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The development of RBL-STEM learning materials to improve the students' forecasting skills in solving resolving efficient dominating set for hydroponic farming

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Abstract

Students' forecasting skills are currently still very low. This study aims to develop learning tools with the Riset-Based Learning (RBL) model and using the STEM (Science, Technology, Engineering, and Mathematics) approach to improve students' forecasting skills in solving resolving efficient dominating set (REDS) problems. The development of the RBL-STEM device was carried out using the 4D development model (define, design, develop, and disseminate). The developed learning tools meet valid criteria with a percentage of 92.3%, practical criteria with a percentage of 96.26%, and effective with a percentage of 89%. Based on the results of the normality test, it can be concluded that the pre-test and post-test scores are normally distributed because the p-value is higher than 0.05, namely 0.404 and 0.117. Furthermore, the paired samples T-test test produces a p-value that is less than 0.05, namely 0.000, indicating that the pretest and posttest results show that students' forecasting skills have increased statistically significant. Thus, it can be concluded that there is a significant increase in students' forecasting skills after participating in RBL-STEM learning.

Keywords: Forecasting Skills; REDS; RBl-STEM; Multistep Forecasting

1. Introduction

Education is a key in developing and advancing the life of the nation through its human resources, because with education every individual can be more insightful in facing life and even compete in the times. The latest education reform at this time is education with a STEM (Science, Technology, Engineering, and Mathematics) approach, with the improvement of a more well-organized education system, the goals of education can be realized properly. The term STEM was first used by NSF in 1990. According to NSF, STEM is an educational approach that integrates science, technology, engineering, and mathematics into a holistic learning discipline. The goal is to prepare students with the necessary skills to face challenges in the real world. The integration of STEM in education is an effort to realize more creative and innovative human resources, because the most profound resources in the context of global education are human resources who are expected to have various points of view in making various alternative solutions that are better in various fields of life.

Learning mathematics by integrating the RBL (research based learning) model with the STEM approach is expected to build and develop various mathematical thinking skills, one of which is forecasting skills. Forecasting is a time series data analysis that uses past events to determine the development of future events. Forecasting skills are widely used in everyday life as a model for future planning, one of which can be applied to graph theory. Graph theory is a branch of mathematics that studies the properties of graphs that are widely applied in various fields of science, such as physics, chemistry, biology, architecture, transportation, computer technology, social economy, and others. One of the topics contained in graph theory is Resolving Efficient Dominating Set (REDS) or distinguishing efficient dominating set. In graph theory, of course, it cannot be separated from the problem of proof. In solving problems about resolving efficient

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dominating sets, 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, students' proof skills are needed in developing graphs and solving resolving efficient dominating set (REDS) problems related to graphs, namely graph neural networks.

This research tries to use Graph Neural Network in solving problems related to forecasting the nutritional needs of Nitrogen (N), Phosphate (P), Potassium (K) fertilizers and water pH of hydroponic plants. The selection of this problem is a development of mathematics itself and can also involve several components of other fields of mathematics. also involve several components of other fields of science, such as graph neural networks (GNN) (Dafik., 2023). Graph Neural Network (GNN) is a type of neural network that uses graph structure data in its dataset and output (ZN Sudrajat, 2021). Forecasting nutrition in hydroponic plants is assisted by a sensor tool that is placed based on the resolving efficient dominating set (REDS) graph arrangement. With the sensor tool, it will facilitate human work to predict the nutritional conditions of NPK fertilizer and water pH for the future.

Forecasting is an activity in estimating what will happen in the future, or more precisely forecasting is an activity of trying to predict changes that will occur (Assauri, 1984). William Stevenson (2009) explains that forecasting is the basis for determining the direction of future company decisions. He continued, forecasting is able to provide information related to future demand which aims to determine production capacity, inventory, budgeting, procurement of goods and services to the supply chain. The use of the past of a variable to estimate future values. Forecasting is a very important tool in effective and efficient planning (Subagyo, 1986).

Forecasting thinking skills are one of the skills of one unit with Science Process Skills . Science Process Skills is useful as a provision for using the scientific method in developing science and is expected to gain new knowledge or develop existing knowledge, forecasting process skills at this stage consist of several indicators and sub indicators including the following:

Table 1 Indicators of forecasting thinking skills

No	Indicator	Sub Indicator
1.	Identify the characteristics of the problem	Applying some cases Identifying patterns of case resolution Extending the pattern of the obtained case solution Collect/use relevant facts
2.	Using patterns of results observations for prediction	Perform argument calculation Testing the algorithm Developing a hypothesis Testing existing hypotheses
3.	Presenting what might happen in a situation that has not been observed	Using concepts that have been learned in a new situation Realizing that an explanation needs to be tested Recognizing that there is more than one possible explanation for an event Propose an open problem

The following are the levels of forecasting thinking skills in this discussion;

Table 2 Level forecasting

Level	Description
High	Students are able to complete all indicators of forecasting skills
Medium	Students are able to complete 2 indicators of forecasting skills
Low	Students are only able to complete 1 indicator of forecasting skills

2. Methods

The stages used in this study refer to the development of Thiagarajan's 4D-Model which consists of the define stage, design stage, develop stage, and disseminate stage (Hobri, 2021). Data obtained from observations of student activity during the learning process were tested statistically using parametric statistical tests. Statistical tests in this study used SPSS. There are two variables in this study, namely the independent variable and the dependent variable. The independent variable is research-based learning tools with STEM approach, while the dependent variable is students' forecasting skill. Furthermore, the normalization test and paired sample t test were conducted on the pre-test and post-test results. The t-test in this study was used to determine whether there was an increase in students' forecasting skills after the application of the RBL-STEM approach to REDS problems with GNN. The hypothesis is formulated in the form of pairs of null hypothesis (H0) and alternative hypothesis (H1). For the assessment criteria, if sig>0.05 then (H0) is accepted, but rejected if sig< 0.05. Thiagarajan's 4-D model learning device development scheme can be seen in Figure 1.

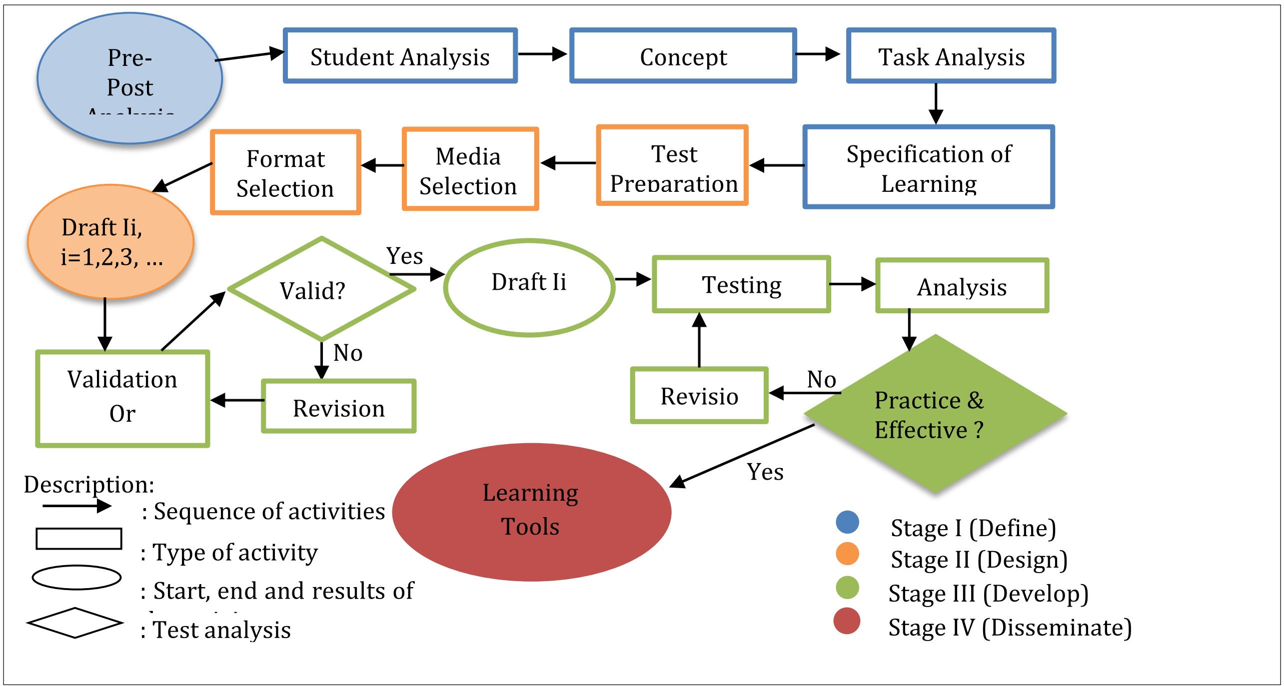


Figure 1 4-D Model Design

3. Results and discussion

This research uses research-based learning with a STEM approach so that students can learn and develop skills in the fields of science, technology, engineering, and mathematics. Learning activities in improving students' forecasting ability on the problem of fulfilling NPK nutrition and water pH in hydroponic farming with the RBL Model and the STEM approach require students to be more active in learning through research. The first step that students must do is to propose basic problems related to sensor placement in hydroponic farming, then determine how to solve these problems. Next, students search for data and information through related literature. In this case, the problem faced is how the fulfillment of NPK nutrition and water pH in hydroponic plants can be fulfilled with the concept of solving an efficient dominance set. An explanation of the STEM aspects in this research can be seen in Figure 2.

The use of elements of science, sensor technology, and Dominating Set algorithms in hydroponic crop cultivation helps improve efficiency, yield, and crop quality. By incorporating close monitoring of NPK nutrients and water pH levels through sensors and automated settings, hydroponic farming becomes more effective and sustainable. This innovation has great potential to increase food production in the future, while reducing environmental impact.	
Science	Determining dominator points in a graph and analyzing the nutritional needs of NPK fertilizer and water pH in hydroponic plants
Technology	Use of canva software to draw graphs. Matlab, thinkspeak, think view and Microsoft excel software to process data.
Engineering	Application of the concept of resolving efficient dominating set for the NPK fertilizer nutrient delivery system and water pH sensor in hydroponic plants by presenting it into a graph.
Mathematics	Testing the effectiveness of using the resolving efficient dominating set to find out the automatic nutrition system in hydroponic plants with the GNN technique.

Figure 2 STEM aspects in research

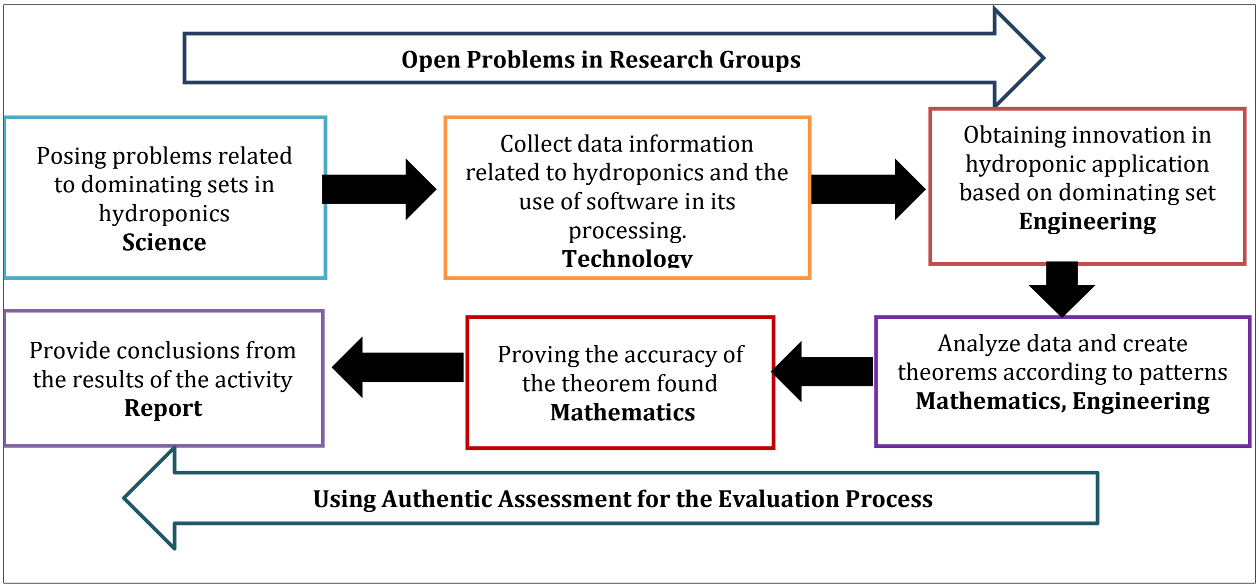


Figure 3 RBL-STEM syntax framework

This research aims to solve the problem of meeting the needs of nutrients and water pH in hydroponic plants by using the resolving efficient dominating set model and graph neural network learning model. This research approach uses the following steps; 1) presenting problems regarding the placement of NPK and pH water sensors in hydroponic farming; 2) developing a strategy with a graph neural network with the concept of REDS; 3) collecting data which will then be modeled and analyzed; 4) implementing the model in the placement of sensors and plants based on REDS topics; 5) evaluating and testing the model that has been obtained; 6) preparing a report on the results and observing students' forecasting skills.

The concept of resolving efficient dominating set (REDS) and graph neural network, the process and results of the development of this RBL-STEM device are used to determine the improvement of learning devices on students' forecasting skills in solving forecasting problems of NPK nutrient requirements and water pH in hoidroponic agriculture. This development process refers to the Thiagarajan (4D) model which includes the define, design, develop, and disseminate stages.

The first step of define aims to establish and define learning needs by analyzing the objectives and limitations of the material to be delivered. There are five steps at this stage, namely: a) End-start analysis is carried out to determine the problems contained in learning activities and the development of learning devices so that the resulting devices are expected to provide solutions to students who are hampered in classroom learning because they find it difficult to learn and understand the concept of REDS. b) Student analysis is used to obtain data on the characteristics of Mathematics Education students, Faculty of Teacher Training and Education, University of Jember. Students must be directly involved in the learning process and be able to work together in groups. c) Concept analysis is carried out to identify, detail and arrange systematically the concepts that will be learned by students in REDS. The REDS concept analysis resulted in the concept map in Figure 4. d) Task analysis was conducted to develop tasks in the MFI in the form of overlapping parts and in the forecasting skills test of thinking ability in the form of questions about REDS in the real world. e) The specification of learning objectives is to identify students' forecasting skills in accordance with the expected final ability.

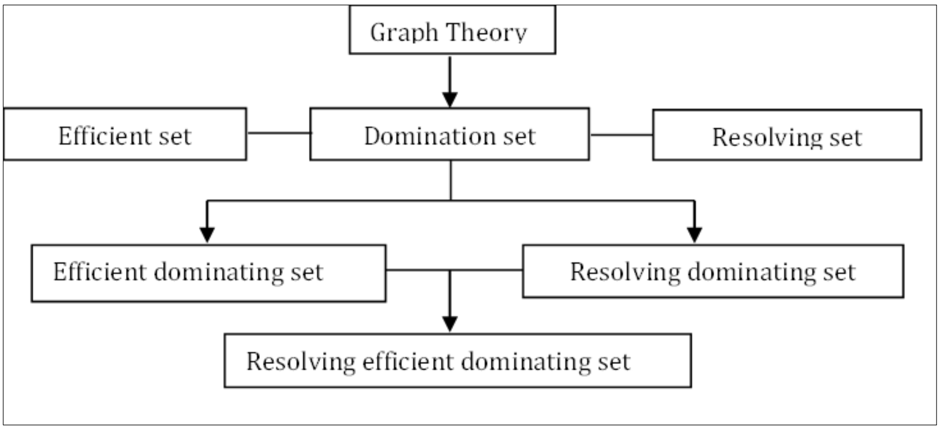
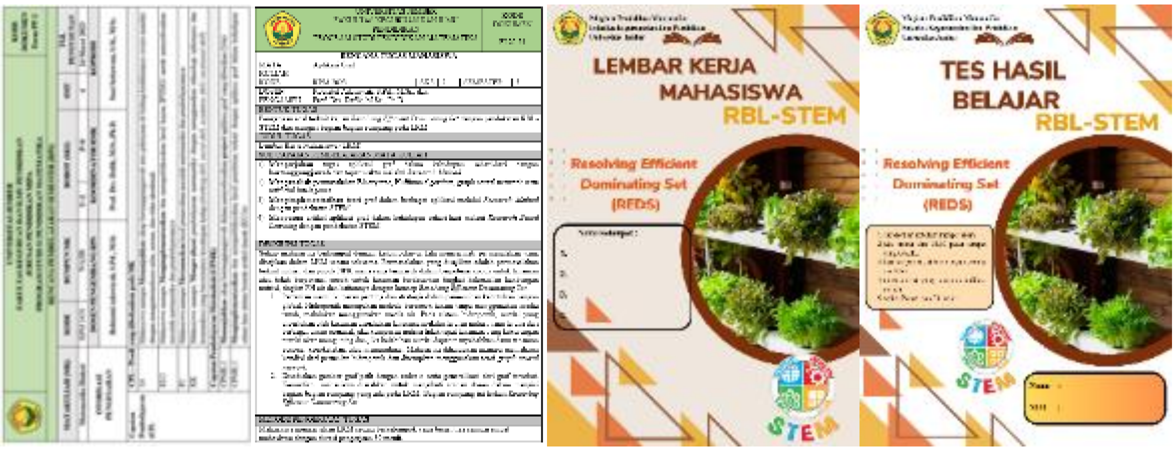


Figure 4 Concept map of REDS topic

The second stage of design aims to design learning devices learning tools that will be used so that a sample of learning tools is obtained. The learning tools developed are (a) Semester Learning Plan designed to compile learning materials that are in accordance with the characteristics of students, (b) Student Assignment Design prepared with the topic of REDS, and the learning model used is RBL-STEM, (c) Learning Outcome Tests prepared with material about graph neural networks and REDS. Pre-test and post-test are done individually to determine the ability before learning and the final ability of students after learning. The results of this test are used with the aim of measuring student forecasting skills, and (d) Student Worksheets are made with REDS concepts using the RBL-STEM learning model. The initial design of the learning device is shown in Figure 5.



(a) (b) (c) (d)

Figure 5 Preliminary design of learning materials

The third stage of development is the stage where researchers begin to develop mathematics learning tools as a whole. At this stage, all devices were validated by validators and then revised according to the suggestions and input from the validators. Teaching materials were validated by two validators from the Mathematics Education Study Program lecturer at the University of Jember. The assessment results from both validators in general are that the learning devices can be used with minor revisions. The suggestions will be used as the basis for improving the learning tools so that they become devices that can and should be used by students and lecturers in the learning process. Based on the results of the validation of learning devices that can be seen in Table 3, the average score of all aspects is 3.69. The device is said to be valid if it scores $3.25 \leq V_a \leq 4$. Thus it can be concluded that the learning device made is valid.

Table 3 Recapitulation of Learning Materials Validation

Validasi	Average Score	Percentage	Criteria
Learning Materials	3.68	92%	Valid
Student Activity Observation Sheets	3.73	93.3%	Valid
RBL-STEM Implementation Sheets	3.58	89.5%	Valid
Student Response Surveys	3.7	92.5%	Valid
Questionnaire	3.76	94%	Valid
Overall average score	**3.69**	92.3%	Valid

The device that had been validated and revised was tested on students. The trial was conducted in Combinatorics class E of the Mathematics Education Study Program, FKIP, University of Jember, which consisted of 28 students. The trial phase began with the researcher opening the lesson followed by giving a pre-test for 40 minutes, after which the researcher gave a little stimulus about resolving efficient dominating sets, and its application to hydroponic farming. The second meeting, students were divided into six groups, each consisting of one observer. Each student discussed with their group. The observers helped guide the groups if there were problems in working on the Student Worksheet for 50 minutes. Furthermore, each group was given the opportunity to present what they had learned during the discussion. In the third meeting, the researcher gave a posttest to be answered for 40 minutes, and a response questionnaire given until the end of the lecture time.

The final step, the dissemination stage, aims to determine whether the devices that have been developed function properly for learning activities. Learning tools that have been tested, revised, and declared valid, effective and practical will be widely disseminated for use by educators or mathematics education lecturers and disseminated via the internet including social media for their respective interests.

Furthermore, we will use quantitative data analysis to analyze the improvement of students' forecasting skills. The following is a graph of the distribution of students' pretest and posttest scores which can be seen in Figure 6. Figure 7 shows the percentage level of student forecasting skills.

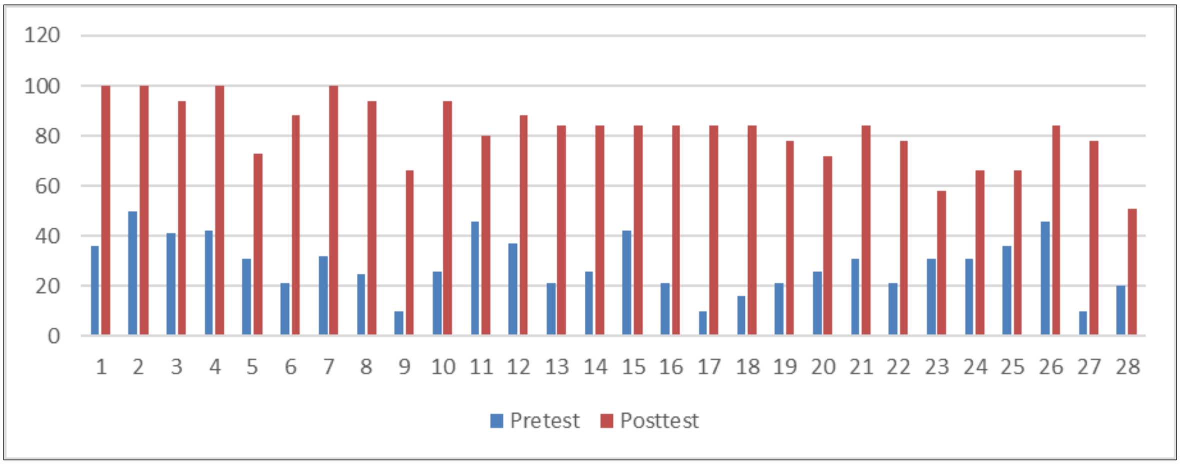


Figure 6 Distribution of students' pretest and posttest scores

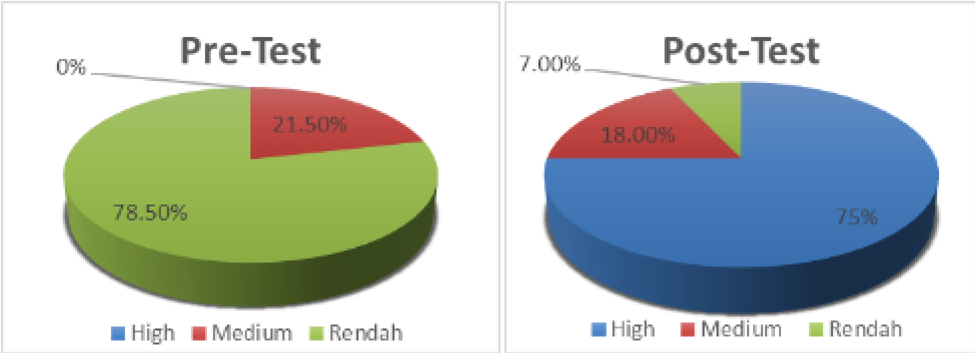


Figure 7 Percentage level of student forecasting skills.

In the pretest results, students who were categorized as students with student forecasting skills were only at the medium and low levels. There were 21.5% students at the moderate level and 78.5% students at the low level. Whereas in the posttest results, students categorized as students with student forecasting skills at a high level reached 75%, students with forecasting skills at a moderate level were 18% and students with low levels decreased to 7%. Furthermore, the normalization test was carried out as a condition for the pared sample t test. Statistical tests were carried out using SPSS software. The results of the data normality test are presented in Table 4.

Table 4 Normality test results

	Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
	Statistic	df	Sig.	Statistic	df	Sig.
pretest	0.114	28	0.200*	0.963	28	0.404
post	0.170	28	0.038	0.941	28	0.117

Based on the results of the data normalization test, it shows that the pre-test and post-test scores are normally distributed because the pre-test value Sig. 0.404> 0.05 and post test value Sig. 0.117 > 0.05, so it can be concluded that there is a significant increase in students' forecasting skills on the skill test scores. After the normalization test is continued with the paired samples T-test presented in table 5.

Table 5 Paired sample t-test results

Paired Samples Test									
		Paired Differences					**t**	**df**	**Sig. (2-tailed)**
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pretest - post	-53.214	13.75273	2.59902	-58.54704	-47.88153	-20.475	27	0.000

The test results in table 5 with 28 data, namely the correlation value of the paired samples T-test, produced a p-value of less than 0.05, namely 0.000 <0.05, which shows that the improvement in forecasting skills between the two groups of pretest and posttest data has increased statistically significantly. Thus, it can be concluded that there is a significant increase in students' forecasting skills.

The learning tool developed is a research-based mathematics learning tool with a STEM approach to improve students' forecasting skills in solving REDS problems and its application to forecasting the time to meet the nutritional needs of NPK fertilizer and water pH for hydroponic farming using the Graph Neural Network (GNN) technique. This learning tool meets the criteria of validity, practicality, and effectiveness. The results of this study are consistent with the findings of Dafik and Maulidiya who stated that the application of RBL-STEM learning creates a more active and interesting learning atmosphere (Dafik, Maryati, et al., 2021; Maulidiya et al., 2023). Therefore, it can be concluded that the application of RBL-STEM learning effectively improves students' forecasting skills.

4. Conclusion

The device developed has been validated by two validators and tested on a trial class. This learning device meets the criteria of validity, practicality, and effectiveness. This device has met the criteria of validity, namely 3.67 $\leq V_a < 4$ with a percentage of 92.3%. This mathematics learning tool also meets the criteria of practicality with a learning implementation observation score of 3.85, indicating that the learning went very well and achieved a success rate of 96.26%. Besides being valid and practical, the device also meets the effective criteria. An average of 89% of students in this trial class were classified as complete students and the response from students was positive. Based on the test results, researchers got 25 students who scored above 60 which means that this class has been completed and meets one of the effectiveness criteria. The student response questionnaire also provided more positive responses than negative responses received from these students.

Compliance with ethical standards

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Disclosure of conflict of interest

I would like to disclose that I am the author responsible for this research, collaborating with other authors as a team. Although I will strive to remain objective throughout the article preparation process, I feel it is important to disclose my relationship with the other authors.

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