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The effectiveness of research-based learning model of teaching integrated with computer simulation in astronomy course in improving student computational thinking skills

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Abstract. This research aims to explore students' computational thinking skills within the implementation of the Research-Based Learning model of Teaching in Astronomy course in Kepler and Titius Bode Laws topics. The research design is comparing the modern class (experimental class) and traditional class with the traditional teaching type. RBL model of Teaching implemented in the experimental class, while direct Teaching implemented in the control class. Computer programming is also integrated into this research related to computational thinking skills. Matlab Software used in this research related to Astronomy course of Kepler's and Titius Bode's Laws topics. This research used triangulation methods. The quantitative methods were applied to analyze students' achievement tests according to computational thinking skills. The Qualitative method was applied using the observation of students' activity. Students' achievement tests are represented by pretest and posttest scores. The posttest results for the experimental class were 80.4167 and the control class was 75.8108. The data analysis form pretest and posttest scores indicate a significant value of 0.012 ($p \leq 0.05$) with the gain in mean that also emerged in both classes. The average value of student activity for the experimental class was 3.7444 and the control class was 2.4266 from a maximum value of 5. This research results that the RBL accompanied with computer simulations have a significant impact towards students' computational thinking skills.

1. Introduction

Science learning is based upon the scientific activities towards the facts and principles of the natural world. Science should be instructed with prioritizing, either the process or product evenly to support the concept implementation by the students [1]. Science literacy and the active role of students hold the crucial parts in science teaching and learning of the undergraduate classroom so that the active learning environment should be provided in class. In active learning, students engage in deeper understanding through teamwork over the discussion of specific science learning content. Therefore, the learning activity will be provided by the scientific process, problem-solving, and exercises that can improve either students' attitude and content knowledge [2]. One of the learning models that provide students to do the team working to solve the problem given through the simple until complex research is called the Research Based Learning (RBL) model [3].

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RBL is a learning model that emphasizes the integration of research activity as the students' learning process so that the cognitive process and other skills related to research activity were deliberately engaged (4). As the research activity underlying the RBL model, the research group becomes the major characteristic of RBL. A research group is a group that covers students and researchers that do the research activity together, including tutoring, doing the project of research, and supervising [3]. The specific issues underlying the research activity based on the real-world problems in a simple until complex problem range [3,4].

The syntax of RBL, which consists of steps within the whole Teaching and learning process, was vary reported due to the development process. The RBL model arranged by Rohim *et al.* have five substances, namely, collect information related to the issue from kinds of literature, enhance problem-solving with identify the information collected, analyze the graph and its content into a generalization, finish the whole rainbow connection process to create the rainbow connection number, and report the result supervised by group members in the form of paper [5]. The RBL model, according to Ridlo consists of seven phases. Those phases are problem-posing arise from research group discussion; developing problem-solving strategy; orientation of the collected data, tabulation, and hypothesis arrangement; analysis the data, prediction, and validation; proofing formulation, computation, and visualization; forum group discussion; and the report of research in the form of the draft that set for publication [3]. While the RBL model developed by Susiani *et al.* is consist of formulating the common question; observing the relevant literature; setting questions; planning the way research conduct; explain the method; investigating then analyze the collected data; analyzing and judging the result; making a report and presenting the result [6]. Furthermore, those RBL syntaxes should be selected by which best supports the learning output demanded.

Computational thinking (CT) can be described as the cognitive process managed by the metacognition to proceed in an efficient way of learning repetitive task completion. In the implementation of CT, algorithms, and abstraction hold the point of the way students discover the solution [7]. Within the implementation of computational thinking, students need to develop some skills, namely problem decomposition, algorithms, and abstraction. Those skills involved in computational thinking will help students understand and solve the problems from the computing perspective [8]. Furthermore, based on the literature review done by Shute *et al.*, the components of CT are five kinds of skills, namely abstraction, generalization, decomposition, algorithms, and debugging [9].

The Abstraction is the skill to analyze the main patterns of the important data collected from sources to create a model that describes the system performance. Generalization shows how students use the sources to a wider point of view in order to solve problems. Decomposition is the skill that represents the problem resolved by degrading the complex problem into its simpler parts together with the structural process to solve each composed simpler part. Algorithms show the way to discover a solution by developing a set of procedures efficiently and then automatically applying the procedure for identical problems. Iteration is the improvement of a solution until it provides a better result. Debugging skill shows the complement of bugs by finding and fixing errors that prevent the system from work correctly [9].

Astrophysics is the part of science that accompanies classical astronomy, which is known as one of the oldest knowledge of science. Practically, astrophysics in the learning process is majority combined with observation activity to help improve the students' understanding of the experience [10]. The knowledge within astronomy is based on the real space object. Therefore the learners should think of the concepts in three or four dimensions. The information of the Universe is gathered by utilization of various tools, and the result is presented in the multitude types of representation in the way astronomers communicate the knowledge. Based on that situation, the multidimensional thinking of space is highly necessary to learn astronomy and astrophysics [11].

The astronomy observation field nowadays highly relates to advanced technology as astronomers constantly record the significant observed data so that the digitalization will practically support access to accurate galactic data analysis. As the highly integration of technology in the astronomical field, the learners should be provided with various technology tools comprehension to help them get used to real-

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world data [12]. The example from previous research about dealing the astronomy course with computation is by using MatLab programming software to calculate the data. In the research done by Hossain and Mallik, MatLab software was used to reveal the spiral structure of the Milky Way by converting and plotting the clouds from different longitudes to the Cartesian coordinates [13]. While in the research done by Rajesvari *et al.*, MatLab programming software was involved in the method to automatically detect the galaxies and their classification with the use of mathematical functions in the area of the processed images [14].

The astrophysics discussed here were about Kepler's law. Kepler's first law states that all the planetary and sky object orbits are elliptical so that they move in an elliptical orbit. As the sky object moves around the orbit, the speed when it moves is explained in Kepler's second law, which states that when the planet moves around its orbit in a certain period, a line connecting a planet to its sun will have the same area in that period. Kepler's third law states that the square of the period of an orbit is equal to the cube of the orbital radius [15].

In this paper research, Kepler's Law and Titius-Bode's Law will be used in the related topic, namely planetary orbital that will represent the mathematical function to discover the picture represented by using MatLab programming software. To get those data, students need to do the research as conducted in the RBL model and tend to actively occupy the Computational Thinking skill to discover the best data output. At the end of the learning section, students will be tested with cognitive tests based on computational thinking to compare the C4-C6 achievement with the result of the research done by students.

The main characteristic of Research-Based Learning in teaching and learning activities is the integration between the research and learning process in the classroom activities. The syntaxes of the RBL model of teaching in Astronomy courses are explained with the phase presented in Figure 1. The Research-Based learning model of teaching adopted from Arifin contains three primary steps. They are the exposure stage, experiment stage, and capstone stage, respectively [15]. The first step is the Exposure stage, which explains the activity where students are gathering information from references that are relevant to the topics. The second step is the experiment stage, which is the step where the students are identifying and compiling formulations based on theory from literature or prior research studies that related to the problem given. In the third stage, the students experiment with the plans or ideas as part of providing the solution, algorithm, data measurement, and computer programming.

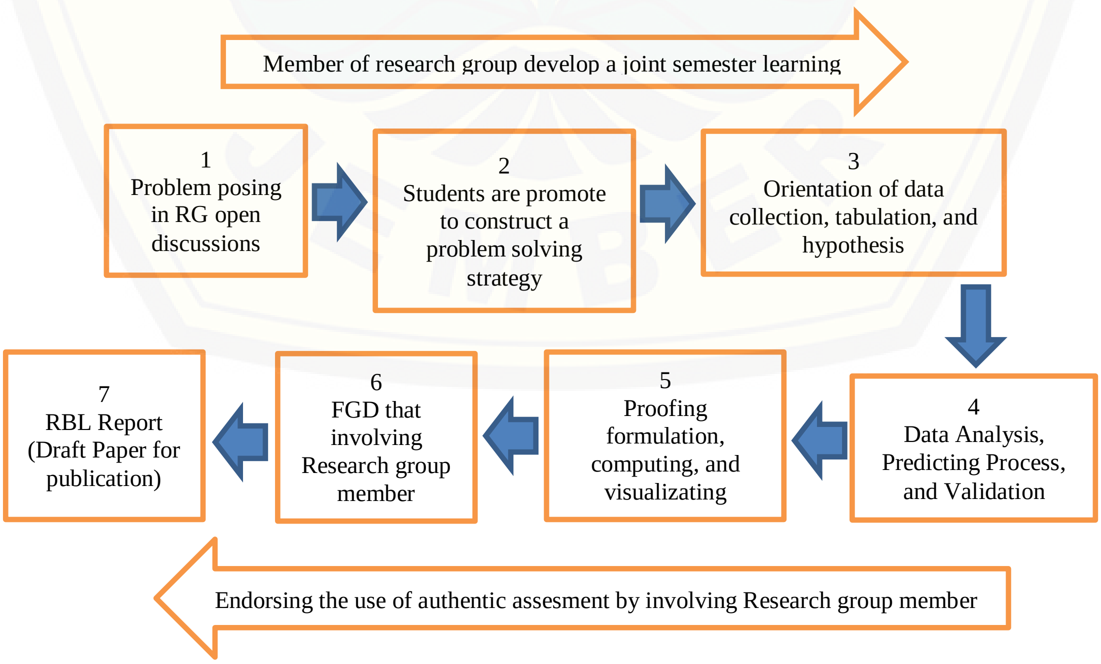

Figure 1. The stages of the RBL model of teaching in the Astronomy course

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Computational thinking has five criteria, namely, abstraction, generalization, decomposition, algorithmic thinking, and debugging [16]. The first element of Computational Thinking (CT) is an abstraction, which represents the students' skill of removing characteristics, variables, and attributes to reduce into the set fundamental characteristics [17]. The main purpose of the abstraction stage is to reduce complexity by removing irrelevant information. The second stage is a generalization, which is the stage that also purposes to reduce complexities by replacing multiple entities that perform similar functions, but with a single construct [18]. The third stage is decomposition, which has the purpose of breaking the complex problems into simpler solution [17]. The fourth stage is algorithmic thinking, which is the problem-solving skills in making computer programming [19]. The last stage is debugging, which is the skill to check and repair some error problems that appear while students are making and running the program [19]. Table 1 below shows the element of computational thinking related to the indicators used in the implementation of the Research-Based Learning model of Teaching in an Astronomy course.

Table 1. Element, Definition, and Indicator of CT in Astronomy Course

Element	Definition	Indicator
Abstraction	Ability to be able to sort the required information [17].	The student can identify and decide the important information to analyze Keppler laws.
Generalization	The ability to create general formulations and later use them in other problems [19].	The student can combine the Newton laws, Keppler laws, and Titius-Bode laws.
Decomposition	Ability to simplify complex problems so that they are easier to understand and solve [16].	The student can derive the formulation from Keppler laws related to period of planet orbit and planet radius.
Algorithms	Ability to be able to make operation steps to solve problems [19].	The student can be making computer program to solve Keppler laws related to Newton laws and Titius-Bode laws
a. Sequencing	The skill to put actions in the correct sequence [19].	
b. Flow of control	The order in which instructions/actions are executed [19].	
Debugging	Ability to find errors and attempt to fix them [19].	The student can find, identify and repair error syntax.

2. Methods

The method used in this research is quasi-experimental research. In this study, two classes will be used, namely the class with traditional learning and modern learning. Traditional learning uses discussion and presentation methods. Meanwhile, the modern class uses the RBL model with a STEM educational approach. The purpose of this study was to analyze the effectiveness of modern learning compared to traditional classrooms. Mixed methods including qualitative and quantitative methods were used as the design of this study. The quantitative methods are used to analyzed students' worksheets of solving problems concerning the astronomy course in topics of Kepler laws integrated with the RBL model of teaching and computer software. The results were analyzed qualitatively interviewing students to determine students' opinions about the RBL. The table 2 show the design of research by using mix methods.

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Table 2. Design of research using mixed methods.

Group	Pretest	Treatment	Post-test
Control Class n=37 Student	O_1	-	O_2
Experiment Class n=36 Student	O_3	X	O_4

O_1 & O_3 = both groups of classes were tested with a pretest to find out their computational thinking skills that were expected to be at the same level.
O_2 = the post-test results of the control class.
O_4 = the post-test results of experiment class [16]

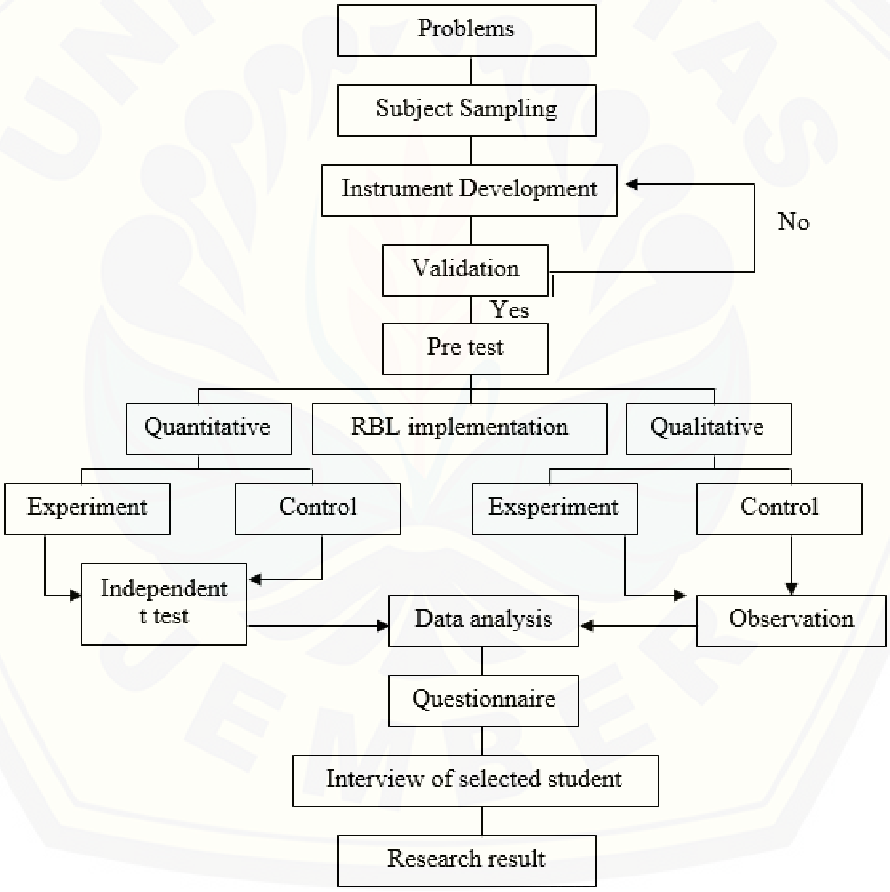

Figure 2. The triangulation model in mixed-method [16].

2.1. Population of Research

The population of this study is undergraduate students of the third semester from the Department of Natural Science Education, University of Jember. The sampling technique uses cluster sampling that randomly selects two classes. The total number of participants is 73 students, with ages ranging from 19-21 years. The experimental class consists of 36 students who are 10 male and 26 female students. In the control class, there were 37 students composed of 8 male and 29 female students. Data is collected from August to December 2020. The data in this study were supported by several types of instruments

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such as assignments, interviews, questionnaires and observation sheets. The task instrument is used to discover the level of students' understanding of the concept of Kepler's laws and Titius-Bode's laws. The observation sheet is used to determine the level of students' activity based on computational thinking skills. Students' opinions about the RBL learning model were assessed from the results of interviews and questionnaires.

2.2. Instrument Data

Giving assignments, observation sheets, interviews, and questionnaires were used as instruments in this study. The experimental class was given an interview and a questionnaire consisting of several questions. Students' computational thinking sheets use a Likert scale. Very Good (Score 5), Good (Score 4), Medium (Score 3), Fair (Score 2), Less (Score 1). All instrument sheets were validated first by experts from the field of physics education.

2.3. Task

Astrophysics

1 Look at the picture below,

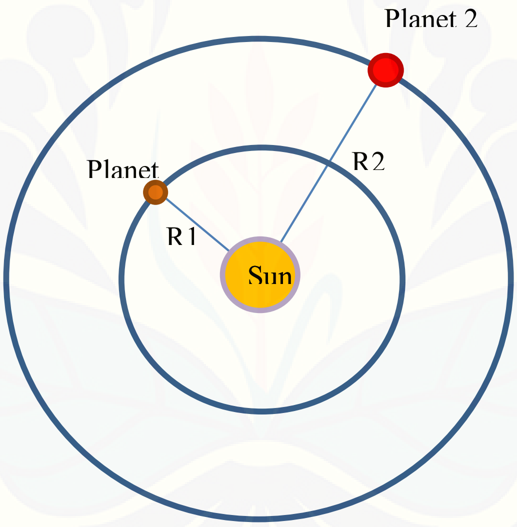

Figure 3. Simple Solar Sytem

Look at the Figure 3, from the picture above there are some important information below,

Table 3. Data

	Sun	**Planet 1**	**Planet 2**
Mass	2×10^{30} Kg	6×10^{24} Kg	$1{,}9 \times 10^{27}$ Kg
Rotation time	27 days	1 days	10 Hour
Orbital velocity	-	$30\ km/s$	$13{,}07\ km/s$
Radius	700.000 km	6.370 km	69.911 km
Inertia	$9{,}8 \times 10^{41}\ kg\ m^2$	$9{,}72 \times 10^{37}\ kg\ m^2$	$93 \times 10^{35}\ kg\ m^2$
Temperature	$6000\ K$	$27°C$	$145°C$
The distance to the sun	-	R_1	R_2

If we want to get the form of the equation from 3rd Kepler's law, then identify the information needed to analyze the equation.

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2 The period of the earth around the sun is 1 year with a distance of 1 AU. Using Kepler's third law and Titius-Bode law, determine the periods of the planets Jupiter and Mars.
3 Kepler's third law states that the quadratic period of a planet is proportional to the cube of its average distance from the sun. Using Newton's law of gravity and the planet's centripetal force, prove Kepler's third law. Derive The formulation to make the relation between Titius-Bode laws Kepler's Thirds law and Newton Laws of Motion.
4 Create a simple algorithm to solve problem number 3 for the other planets.

Consider the following simple algorithm, if your answer correct the result of picture from algoritm shown in Figure 4.

```
n=[0 3 6 12 24 48 96 192]: % integrer
for i=1:length(n+1)
   R(i)=(4+n(i))/10; % distance in AU
end
x=[1 2 3 4 5 6 7 8]; % number of planet
plot(R,x)
xlabel('number of planets'),ylabel('the distance of the planet to the sun (AU)');
```

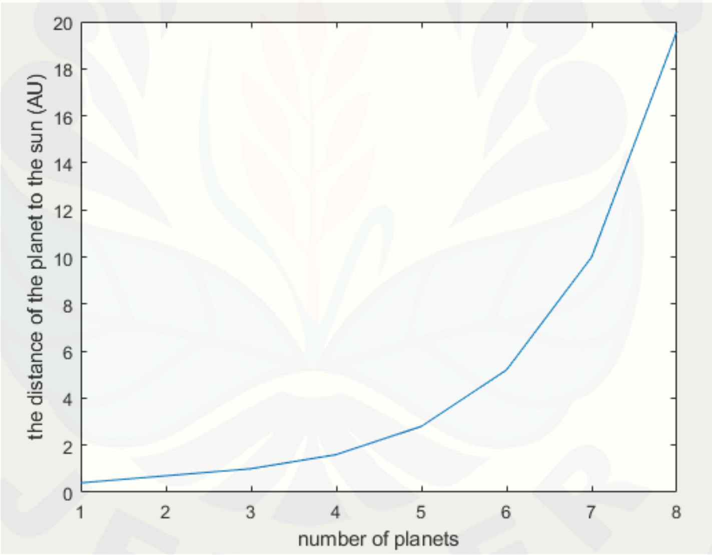

Figure 4. Graphics from Matlab

2.4. Data Collection and Analysis
In the control and experimental classes, both pretest and posttest were given. The process of analyzing quantitative data used independent sample t-test, while qualitative data were analyzed using tests based on ordinal data from interview and observation instruments. The results of the pretest and posttest were used to analyze the increase in computational thinking skills of students in the astronomy subject in Kepler and Titius Bode Law. The information presented in the data, namely frequency, mean, std deviation, and sig (2-tailed) were used to express inferential data statistically. The statistical results represent the impact of implementing the RBL Teaching model accompanied by computer programming.

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3. Result

The data of students' pretest and posttest scores within the implementation of the RBL model of Teaching was analyzed using the independent sample t-test. The comparison results of the pretest score of the control and experiment class are normally distributed, which indicates that the class is homogenous. A homogeneity test is used to test whether a model t-test data is homogeneous or not. If the data is homogeneous, then the research data can be carried out in the next stage, whereas if the data is not homogeneous, methodological correction is necessary. The next step is to perform analysis using statistical software (SPSS). In Table 4, it can be seen that the results of the students' pretest scores showed significant scores in both the control class and the experimental class

Table 4. The pretest score and the mean value of the control and experimental classes

Group Statistics

	Class	N	Mean	Std. Deviation	Std. Error Mean
Score	Experiment	36	50.5556	9.00617	1.50103
	Control	37	50.8108	9.31796	1.53186

Significant values provide the primary information needed to be analyzed and to draw conclusions from the data results. The significant value in this study is 5% or 0.05. The average pretest score for the control class was 50.81 with a standard deviation of 9.31, while the pretest mean score for the experimental class was 50.55 with a standard deviation of 9.006. From this data we can see that there is no significance between the control and experimental classes.

Table 5. The comparison of pretest results and mean value of control class and experiment class.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Score	Equal variances assumed	.022	.882	-.119	71	.906	-.25526	2.14570	-4.53366	4.02315
	Equal variances not assumed			-.119	70.997	.906	-.25526	2.14469	-4.53165	4.02114

In Table 5, it can be seen that the pretest results from the experimental and control classes will be analyzed using SPSS software. based on the results of the t-test shows a significance value (2-tailed) of 0.254, with a significant value criterion of 0.05. Because from the homogeneity criteria the sig (2-tailed) value is higher than the significant value, it can be concluded that the data between the control and experimental classes is homogeneous.

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The posttest results of the two classes were also analyzed using SPSS software. The comparison between the posttest results in the control class and the experimental class can be seen in Table 6. The mean value of the control class is 75.8108 with a standard deviation of 6.29302, while the mean value for the experimental class is 80.4167 with a standard deviation of 6.13829. The data in Table 7, the t value on the Levene's Test score is 0.324 with a p value <0.005, this indicates that there is a significant value between the two classes.

Table 6. The table display posttest result and mean value of control class and experiment class.

Group Statistics

	Class	N	Mean	Std. Deviation	Std. Error Mean
Score	Experiment	36	80.4167	6.13829	1.02305
	Control	37	75.8108	6.29302	1.03457

Table 7. The comparison of posttest results and mean value control class and experiment class.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Score	Equal variances assumed	.986	.324	3.164	71	.002	4.60586	1.45548	1.70371	7.50800
	Equal variances not assumed			3.166	70.999	.002	4.60586	1.45498	1.70472	7.50700

The data in Table 7. also presents the result of the independent sample t-test, which indicates a significant value of 0.002 ($p \leq 0.05$). So, it is known as a value of significance is achieved. From the results, it can be concluded that both of the two classes have differences in computational thinking skills test results after the treatment of implementing the research-based learning model of Teaching in the learning process.

The students' activity in the experimental class was observed by 11 observers with the Likert scale of students' activity, which spread into five categories, namely excellent (score 5), good (score 4), average (score 3), fair (score 2), and poor (score 1). The results of student's activity in the control class are explained in figure 3, and the results of the experiment class in shown in Figure 5.

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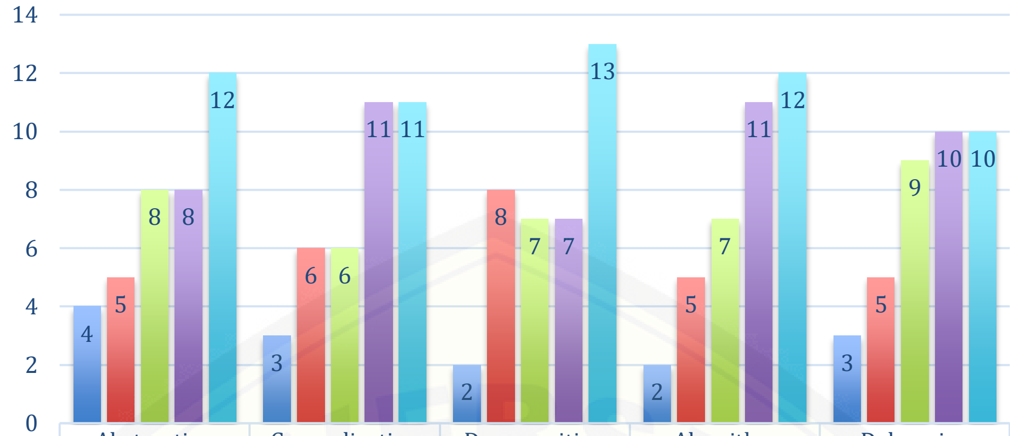
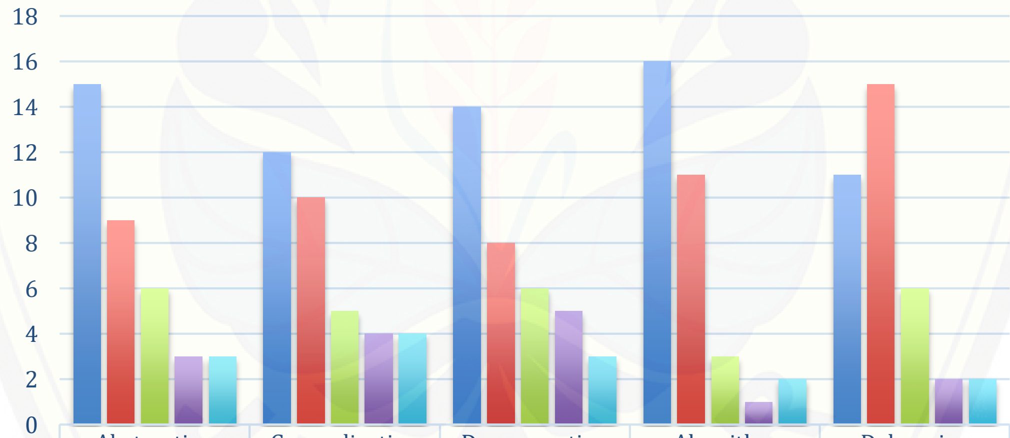


	Abstraction	Generalization	Decompsition	Algorithm	Debugging
Excellent	4	3	2	2	3
Good	5	6	8	5	5
Average	8	6	7	7	9
Fair	8	11	7	11	10
Poor	12	11	13	12	10

Figure 5. The results of students' activity about computational thinking in class control



	Abstraction	Generalization	Decompostion	Algorithm	Debugging
Excellent	15	12	14	16	11
Good	9	10	8	11	15
Average	6	5	6	3	6
Fair	3	4	5	1	2
Poor	3	4	3	2	2

Figure 6. The results of students' activity about computational thinking in the experimental class

Based on the data from Figure 5 and Figure 6, we can calculate the average scores of student's activity for each class using a predetermined Likert scale. We make it per indicator of computational thinking in order to see which parts are mastered by students and which parts are less mastered. For more details, see Figure 7 below.

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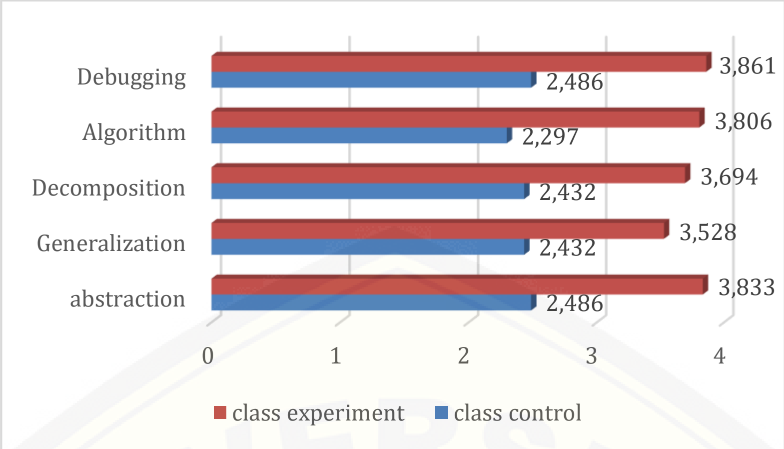

Figure 7. The total scores of students' activity per indicator of computational thinking for the class of control and class of experimental

4. Discussion

This study explores the effectiveness level of implementing research-based learning combined with computer programming to improve computational thinking skills. This capability is one of the important keys in 21st-century capabilities [21,22]. Research in this experimental class is based on STEM education. The topic of science discussed is about the movement of celestial bodies, especially the revolution of the planets in the solar system by using several related physical laws. Meanwhile, the technology and engineering elements of the algorithm are made in numerical simulation to facilitate the calculation and visualization of the results of the motion of the planets around the sun. Meanwhile, the mathematical elements are obtained from combining the formulas of Titius-Bode law, Newton's law and Keppler's law to obtain a compact equation for the motion of planets and their evolutionary time. STEM learning is very suitable to be applied in this era to be able to support 21st-century learning. STEM education is proven to increase student creativity, which will also affect students' self-confidence and psychomotor abilities [23,24]. This is because this education provides more space for students to be able to explore a problem and solve it according to their own thinking. The teacher, in this case, is only a companion for the students.

Based on the t-test, it can be seen that in the pretest scores of the two classes, there is no significant difference or is homogeneous. After applying the treatment in the form of research-based learning and computer programming, the posttest scores of the two classes experienced a significant difference with a Sig.2-Tailed value of 0.002. This shows that the computational thinking ability of the experimental class is better than the control class. Based on five indicators of computational thinking, namely abstraction, generalization, decomposition, algorithm, and debugging, an assessment is carried out to see student activity. Based on figures 3 and 4, we can do calculations to see the activeness of students. In the abstraction indicator, the average value of student activeness in the control class is 2.486, while in the experimental class, it is 3.833 with a maximum value of 5. From this data, it can be seen that students in the experimental class have been able to choose the information needed well. On the generalization indicator, the average value for the control class is 2.432, while the experimental class is 3.528, with a maximum value of 5. From this, students can say that students in the experimental class have been able to combine Kepler's laws, Newton's laws, and Titius-Bode law to solve the problems given, even though there were still 8 students who had difficulties and got low points. Similar to the decomposition indicator, the activity value of the experimental class was still higher than the control class, with a value of 2.432 compared to 3.694. From this value, it shows that students in the experimental class have been able to simplify a complex problem into simpler parts. Then in terms of making a simple algorithm, students in the experimental class tended to have a higher score than the control class with a value ratio of 2.297 and 3.806 from a maximum value of 5.While on the debugging indicator, the control class had an average activity value of 2.486, and the experimental class was 3.861.

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of the maximum value 5. In task number 5 an algorithm is given that there is an error in the syntax, then students are asked to correct it so that the appropriate results are obtained in Figure 2.In the computational world, errors in the syntax are very often encountered so that with this learning students are expected to be able to analyze errors in the algorithm and be able to correct them. In the control class and experimental class], there were still some students who scored below the average value. This is because students are using MatLab software for the first time, so they are still not familiar with the tools and algorithms used. Besides that, the language factor also affects the test results. Based on the results of interviews and questionnaires conducted, there were about 20% of students admitted that they still had difficulty understanding the instructions given because they were constrained by language.

Research-based learning, accompanied by numerical simulations, has a very significant impact compared to traditional learning, which is only a one-way lecture. With this learning, students become more active and dare to try new things, so that learning can occur in two directions and have a good impact on students. Learning the RBL model is proven to be able to improve higher-order thinking skills such as the ability to think critically and think creatively [25,26]. In addition, this model will increase knowledge, cognitive skills, psychomotor, and technological information processing skills [26]. Based on the test results and student activities, it can be seen that students' computational thinking skills are better in the experimental class. The ability to think computation is one of the abilities that is needed in the world of work, so it is expected to help students to compete in the world of work later.

5. Conclusion

RBL with computer simulations based on STEM education is proven to have an effect on student learning outcomes. This can be seen based on the t-test value, which shows the 2-tail sig.value is 0.002. The mean score of students in the experimental class was 80.41, while in the control class, it was 75.81. Based on the value of student activity for the experimental class showed better results than the control class for all indicators of computational thinking ability. So it can be concluded that RBL accompanied by computer simulations has a significant impact on students' computational thinking skills.

Acknowledgment

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