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The Development of RBL – STEM Learning Materials to Improve Student's Conjecturing Thinking Skills in Solving Rainbow Vertex Antimagic Coloring Promblems and it's Application to Supply Chain Management Using ANN

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ABSTRACT: One of the educational developments in recent years has to do with STEM. The term STEM (Science, Technology, Engineering, and mathematics) is one approach in the learning process that is quite influential to be used today. STEM-based learning focuses students on solving problems in everyday life by combining the four fields of science: science, technology, engineering, and mathematics. The resulting device has met the validity criterion of $3.25 \leq Va < 4$; the suggestion from validators does not change the device as a whole, but only a tiny part. The validity score obtained in each device is 3.6 for RTM (valid), 3.5 for LKM (practical), and 3.6 for THB (practical). This math learning tool also meets the criteria of practicality, and the practitioner's advice does not change the device as a whole but only a tiny part. In addition to being valid and practical, the device also meets the criteria of effectiveness. The average student in this trial class is classified as a complete student, and the response from students is positive. Based on the test results, researchers found 16 students with 70% presentations who scored above 60.

KEYWORDS: Conjecturing Thinking Skills, RBL – STEM, Rainbow vertex antimagic coloring.

INTRODUCTION

Education is an essential factor in advancing each individual's mindset so they can advance a country. The 21st century is the era of the industrial revolution 4.0, where education is increasing along with the progress of science and technology, which is also increasingly rapid. One of the objectives of the curriculum in Indonesia is to form productive, creative, innovative, and effective human beings. One of the learning models that can realize the objectives of the Curriculum is Research-Based Learning (RBL). Research-based learning (RBL) is a learning model that leads to analysis, synthesis, and evaluation activities and improves the ability of students and lecturers in terms of assimilation and application of knowledge (Mufidati et al., 2023). This learning model can be used as a learning reform in higher education to improve the quality of learning and graduates ready to face the challenges of the 21st century; work ethic, collaboration, good communication, social responsibility, critical thinking, and problemsolving (Dafik et al., 2023).

One of the educational developments in recent years has to do with STEM. The term STEM (Science, Technology, Engineering, and mathematics) is one approach in the learning process that is quite influential to be used today. STEM-based learning focuses students on solving problems in everyday life by combining the four fields of science: science, technology, engineering, and mathematics (Mursyidah et al., 2023). Mathematics is a stand-alone discipline that studies everything related to reasoning, logic, geometry, etc. Problems in mathematics have a lot to do with everyday life. Solving mathematical problems in school assignments can train students to improve logical, analytical, systematic, critical, and creative thinking skills (Syaibani, 2016). Mathematics learning with a STEM approach can train students to reason, solve problems and grow and develop various thinking skills needed to face challenges in the real world (Izza et al., 2023).

One of the thinking skills that is quite influential in the learning process is the Conjecture thinking skill. A conjecture is a logical statement, but it cannot be ascertained. In the process, this Conjecture skill makes students actively create meaningful guesses based on their knowledge. This process is carried out based on an individual's learning experience in solving the problem at hand. Conjecture thinking skills can be trained and developed in various mathematics learning, including graph theory. One example of a graph application that refers to rainbow vertex antimagic coloring is artificial neural networks. An artificial neural network is a network of a group of small processing units modeled after the human nervous system. Supply Chain Management is one of the real-life applications of the concept of artificial neural networks. Supply Chain Management is an activity that utilizes information technology to manage all processes involved in making products, from raw material processing to distribution to consumers. Learning materials developed in this study are Student Task Design (RTM), research-based Student Worksheets (LKM) with a STEM approach containing assignments, instructions, and work steps related to topics, and Learning Outcomes Tests (THB).

Graph Theory is a fascinating and fundamental branch of mathematics that deals with the study of graphs and their properties. A graph, in this context, is a mathematical structure used to model and represent relationships between objects. It consists of a set of vertices (also known as nodes) and a set of edges (also known as links or connections) that connect pairs of vertices (Mursyidah et al., 2023) (Kristiana, A. I., 2023). Graphs provide a versatile and powerful way to analyze and understand various real-world problems, making them an essential tool in computer science, operations research, social sciences, and numerous other fields. One of the topic in graph is rainbw vertex antimagic coloring. Develop a new concept in rainbow coloring namely rainbow vertex antimagic coloring. Let $G(V(G), E(G))$ be a connected graph of size q and $f : E(G) \rightarrow \{1, 2, 3, . . . , q\}$ be a labeling of a graph G. The function f is called a rainbow vertex antimagic labeling if for any two vertices u and v in $V(G)$, all internal vertices in path $u - v$ have different weight. The vertex weight denoted by $wf(u)$ for every $u \in V(G)$, where $wf(u) = \Sigma uu0 \in E(G) f(uu0)$. If each edge of G is assigned with the color of the vertex weight $wf(u)$, then G admits a rainbow vertex antimagic coloring. The $rvac(G)$ is a notation of rainbow vertex antimagic connection number of graph G which means the minimum colors taken over all rainbow vertex antimagic coloring induced by rainbow vertex antimagic labeling of graph G (Marsidi et al., 2021).

Based on this background, researchers aim to develop learning materials with a research-based learning model with a STEM approach to determine how it affects students' cognitive thinking skills. Therefore, this study is entitled "Development of RBL-STEM Learning materials to Improve Student Conjecture Thinking Skills Analyzing the Value of Rainbow Vertex Antimagic Coloring Connection in Solving Artificial Neural Network-Based Supply Chain Management Problems."

METHOD

This research was carried out in the even semester of the 2023/2024 academic year. The research place to conduct research is one lecture class in the Mathematics Education Study Program, FKIP, Jember University. The subject of this research is S1 students of the Mathematics Education Study Program, FKIP, Jember University. This research is a 4-D development model developed by S. Thiagarajan, Dorothy S. Semmel, and Melvyn I. Semmel in 1974. According to Hobri (2010), the 4-D development model has four stages that must be done in making learning materials, namely the defining stage (Define), the design stage (Design), the development stage (Develop), and the deployment stage (Disseminate). The research design used is quasiexperimental.

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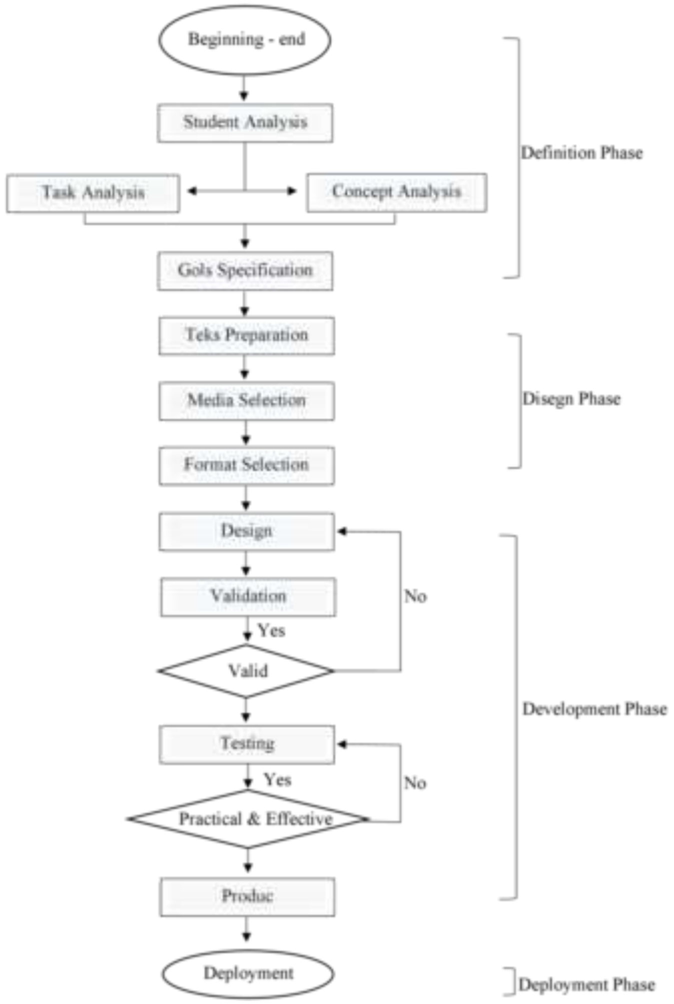

Fig.1. Desain Model 4D

Researchers used a pretest-post-test control group with one type of treatment. According to Hobri (2010), there are several data collection techniques based on the research instruments used, 1) Validation of learning devices, namely to validate learning devices that have been made, researchers provide validation sheets to validators (expert lecturers). Then validators are asked to provide assessments and suggestions for improvements related to aspects contained in learning materials that have been made; 2) Observation of the implementation of learning, namely Observation of the performance of knowledge, is carried out directly in class. Observers have received learning materials (RTM, LKM, and THB), learning observation sheets, and observation sheets of student activities in class. The results of the observations will be used to assess the effectiveness and practicality of the learning materials made; 3) 3. Collection of student learning outcomes, namely learning outcome data obtained from the results of LKM work, results from THB in the form of pre-test and post-test questions given to students during learning; 4) Activity observation, namely Observation of student activities carried out directly in class, where observers assess students during education by student activity observation sheets that researchers have provided; 5) Response questionnaire, namely after learning is complete, each student is given a questionnaire to respond to the learning materials developed whether they are practical and effective and assess learning activities in class. The results of the observations will be used to evaluate the effectiveness and practicality of the learning materials made; 3) 3. Collection of student learning outcomes, namely learning outcome data obtained from the results of LKM work, results from THB in the form of pre-test and post-test questions given to students during learning; 4) Activity observation, namely Observation of student activities carried out directly in class, where observers assess students during education by student activity observation sheets that researchers have provided; 5) Response questionnaire, namely after learning is complete, each

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student is given a questionnaire to respond to the learning materials developed whether they are practical and effective and assess learning activities in class; 4) Device Effectiveness Analysis where there are three indicators to measure the effectiveness of the device, namely learning outcome test data, student activity data, and also student response data.

RESULT

STEM is a term that represents four interrelated and continuous disciplines, namely science, technology, engineering, and mathematics. An explanation of the STEM aspects of the study can be seen in Fig. 2

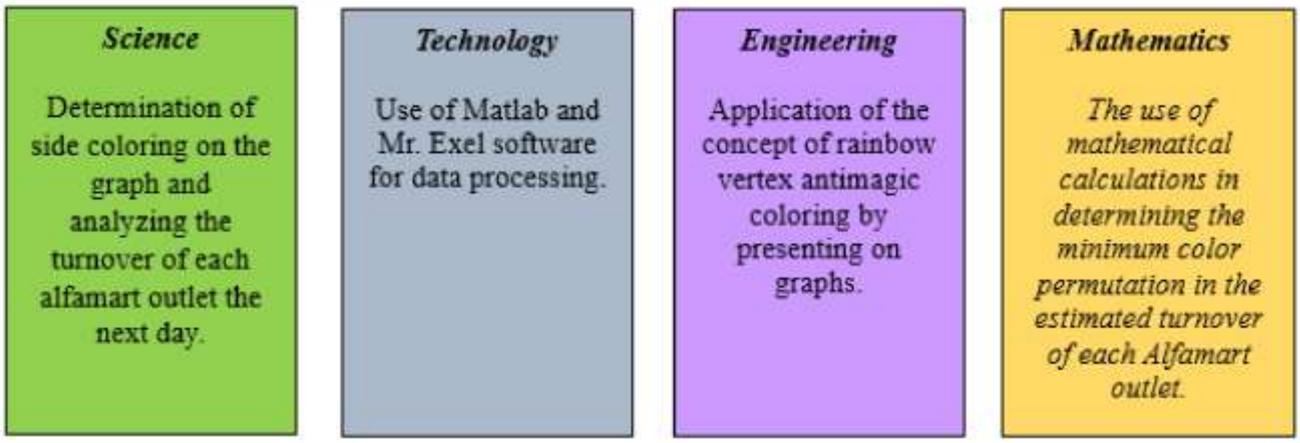

Fig. 2. STEM aspect in research

Research-based learning has six stages. In this section, we will discuss the stages of research-based learning with a STEM approach.

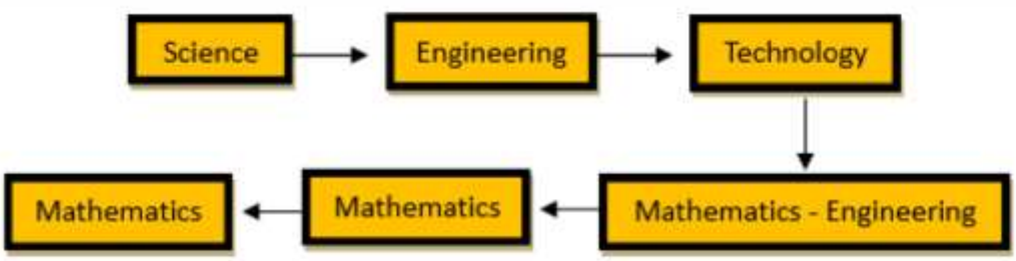

Fig. 3. Stage of RBL – STEM

These six stages describe the student learning process using a research-based learning model with a STEM approach in solving supply chain management problems to improve student conjecturing skills.

(Science)	Provision of problems regarding supply chain management whose solutions are related to neural networks, artificial graphs, and rainbow vertice, antimagic coloring. Place Alfamart outlets must have different placements according to their side weight. This is related to the topic of rainbow vertex antimagic coloring.
(Engineering)	Plan solutions to problems related to rainbow vertice, antimagic coloring, neural networks, and artificial graphs. This is intended to improve students' conjecturing skills in solving supply chain management problems. Students are asked to find information and understand the concepts of rainbow vertice, antimagic coloring, and neural networks.
(Technology)	Collect information related to problems and things that will be solutions to problems.

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(Mathematics Engineering)	Building a theorem on the topic of rainbow vertex antimagic coloring from several selected graphs
(Mathematics)	Prove theorems built on anti-magical rainbow coloring and analyze Supply Chain Management.
(Research Report)	We are presenting the results obtained regarding problem-solving and theorems obtained on rainbow vertex antimagic coloring.

Fig.4. Describe RBL-STEM Student

The process of developing STEM-based research-based learning materials is used to determine the effect of this tool on students' conjecture skills in solving supply chain management problems using artificial neural networks and rainbow vertex antimagic coloring analysis. This development process refers to the Thiagarajan model (4D), which includes the stages of defining (define), design (design), development (develop), and dissemination (disseminate). a. Defining Stage

This defining stage has the aim of setting and defining learning needs by analyzing the objectives and limitations of the material to be delivered. There are five steps at this stage, namely:

1) End-to-end analysis

The beginning-end analysis is carried out to determine the problems contained in learning activities and the development of learning materials. The resulting devices are expected to provide solutions to students hampered in classroom learning because they find it challenging to learn and understand the concept of antimagic rainbow coloring. The existence of this device will make it easier for students to understand the concept of rainbow vertex antimagic coloring and apply it to a graph. In addition, students can also use the Internet of Things (IoT).

Anti-magical rainbow coloring was chosen as a topic of study because this topic is classified as a new topic that combines two topics, namely antimagic labeling coloring and rainbow coloring. The existence of learning on this topic is expected to add insight to students and be used as a reference to compile a final project. Solving this problem requires active and creative students to find the predicted coloring pattern—a suitable learning model used in research-based learning to train students' conjecture skills.

2) Student analysis

Student analysis was used to obtain data on the characteristics of S1 Mathematics Education students at FKIP, Jember University. Students must be directly involved in the learning process and be able to work together in groups. Students of the Graph Application class can quickly understand the problems and concepts given. However, at first, they find it difficult to understand the anti-magical rainbow coloring because of this relatively new topic.

3) Concept analysis

This process identifies, details, and systematically compiles the concepts that students on anti-magic rainbow coloring will learn. Based on the start-end analysis that has been done, the concept analysis carried out produces the following concept map:

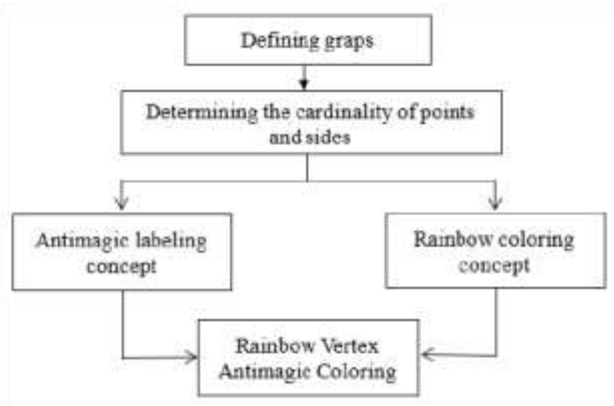

Fig. 5. Rainbow Vertex Antimagic Coloring Concept Analysis

4) Task analysis

Task analysis aims to identify the critical skills required in learning that fit into the curriculum. The purpose of this activity is to identify student conjecture skills by the expected final abilities, including the following:

1. Identify the problems developed and determine the solution to the issues;
2. Formulate a provisional basic assumption of the given problem;
3. Identify the stages to be taken to get a solution to the problem;
4. Using the Internet of Things to find information about problems and solutions;
5. Analysis of the results obtained based on observations made and compared with the fundamental assumptions compiled previously;
6. Sharing solutions obtained using the Internet of Things such as (Social Media, OER, MOOCs, Teaching Platform);
7. Cooperate with others using the Internet of Things and encourage others to conduct the same research to improve previous research.

b. Design Phase

The planning stage aims to design learning devices to be used so that examples of learning devices are obtained. At this stage, the design of research-based learning materials using a STEM approach was carried out to determine the effect of learning materials on increasing student conjecture on rainbow vertex antimagic coloring material. There are four steps at this stage, namely:

1) Preparation of tests and instruments used in research. The preparation of the pretest and posttest is based on tasks and analysis of concepts that have been described in the formulation of learning objectives. This test is in the form of a description that contains STEM, in this case the problems raised are supply chain management problems, rainbow vertex antimagic coloring topics and determination of alfamart outlets that have the potential to get a turnover of more than Rp. 10,000,000 and get a turnover of less than Rp. 10,000,000 related to neural networks.
2) Media selection is a step taken to determine the right media with the material that has been selected. The process of choosing media will be adjusted to the analysis of assignments, analysis of concepts and student characteristics. In this case, the media used are power points that can support understanding to students, as well as the development of Student Worksheets (LKM) containing conjecturing indicators.
3) Format selection is a step related to the selection of media aimed at designing content, selecting learning strategies and learning resources as support for learning activities. In this case, the learning model used is STEM-based research-based learning which contains the topic of rainbow vertex antimagic coloring and contains several things that can measure students' conjecture skills based on conjecture indicators.
4) Initial design is the entire design of learning materials that must be done before testing. The learning materials are in the form of Student Task Designs (RTM), Learning Outcomes Tests (THB) and Student Worksheets (LKM).

Fig. 6. LKM and THB Page Cover c.

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Development Phase

At the development stage, all developed tools are validated by validators and revised according to the suggestions given. After the device was declared valid, a trial was held in the Combinatorial D class of the Mathematics Education Study Program FKIP Universitas Jember. The results of this stage of development are as follows:

1) Validator assessment

The developed tools are revised according to the judgment and advice of validators. The device was validated by two validators, both of whom are lecturers of the Mathematics Education study program, FKIP, Jember University.

Table 1: Validator Field

No	Validator	Field
1	Validator 1	Graph Theory
2	Validator 2	Learning

In general, based on the assessments of both validators, the device can be used with minor revisions. The detailed assessment results of the two validators can be seen in Table 2.

Table 2: Assessment by Validators

Advocacy Device	Validator 1	Validator 2
Student Assignment Design (RTM)	Can be used with few revisions	Can be used with few revisions
Student Worksheet (MFI)	Can be used with few revisions	Can be used with few revisions
Learning Outcomes Test (THB)	Can be used with little revision	Can be used with little revision

Some suggestions from validator one regarding the justification of graph representations, the definition of material concepts, and graph drawings in LKM. Recommendations from validator two regarding the completeness of RPS updated RTM format and writing RBL ledges on LKM. Suggestions from these validators are used to revise learning materials so that the developed devices are suitable for learning.

The validation result of the student assignment design received a score of 3.6, the validation result of student worksheets was 3.5, and the validation result of the learning outcomes test was 3.6. Based on the validation result, it can be concluded that the learning materials is valid.

Table 3: RTM Validation Recapulation Results

Assessed Aspects	Avarage Score	Avarage Percentage
Format	3,5	88%
Content	3,75	94%
Language and Writing	3,6	90%
Overall aspect avarage score	3,6	91%

Table 4: LKM Validation Recapulation Results

Assessed Aspects	Avarage Score	Avarage Percentage
Format	3,5	88%
Content	3,4	85%
Language and Writing	3,5	88%
Overall aspect avarage score	3,5	87%

Table 5: THB Validation Recapulation Results

Assessed Aspects	Avarage Score	Avarage Percentage
Format	3,5	88%
Content	3,6	89%
Language and Writing	3,7	92%
Overall aspect avarage score	3,6	90%

2) Test drive the device

This validated and revised device trial was conducted on students of Kombinatorika class D of the Mathematics Education Study Program FKIP Universitas Jember. The class taught by this trial consisted of 23 students as test objects. An observer and one lecturer accompanied this trial process. The observer comprises five people and is taken from master students of Mathematics Education FKIP Universitas Jember. The supervisor who observed this trial was Mrs. Dr. Arika Indah Kristiana, S.Si., M.Pd. The results of the trial assessment consisting of observer assessments and student work were used to assess the effectiveness and practicality of the device.

Learning in this trial class was opened by Mrs. Arika Inda Kristiana as a lecturer, then handed over to researchers to conduct device trials with researchers acting as lecturers. Researchers extend learning followed by giving tests first before entering education using LKM. After the tests, the researchers provided little stimulus about anti-magic rainbow coloring, irrigation problems related to soil moisture, and graph representations of plants. This trial class uses a research-based learning model with a STEM approach. After understanding some of the things explained by the researcher, students were divided into six groups accompanied by one observer. Each student discusses with the group with observers helping guide the group if there are problems working on LKM. The time given for discussion is approximately 40 minutes, then students return to the initial learning. Groups are welcome to make presentations according to the results obtained during the meeting. After making a presentation, the lecturer reinforced to conclude related to some of the things learned. Lecturers provide opportunities for students to ask questions about things that need to be understood. After there are no questions, the lecturer gives post-test questions to do until the lecture time ends.

Before ending the lesson, the lecturer gives a questionnaire sheet file to students and is asked to fill in honestly and openly.

The data obtained from the trial implementation include student activity data, implementation observation data, student response questionnaires, and pre-test and post-test results. Analysis of the practicality and effectiveness of the device will be carried out on the data obtained. The results of this analysis can be used as a consideration for revising learning materials until a draft of learning materials is received that is ready for use.

Fig. 7. Presentage Students Value

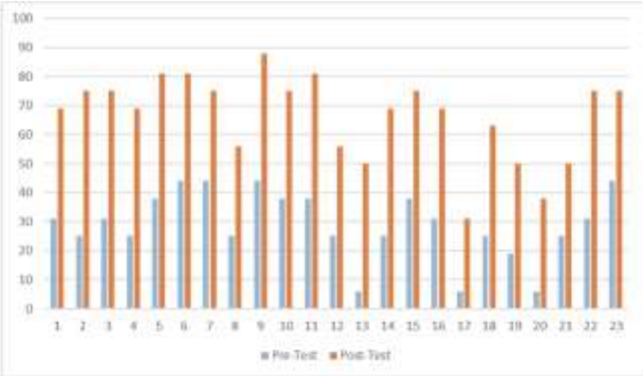

Fig. 8. Pretest Value and Posttes Value

d. Deployment Phase

The last stage is the deployment stage, which applies learning materials developed on a larger scale, such as in classes that have yet to be tested or at other universities by other lecturers.

DISCUSSION

The developed device has been validated by two validators and tested on a test class. The results of this validation meet the criteria of validity, practicality, and effectiveness. This device has completed the validity criterion of $3.25 \leq Va < 4$; the advice from validators does not change the device as a whole, but only a tiny part. The validity score obtained in each device is 3.6 for RTM (valid), 3.5 for MFI (good), and 3.6 for THB (functional). One of the objectives of this study is to analyze students' conjecture skills through test results. The Pretest results show 15 students (65% of students) can be categorized as medium conjecture level students. Eight students (35% of students) are at a low conjecture level, while the Post-test results show 16 students (70% of students) can be categorized as students at a high conjecture level. At the medium conjecture level, there are 6 students (26% of students), and 1 student (4%) is at the low conjecture level. This research-based learning model is recommended in the implementation of education to produce higher student motivation, can improve student learning outcomes, and be able to apply what is learned in everyday life. The goal of research-based learning is to make students more active, creative, and able to think more critically compared to students who use conventional education. This is by Suntusia (2019) explains that learning carried out in traditional classes causes students to tend to be passive and lack the drive to develop their potential. The results of applying learning devices are proven to significantly improve students' computational thinking skills. This can be seen from the results of the sample t-test paired between the pretest value and the post-test value, which shows an influence in the form of an increase in results.

CONCLUSION

Based on the process and results of developing research-based learning materials with a STEM approach to improve student conjecture skills, it can be concluded as follows: a) Syntax: Research-based learning with a STEM approach, among others: Provision of supply chain management problems whose solutions are related to neural networks and rainbow vertex antimagic coloring (Science), planning solutions to the problems given related with rainbow vertex antimagic coloring (Engineering), collect information related to problems and things that will be solutions to problems (Technology), build theorems on the topic of rainbow vertex antimagic coloring from several graphs (Mathematics-Engineering), prove theorems built on the topic of rainbow vertex antimagic coloring (Mathematics), and present the results obtained about solving problems and theorems obtained about rainbow vertex antimagic coloring topic (Research Results Report).; b) This development research refers to the Thiagarajan model (4D) which includes the stages of defining (define), design (design), development (develop), and dissemination (disseminate). At the defining stage there are five steps at this stage, namely. (a) Beginning-end analysis, (b) Student analysis, (c) Concept analysis, (d) Task analysis. This activity aims to identify students' conjecture skills by the expected final ability. At the planning stage, it seeks to design learning materials to be used so that examples of learning materials are obtained. There are four steps at this stage, namely. (a) Preparation of tests and instruments used in research; (b) Selection of media; (c) Format selection; (d) Initial design is the entire design of learning materials that must be done before testing. The learning materials are in the form of Student Assignment Design

(RTM), Learning Outcome Test (THB), and Student Worksheet (LKM); 3) At the development stage, all developed tools are validated by validators and revised according to the suggestions given. After the device is declared valid, a trial is held. The last stage, namely the dissemination stage carried out to research subjects, namely S1 students of Mathematics Education FKIP Universitas Jember. The results of the development of tools include Student Worksheets (LKM), pre-test questions, and post-test questions. After testing the device and analyzing it, it can be concluded that it meets the valid, practical, and effective criteria.

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