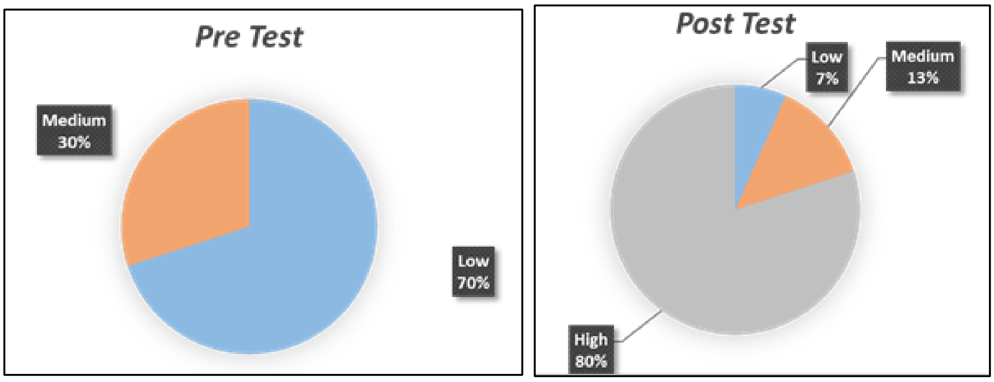
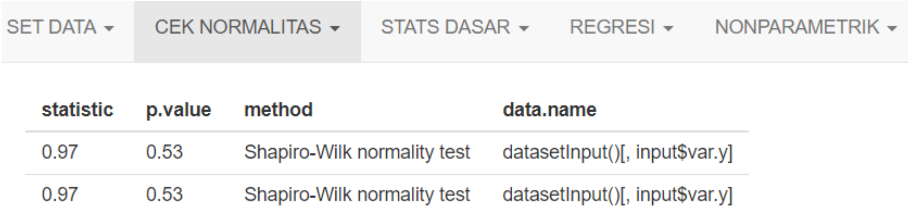


Fig 7: Percentage of pre-test and post-test conjuring levels

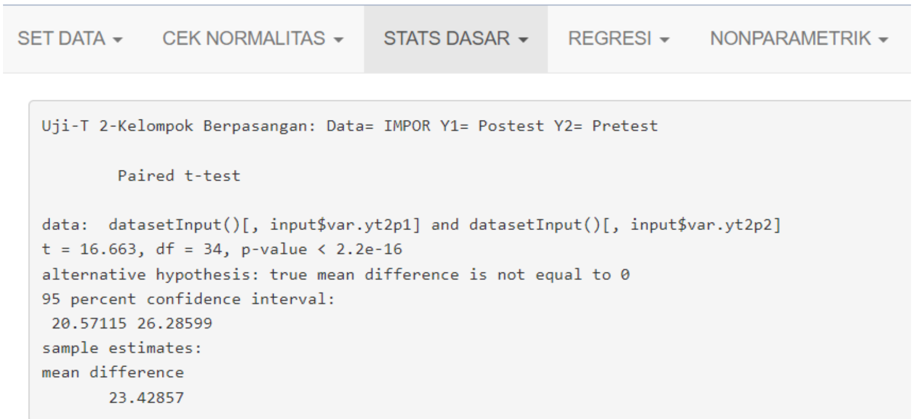
Based on Figure 7, the pre-test data results were obtained with a percentage of 70% for low-level category students and 30% for medium-level category students. While the post-test results for the low-level student category low level a percentage value of 7%, a medium level of 13%, and a high level category of 80%. Furthermore, the normality test is carried out as a requirement before the paired sample t-test is carried out. The results of the normality test can be seen in Figure 8.



statistic	p.value	method	data.name
0.97	0.53	Shapiro-Wilk normality test	datasetInput()[, input$var.y]
0.97	0.53	Shapiro-Wilk normality test	datasetInput()[, input$var.y]

Fig 8: The results of normality test

Based on Figure 8, the normality test results show that the data from the pre-test and post-test scores of students are normally distributed because the p. value results in $0{,}53 > 0{,}05$. After that, a paired sample t-test can be conducted with the results shown in Figure 9.

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Uji-T 2-Kelompok Berpasangan: Data= IMPOR Y1= Postest Y2= Pretest

        Paired t-test

data:  datasetInput()[, input$var.yt2p1] and datasetInput()[, input$var.yt2p2]
t = 16.663, df = 34, p-value < 2.2e-16
alternative hypothesis: true mean difference is not equal to 0
95 percent confidence interval:
 20.57115 26.28599
sample estimates:
mean difference
       23.42857
```

Fig 9: The results of *paired sample t-test*

In Figure 9, the results of the paired sample t-test show that the p.value on the pre-test and post-test values is as follows $2{,}2 \times 10^{-16} < 0{,}05$, Therefore, it can be concluded that there is a difference in the students' conjecturing skills test after the trial of research-based learning materials with a STEM approach.

Discussion

The learning devices in this study have met the valid criteria, then the device trials were carried out by starting with pretest activities for students. After the pre-test, the applied learning used the RBL learning model with the STEM approach. It can be seen from the data obtained from the observers, students who were originally passive became a little more active and dared to express opinions or questions and slowly showed their skills in conjuring thinking, namely conveying a conjecture on existing problems. After learning takes place for 3 meetings with the RBL-STEM model, the post-test results can be concluded that there are a number of 2 students classified as low level of conjunctive thinking skills with a percentage of 7%, 4 students classified as moderate level of conjunctive thinking skills with a percentage of 13%, 24 students classified as high level of conjunctive thinking with a percentage of 80%. This is in line with Wahyuni (2021) [11] that the implications of STEM-based learning have an impact on creating a more active learning atmosphere so that it can improve student learning outcomes.

The learning materials developed using the RBL-STEM model and indicators of conjecturing that can improve students' conjecturing thinking skills. This can be seen from the observation results, which initially only 1-2 groups were active in conveying their opinions and conjectures, to almost the entire group conveying their ideas and opinions in the form of good conjectures during the problem solving process given. This is in line with Maylisa, *et al*., (2020) [4] and Mursyidah, *et al*., (2023) [3, 5] that the RBL-based MFI integrated with the STEM approach provides a positive learning process for students in solving problems and can improve students' thinking skills.

Conclusion

The developed devices have met the valid criteria. The validity score obtained in each device is 3.53 for RTM, 3.46 for LKM, and 3.50 for THB. This learning device has also met the practical criteria from the observation score of the implementation of the learning model, which is 3.78 with a percentage of 94.42%, which means that the learning is very well implemented. Besides being valid and practical, the device also meets the effective criteria. On average, 94.47% of students in the trial class gave positive responses.

The results of students' pretest and posttest data in this study showed normal distribution, because the p.value resulted in $0{,}53 > 0{,}05$. Then the paired sample t-test test was carried out by producing a p.value of $2{,}2 \times 10^{-16} < 0{,}05$, which means that there is an increase in students' ability to conjecture on the results of student pre-test and post-test.

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