The effectiveness of research-based learning with computer programming and highly interactive cloud classroom (HIC) elaboration in improving higher order thinking skills in solving a combination of wave functions

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Abstract. The aim of this research was to compare the HIC (Highly interactive classroom) system with a traditional method of teaching superposition of wave functions courses especially. In order to examine it’s learning effectiveness across three dimensional, knowledge, comprehension, and application. The highly interactive classroom which collaborated with proof mathematics formulation, computer programming, and cloud classroom. The study followed a pretest, posttest, and delayed posttest with the quasi-experimental design. A total of 66 students (aged 18-19 years) divided into experimental group and control group. Experimental group 33 student (10 males and 23 females) was utilizing of cloud classroom and 33 students (12 males and 21 females) in the control group. Pretest, and posttest were evaluated by using inferential statistics t-test. The significant value of t-test score is -0.817 (p < 0.05) means there are significant of post-test score between control class and experiment class. The result indicated that student on an experimental group that teaching utilizing collaboration of computer programming, and highly interactive classroom better than control group was teaching by traditional method in post-test and delayed posttest across three learning dimensions. According to these result. The collaboration of mathematics formulation, computer programming, and HIC (highly interactive cloud classroom) is recommended to be a strategy for teaching on the combination of wave function topic.

1. Introduction
In general, thinking skill can be divided into Low Order Thinking (LOT) and High Order Thinking (HOT). HOT is important to be developed because it can make someone able to manage information obtained previously to bring up ideas as a solution to new problems. In Bloom’s taxonomy, HOT is at level C4 to C6 while in the dimension of the cognitive process are analysis, evaluation and creating activities. This is in line with the development of education which focuses on developing critical and creative thinking skills. The ability to think critically and creatively is part of HOT. However, in fact, thinking skills possed by most Indonesian students are still weak when resolving contextual problems. Especially if given a complicated problem. To deal with this situation, a teacher is required to make teaching and learning activities run efficiently and pleasantly. One effort that can be done is to use an interactive
learning model so that students can be interested in participating in learning and can also develop HOT students' abilities [2].

Table 1. Bloom Revised Taxonomy Verbs for HOT [3].

| The knowledge Dimension | The Cognitive Process Dimension |
|-------------------------|--------------------------------|
|                         | C4 Analyze                     |
|                         | C5 Evaluate                    |
|                         | C6 Create                      |
| Factual                 | Making structure, classifying  |
|                         | Comparing, correlating         |
| Conceptual              | Explain, analyze               |
|                         | Examine, interpret             |
| Procedural              | Distinguish                    |
|                         | Conclude, resume               |
| Metacognitive           | Create, find                   |
|                         | Make, asses                    |
|                         | Realization                    |

In learning activities, there are many things that need attention. The learning model plays an important role in the teaching and learning process. 21st-century education which is dominated by easy access to information makes the flow of education more sophisticated and demands an active role in conducting research. One of the learning models that support research is Research-Based Learning (RBL). RBL is a learning model that aims to improve students' academic abilities and can build their own knowledge. In addition, it can also improve and build students' thinking skills by connecting between theory and practice [4]. RBL-based modules are proven to be able to improve student competence, increase student activity and increase students' attractiveness towards learning content [5].

Increasing sophisticated technology makes access to information much easier than before. In the world of education, technology makes it easy for a teacher or lecturer to carry out teaching and learning activities. Computer programs are usually used to make presentations, display images or videos, conduct virtual demonstrations and computations on learning material. Especially in physics which is a scientific process. One of the important things in the function of technology especially computer programs in learning physics is when applied to virtual laboratories and understanding of difficult concepts in the implementation of learning [6].

Virtual Classroom is one of the devices that have a big impact on online learning activities. In its implementation, technology support that makes it possible to exchange information and also be able to carry out two-way interactions is needed [7]. One virtual class used in the learning process is a Highly Interactive Cloud classroom (HIC). HIC is a teaching system that can be used to examine the effectiveness of three dimensions, namely knowledge, understanding and application. Because of that, the aim of this research is to compare the HIC system with a traditional method of teaching superposition of wave function course especially.

2. Method
This research was conducted with the aim of comparing traditional learning with learning using the RBL model. In its implementation, using qualitative and quantitative methods. Quantitative methods are used to analyze student work in solving problems regarding the superposition of wave functions after being subject to the RBL learning model. Qualitative methods are used to analyze data from the results of interviews conducted on students to find out their opinions about RBL. The independent variable of this study is the RBL learning model. While the dependent variable is student learning outcomes. At the end of the session, interviews were conducted with the experimental class to find out their opinions about the research-based learning model. The research design uses two classes composed of control classes and experimental classes selected by purposive random sampling and examined using a pre-test and post-test using the following design.
In the design of this study, the two classes used were randomly selected (R). One class is subject to the RBL (X) class, while the other class uses traditional learning. The class subjected to treatment is called the experimental class while the non-treated class is called the control class.

The effect of the treatment is shown by \((O_2: O_4)\). Then analyzed using a t-test, as stated by Sugiono [10]. Figure 1 shows a triangulation model. At that picture showed triangulation qualitative data with quantitative data to determine the effect of learning model RBL in resolving problems in waves and vibration course, a combination of trigonometry on superposition on a wave functions.

Variations in wave functions are divided into variations in coefficients, phase and trigonometric functions.

a. Variation of wave function same amplitude and difference phase angle (superposition of sinus and sinus).

b. Variation of wave function same amplitude and difference phase angle (superposition of sinus and cosine).

c. Variation of wave function different amplitude and same phase angle (superposition of sinus and sinus).

d. Variation of wave function different amplitude and same phase angle (superposition of sinus and cosine).

2.1 Population

In this study, the population used was first semester students from the department of physical education of the University of Jember. Next, class selection uses cluster sampling to randomly select two classes. The total number of students in this study was 66 students with ages ranging from 18-19 years. There were 33 students in the experimental class consisting of 10 male and 23 female. In the control class, there were 33 students composed of 12 male and 21 female. Data is taken from September to October 2018. To retrieve data, there are several instruments provided. These instruments are task, interviews, questionnaires and observation sheets. Instruments in form of the task are used to find out the extent of students in the understanding the concept of superposition wave function. While, the observation sheet is used to determine the level of student activity. Interviews and questionnaires is used to determine students' opinions regarding research-based learning models.

2.2 Instrument

The instruments used in this study were a task, observation sheets, interviews and questionnaires. Interviews and questionnaires were only given to the experimental class which consisted of several question items. The observation sheet uses a Likert scale Very Active (Score 5), Active (Score 4), Hesitate (Score 3), Inactive (Score 2), Very Inactive (Score 1). The instrument sheet was validated by the expert of physics education.
2.3 Task
In this study, students in both classes were given questions about the wave function. In the experimental class, research-based learning was applied. Students are instructed to look for super positions wave function. On the assignment sheet, there are various wave functions. Variations in wave functions are divided into variations in coefficients, phase and trigonometric functions.

| First Wave Function | Second Wave Function | Amplitude | Phase |
|---------------------|----------------------|-----------|-------|
| Sin                 | Sin                  | Same      | Same  |
| Cos                 | Cos                  | Different | Different |

Figure 1. The model of triangulation method [11]
Then students will be directed to simulate the results of their work using a computer program to be compared and analyzed. The purpose of this task is that students can create a programming language to validate their work manually with the simulation results in a computer program.

3. Result and Discussion

HOT requires students to think critically and creatively in responding to problems using the information provided. In addition, students must be required to learn actively in the learning process. HOT abilities possessed by students can be seen from the results of learning. The average value of student learning outcomes is used to determine the increase in learning outcomes using the RBL learning model. Whereas, the average student activity is used to determine student learning activities during the learning process by using the RBL learning model based on student activity criteria.

In table 2 it can be seen that the average value of Pre-Test between control class and experiment has a slight difference. The average value of the experimental class is greater with a difference 2.4243. Based on Figure 2 it can be seen that there was 48.48% of students in the experimental class have very active status, 29.55% active, 8.33% hesitate, 8.33% inactive and 5.30% very inactive. This shows that the Research-Based Learning model makes most students in class become more active. Furthermore, in table 5, it is also shown that there is a difference in the average value of post-test between control class and experiment. Average value of experimental class remains higher with a difference 9.0303. This means that Research-Based Learning model in addition to increase student activities also improves student learning outcomes.

3.1 Task Explanation (superposition of wave functions)

There are several tasks to finish wavefunction superposition. (precondition, organizing, thinking, simulation)

3.1.1 Precondition

Before we understand more about wave superposition, there are several things that must be mastered first. These things will help you to understand more about this topic. Things that you need to master is:

a. Trigonometry

We talk about the wave. Of course, we need to understand Trigonometry (especially sinus and cosinus), both addition, subtraction (not too use), and how to process trigonometry into a new form without changing its value when we add any number in that equation.

b. Derivative

Derivative concept is needed when you will prove an equation including to the wave equation or not (especially when we add two different wave equation). Because of that, you need to master how to derive an equation (especially trigonometry). It will help you in determining which are included in the wave equation or not.

c. Wave concept

Of course we have to know first what the wave is, what elements are in a wave, and anything else. Wave concept is really important to understand because not all equation can be said as a wave if it does not have an element of a wave.

d. Mathematical operations

This is something that absolutely must be mastered. How to add, subtract, multiply, and divide numbers (not only number but also in trigonometry too). This is sometimes underestimated. But in complex number operations, it sometimes results in an error (error
means you did not do the calculation correctly). This will be very influential in studying this material.

3.1.2 Organizing (Mindmapping)

3.1.3 Thinking (analysis)
To prove a function belongs to a wave function, we can use the derivative twice, then test it in the wave equation. In wave superposition, there are many different combinations that we can make (based on the amplitude, angle of the phase and the combination of sinus and cosinus). There is four combinations in this case. The combination is: Sin + Sin with the same amplitude and different phase angles, Sin + Cos with the same amplitude and different phase angles, Sin + Sin with the different amplitude and same phase angles, and Sin + Cos with the different amplitude and same phase angles.

\[ \text{Sin + Sin} \]

Combined wave function with a combination “Sin + Sin” of same amplitude and different phase angles will produce a new wave function. There are two ways that we can do in this combination. The way is:
1. You can use derivative twice directly and then test it in the wave equation or
2. You can use Trigonometry to add both functions, use derivative twice, and test it in the wave equation

Both of them must be equal although we use a different way.

This is the analysis that I have made (the amplitude of both functions is 12 and first period 9 for the first function and 22 for the second function)

Given:
\[
\psi_1 = 12 \sin \left( \frac{2\pi}{9} t \right) \\
\psi_2 = 12 \sin \left( \frac{2\pi}{22} t \right)
\]

\[
\psi_3 \text{ (new wave function)} = \psi_1 + \psi_2
\]

\[
\psi_3 = 12 \sin \left( \frac{2\pi}{9} t \right) + 12 \sin \left( \frac{2\pi}{22} t \right)
\]

\[
\psi_3' = 12 \cdot \frac{2\pi}{9} \cos \left( \frac{2\pi}{9} t \right) + 12 \cdot \frac{2\pi}{22} \cos \left( \frac{2\pi}{22} t \right) \quad \text{(first derivative)}
\]

\[
\psi_3'' = \left( -12 \cdot \frac{2\pi}{9} \cdot \frac{2\pi}{9} \sin \left( \frac{2\pi}{9} t \right) - 12 \cdot \frac{2\pi}{22} \cdot \frac{2\pi}{22} \sin \left( \frac{2\pi}{22} t \right) \right) \quad \text{(second derivative)}
\]
\[
F = \left( -12 \left( \frac{2\pi}{9} \right)^2 \sin \left( \frac{2\pi}{9} \cdot t \right) - 12 \left( \frac{2\pi}{22} \right)^2 \sin \left( \frac{2\pi}{22} \cdot t \right) \right)
= \left( -\frac{48\pi^2}{9^2} \sin \left( \frac{2\pi}{9} \cdot t \right) - \frac{48\pi^2}{22^2} \sin \left( \frac{2\pi}{22} \cdot t \right) \right)
\]

proving process

\[
\frac{d^2\psi_3}{dt^2} + \sum_{n=1}^{2} \omega_n^2 \psi_n = 0 \quad \text{(wave equation)}
\]

Remember:

\[
\psi_3'' = \frac{d^2\psi_3}{dt^2}
\]

\[
\left( -\frac{48\pi^2}{9^2} \sin \left( \frac{2\pi}{9} \cdot t \right) - \frac{48\pi^2}{22^2} \sin \left( \frac{2\pi}{22} \cdot t \right) \right) + \left( \frac{2\pi}{9} \right)^2 \cdot 12 \sin \left( \frac{2\pi}{9} \cdot t \right) + \left( \frac{2\pi}{22} \right)^2 \cdot 12 \sin \left( \frac{2\pi}{22} \cdot t \right) = 0
\]

(Proven)

Wave superposition analysis above has been proven to be a wave function according to the wave equation.

Figure 3. Superposition of wave function same amplitude and different phase angles

Based on the picture above, the result of the combined function “\( \sin + \sin \)” of the same amplitude and different phase angles produce wave packets with a starting point \((0, 0)\). This corresponds to the wave function we use, with a sinus wave as a carrier and carried.

b. Superposition wave function \( \sin + \cos \) with the same amplitude and different phase angles

Combined wave function with a combination “\( \sin + \cos \)” of the same amplitude and different phase angles will produce a new wave function. Because there are no trigonometric formulas that can combine “\( \sin + \cos \)” into a simple equation, I use derivative twice directly and then test it in the wave equation.
This is the analysis that I have made (the amplitude of both functions is 12 and first phase angle 9 for the first function and 22 for the second function)

Given:

\[ \psi_1 = 12 \sin \left( \frac{2\pi}{9} \cdot t \right) \]
\[ \psi_2 = 12 \cos \left( \frac{2\pi}{22} \cdot t \right) \]

\[ \psi_3 \text{ (new wave function)} = \psi_1 + \psi_2 \]
\[ \psi_3 = 12 \sin \left( \frac{2\pi}{9} \cdot t \right) + 12 \cos \left( \frac{2\pi}{22} \cdot t \right) \]
\[ \psi_3' = 12 \left( \frac{2\pi}{9} \right) \cos \left( \frac{2\pi}{9} \cdot t \right) - 12 \left( \frac{2\pi}{22} \right) \sin \left( \frac{2\pi}{22} \cdot t \right) \]
\[ \psi_3'' = (-12 \left( \frac{2\pi}{9} \right)^2 \sin \left( \frac{2\pi}{9} \cdot t \right) - 12 \left( \frac{2\pi}{22} \right)^2 \cos \left( \frac{2\pi}{22} \cdot t \right)) \]

proving process

\[ \frac{d^2 \psi_3}{dt^2} + \sum_{n=1}^{2} \omega_n^2 \psi_n = 0 \quad \text{(wave equation)} \]

Remember:

\[ \psi_3'' = \frac{d^2 \psi_3}{dt^2} \]
\[ (-12 \left( \frac{2\pi}{9} \right)^2 \sin \left( \frac{2\pi}{9} \cdot t \right) - 12 \left( \frac{2\pi}{22} \right)^2 \cos \left( \frac{2\pi}{22} \cdot t \right)) + \]
\[ (12 \left( \frac{2\pi}{9} \right)^2 \sin \left( \frac{2\pi}{9} \cdot t \right) + 12 \left( \frac{2\pi}{22} \right)^2 \cos \left( \frac{2\pi}{22} \cdot t \right)) = 0 \]
\[ 0 = 0 \quad \text{(Proven)} \]

Wave superposition analysis above has been proven to be a wave function according to the wave equation.

Figure 4. Superposition of wave function same amplitude and different phase angles
Based on the picture above, the result of the combined function “Sin + Cos” of the same amplitude and different phase angles produce wave packets with a starting point (0, 12). This corresponds to the wave function we use, with a cosinus wave function as a carrier and sinus as being carried.

c. Superposition wave function Sin + Sin with the different amplitude and same phase angles
Combined wave function with a combination “Sin + Sin” of different amplitude and same phase angles will produce a new wave function. Because the phase angles are the same, we can add them manually (without using a special trigonometric formula). It is like:

\[ A \sin (x) + B \sin(x) = (A + B) \sin(x) \]

After that, I use derivative twice and then test it in the wave equation.

This is the analysis that I have made (the amplitude (9 for the first function and 22 for the second function) and phase angles of both function are 12)

Given:

\[ \psi_1 = 9 \sin \left( \frac{2\pi}{12} \cdot t \right) \]
\[ \psi_2 = 22 \sin \left( \frac{2\pi}{12} \cdot t \right) \]
\[ \psi_3 = \psi_1 + \psi_2 \]
\[ \psi_3 = 9 \sin \left( \frac{2\pi}{12} \cdot t \right) + 22 \sin \left( \frac{2\pi}{12} \cdot t \right) \]
\[ \psi_3' = 31 \cdot \frac{2\pi}{12} \cos \left( \frac{2\pi}{12} \cdot t \right) \]
\[ \psi_3'' = (-31 \cdot \frac{2\pi}{12}) \cdot \frac{2\pi}{12} \sin \left( \frac{2\pi}{12} \cdot t \right) \]

proving process

\[ \frac{d^2\psi_3}{dt^2} + \sum_{n=1}^{2} \omega_n^2 \cdot \psi_n = 0 \quad \text{(wave equation)} \]

Remember:

\[ \psi_3'' = \frac{d^2\psi_3}{dt^2} \]

\[ (-31 \cdot \frac{2\pi}{12})^2 \sin \left( \frac{2\pi}{12} \cdot t \right) + 9 \cdot \left( \frac{2\pi}{12} \right)^2 \sin \left( \frac{2\pi}{12} \cdot t \right) + 22 \cdot \left( \frac{2\pi}{12} \right)^2 \sin \left( \frac{2\pi}{12} \cdot t \right) = 0 \]

Wave superposition analysis above has been proven to be a wave function according to the wave equation.
Based on the Figure 5, the result of the combined function “Sin + Sin” of different amplitude and same phase angles produce a wave with a starting point (0, 0). This corresponds to the wave function we use, with a sinus wave as a carrier.

d. Superposition wave function Sin + Cos with the different amplitude and same phase angles

Combined wave function with a combination “Sin + Cos” of different amplitude and same phase angles will produce a new wave function. Because there are no trigonometric formulas that can combine “Sin + Cos” into a simple equation (although the phase angles are the same), I use derivative twice directly and then test it in the wave equation.

This is the analysis that I have made (the amplitude (9 for the first function and 22 for the second function) and phase angles of both function are 12)

Given :

\[
\psi_1 = 22 \sin \left( \frac{2\pi}{12} \cdot t \right) \\
\psi_2 = 9 \cos \left( \frac{2\pi}{12} \cdot t \right) \\
\psi_3 \text{ (new wave function)} = \psi_1 + \psi_2 \\
\psi_3' = 22 \left( \frac{2\pi}{12} \right) \cos \left( \frac{2\pi}{12} \cdot t \right) - 9 \cdot \left( \frac{2\pi}{12} \right) \sin \left( \frac{2\pi}{12} \cdot t \right) \\
\psi_3'' = \left( -22 \cdot \left( \frac{2\pi}{12} \right)^2 \cos \left( \frac{2\pi}{12} \cdot t \right) \right) - 9 \cdot \left( \frac{2\pi}{12} \right)^2 \sin \left( \frac{2\pi}{12} \cdot t \right)
\]

proving process

\[
d^2\psi_3 \over dt^2 + \sum_{n=1}^2 \omega_n^2 \psi_n = 0 \quad \text{(wave equation)}
\]
Remember:

\[
\psi_3'' = \frac{d^2\psi_3}{dt^2} = -22 \left(\frac{2n}{12}\right)^2 \cos\left(\frac{2n}{12}.t\right) - 9 \left(\frac{2n}{12}\right)^2 \sin\left(\frac{2n}{12}.t\right) + \left(22 \left(\frac{2n}{12}\right)^2 \cos\left(\frac{2n}{12}.t\right)\right) + 9 \left(\frac{2n}{12}\right)^2 \sin\left(\frac{2n}{12}.t\right) = 0 \quad (Proven)
\]

Wave superposition analysis above has been proven to be a wave function according to the wave equation.

**Figure 6.** Superposition of wave function different amplitude and same phase angles

Based on the picture above, the result of the combined function “Sin + Cos” of different amplitude and same phase angles produce a wave with a starting point (0, 9). This corresponds to the wave function we use, with a sinus wave as a carrier.

Creating M-File, a combination of the trigonometric function should be change function. In this research, we focus on the effectiveness of implementation RBL (Research-Based Learning) integrated with HIC (highly interactive cloud classroom). Analysis of pre-test and post-test score to investigate the impact of implementation RBL used independent sample t-test with SPSS software. Analysis of score pre-test in the control class and experimental class show on Table 2 and Table 3. Table 2 shows a score of pre-test in control class is 55.1515 with standard deviation value is 9.14167, experiment class get score 57.5758 on pre-test with standard deviation is 15.56864. The differences of standard deviation value both of class are 6.42679 (\(\gamma > 0.05\)) implies sa core on control class and experimental class is not significant.
4. Simulation (Creating M-file)

| Equations | M-Files |
|-----------|---------|
| Wave superposition special for Sin + Sin | ![Image of M-file code and output] |

```matlab
clear;
disp('Gambar gelombang');
A=input('masukkan nilai amplitude, A:');
B=input('masukkan nilai amplitude, B:');
T_1=input('masukkan nilai periode, 1, T_1:');
T_2=input('masukkan nilai periode, 2, T_2:');
T=input('masukkan batas waktu, t:');
w=(2.*pi/T_1);
v=(2.*pi/T_2);
x=(0:0.01:t);
y_1=A.*sin(w.*x);
y_2=B.*sin(v.*x);
y = y_1 + y_2;
plot(x,y);
grid on
```

Table 2. Result Statistics on Pre-Test

| Class      | N  | Mean     | Std. Deviation | Std. Error Mean |
|------------|----|----------|----------------|-----------------|
| Pre-Test Score | 33 | 55.1515  | 9.14167        | 1.59136         |
| Experiment | 33 | 57.5758  | 15.56846       | 2.71012         |

Analysis of comparison between experiment class and control class using independent t-test methods shows in Table 3. Sig. (2-tailed) value of pretest is 0.443 (p > 0.05), this value is not significant differences of score of two classes, the conclusion two classes are homogenous.

Table 3. Independent Samples Test Pre-Test

| Levene’s Test for Equality of Variances | t-test for Equality of Means |
|----------------------------------------|-----------------------------|
| F | Sig. | t | df | Sig. (2-tailed) | Mean | Std. Error Difference | 95% Confidence Interval of the Difference |
|   |      |   |    |               |      |                      |     |
|   |      |   |    |               |      |                      |     |

| Lower | Upper |
|-------|-------|
|       |       |
Pre-Test Score

| Equal variances assumed | 4.790 | .032 | -.771 | 64 | .443 | -2.42424 | 3.14280 | 8.70270 | 3.85422 |
| Equal variances not assumed | -.771 | 51.722 | .444 | -2.42424 | 3.14280 | 8.73153 | 3.88305 |

Post-test score between control class and experiment class shows on Table 4 and Table 5. The Post-test of control class is 71.3333 with a value of standard deviation 3.18852 while the score of experiment class is 80.3636 with a value of standard deviation 5.02381. The significant value of t-test score is -0.817 (p < 0.05) means there are significant of the post-test score between control class and experiment class.

Table 4. Group Statistics Post-Test

| Post-Test Score | Class   | N  | Mean   | Std. Deviation | Std. Error Mean |
|-----------------|---------|----|--------|----------------|-----------------|
|                 | Control | 33 | 71.3333 | 3.18852        | .55505          |
|                 | Experiment | 33 | 80.3636 | 5.02381        | .87453          |

Value of sig (2-tailed) shows on table 5 is 0.000 of independent t-test methods means the value of score in experiment class and control class is significant. The process of teaching and learning using Research-Based Learning model in experiment class give significant impact to a student in solving a combination of the wave function on the wave and vibration course.

Table 5. Independent Samples Test Post-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 |
| Equal variances assumed                 | 3.361 | .071 | 8.718 | 64 | .000 | -9.03030 | 1.03580 | -11.09956 | 6.96105 |
| Equal variances not assumed             | 8.718 | 54.181 | .000 | -9.03030 | 1.03580 | -11.10680 | 6.95380 |

Additional information supported by of this research supported by the observation of student activity of experiment class by 11 observers and it used a Likert scale encompassing Very Active (Score 5), Active (Score 4), Hesitate (score 3), Inactive (score 2), Very Inactive (score 1). There are 4 items that observe in experiment class.
1. Analyze Mathematics and Physics Concept
2. Making Mind Mapping
3. Superposition Wave Functions
4. Creating M-File
The observation results of student activity can be shown in the following chart in Figureure 7.
Table 6. Student activity in experiment class

| Activity                  | Analyze Mathematics and Physics Concept | Making Mind Mapping | Superposition of Wave Functions | Creating M-File |
|---------------------------|-----------------------------------------|---------------------|----------------------------------|-----------------|
| Very Active               | 15                                      | 13                  | 16                              | 20              |
| Active                    | 10                                      | 9                   | 12                              | 8               |
| Hesitate                  | 3                                       | 5                   | 2                               | 1               |
| Inactive                  | 2                                       | 4                   | 2                               | 3               |
| Very Inactive             | 3                                       | 2                   | 1                               | 1               |
| Total                     | 33                                      | 33                  | 33                              | 33              |

**Figure 7.** The observation results distribution of all subjects in the experimental class

**Figure 8.** The observation results distribution (pie chart) of all subjects in the experimental class.

According to
Table 7. The first task for wave functions with phase angles

| First Way | Equation | Second Way | Equation |
|-----------|----------|------------|----------|
| \( \psi_1(t) \) | \( 5 \sin \left( \frac{2 \pi}{3} \cdot t \right) \) | \( \psi_1(t) \) | \( 5 \sin \left( \frac{2 \pi}{3} \cdot t \right) \) |
| \( \psi_2(t) \) | \( 5 \sin \left( \frac{2 \pi}{17} \cdot t \right) \) | \( \psi_2(t) \) | \( 5 \sin \left( \frac{2 \pi}{17} \cdot t \right) \) |
| \( \psi_1(t) + \psi_2(t) \) | \( 10 \sin \left( \frac{2 \pi}{51} \cdot t \right) \cos \left( \frac{14 \pi}{51} \cdot t \right) \) | \( \psi_1(t) + \psi_2(t) \) | \( 5 \sin \left( \frac{2 \pi}{3} \cdot t \right) + 5 \sin \left( \frac{2 \pi}{17} \cdot t \right) \) |
| \( (\psi_1(t) + \psi_2(t))' \) | \( \frac{10}{3} \pi \cos \left( \frac{2 \pi}{3} \cdot t \right) + \frac{10}{17} \pi \cos \left( \frac{2 \pi}{17} \cdot t \right) \) | \( \psi_1'(t) + \psi_2'(t) \) | \( \frac{10 \pi}{3} \cos \left( \frac{2 \pi}{3} \cdot t \right) + \frac{10 \pi}{17} \cos \left( \frac{2 \pi}{17} \cdot t \right) \) |
| \( (\psi_1(t) + \psi_2(t))'' \) | \( \frac{-20 \pi^2}{9} \sin \left( \frac{3 \pi}{3} \cdot t \right) - \frac{20 \pi^2}{289} \sin \left( \frac{2 \pi}{17} \cdot t \right) \) | \( \psi_1''(t) + \psi_2''(t) \) | \( \frac{-20 \pi^2}{9} \sin \left( \frac{2 \pi}{3} \cdot t \right) - \frac{20 \pi^2}{289} \sin \left( \frac{2 \pi}{17} \cdot t \right) \) |

In table 7, the results of student work are shown about combining two wave functions. The two wave functions used have different phase angles. The first wave function is symbolized by \( \psi_1 \) which has a phase angle preceding the second wave function. The second wave function is symbolized by \( \psi_2(t) \). From table 7 can be seen in first way, the solution is done by using a trigonometric identity for \( \psi_1(t) + \psi_2(t) \). This indicates students to think creatively in progress. Whereas in second way, the settlement for is done \( \psi_1(t) + \psi_2(t) \) using algebraic addition. After calculating function by doing first derivative, the result is in accordance with the first and the second way. But the difference is that in the first way a partial decrease was made while in the second way the decrease was carried out algebraically. After the second derivative, the same results are obtained.

Table 8. The second task for wave functions with different trigonometric functions and phase angles

| First Way | Equation | Second Way | Equation |
|-----------|----------|------------|----------|
| \( \psi_1(t) \) | \( 5 \sin \left( \frac{2 \pi}{3} \cdot t \right) \) | \( \psi_1(t) \) | \( 5 \sin \left( \frac{2 \pi}{3} \cdot t \right) \) |
| \( \psi_2(t) \) | \( 5 \cos \left( \frac{2 \pi}{17} \cdot t \right) \) | \( \psi_2(t) \) | \( 5 \cos \left( \frac{2 \pi}{17} \cdot t \right) \) |
| \( \psi_1(t) + \psi_2(t) \) | \( 10 \sin \left( \frac{2 \pi}{3} \cdot t \right) \cos \left( \frac{2 \pi}{17} \cdot t \right) \) | \( \psi_1(t) + \psi_2(t) \) | \( 5 \sin \left( \frac{2 \pi}{3} \cdot t \right) + 5 \cos \left( \frac{2 \pi}{17} \cdot t \right) \) |
| \( (\psi_1(t) + \psi_2(t))' \) | \( \frac{10 \pi}{3} \cos \left( \frac{2 \pi}{3} \cdot t \right) + \frac{10 \pi}{17} \sin \left( \frac{2 \pi}{17} \cdot t \right) \) | \( \psi_1'(t) + \psi_2'(t) \) | \( \frac{10 \pi}{3} \cos \left( \frac{2 \pi}{3} \cdot t \right) + \frac{10 \pi}{17} \sin \left( \frac{2 \pi}{17} \cdot t \right) \) |
| \( (\psi_1(t) + \psi_2(t))'' \) | \( \frac{-20 \pi^2}{9} \sin \left( \frac{3 \pi}{3} \cdot t \right) - \frac{20 \pi^2}{289} \cos \left( \frac{2 \pi}{17} \cdot t \right) \) | \( \psi_1''(t) + \psi_2''(t) \) | \( \frac{-20 \pi^2}{9} \sin \left( \frac{2 \pi}{3} \cdot t \right) - \frac{20 \pi^2}{289} \cos \left( \frac{2 \pi}{17} \cdot t \right) \) |
In table 8, the results of the students' work about combining two wave functions are shown. The two wave functions used have different trigonometric functions and phase angles. The first wave function is symbolized by \( \psi_1(t) \) as a function of \( \sin \) with phase angle preceding the second wave function. The second wave function is symbolized by \( \psi_2(t) \) as a function \( \cos \). Based on the work that has been done by students, it can be seen that the resolution of the problems carried out in the first way and second way is same. In contrast to first problem, there is no simplification of this problem using trigonometric identities. After the first and second derivative of wave the function equation, the same result is obtained.

| Table 9. The third task for wave functions with different amplitude |
|---------------------------------------------------------------|
| **First Way** | **Equation** | **Second Way** | **Equation** |
| \( \psi_1(t) \) | 3 sin \( \frac{2\pi}{5} \cdot t \) | \( \psi_1(t) \) | 3 sin \( \frac{2\pi}{5} \cdot t \) |
| \( \psi_2(t) \) | 17 sin \( \frac{2\pi}{5} \cdot t \) | \( \psi_2(t) \) | 17 sin \( \frac{2\pi}{5} \cdot t \) |
| \( \psi_1(t) + \psi_2(t) \) | 20 sin \( \frac{2\pi}{5} \cdot t \) | \( \psi_1(t) + \psi_2(t) \) | 3 sin \( \frac{2\pi}{5} \cdot t \) + 17 sin \( \frac{2\pi}{5} \cdot t \) |
| \( (\psi_1(t) + \psi_2(t))' \) | 8\( \pi \) cos \( \frac{2\pi}{5} \cdot t \) | \( \psi_1'(t) + \psi_2'(t) \) | \( \frac{6\pi}{5} \cos \left( \frac{2\pi}{5} \cdot t \right) \) + \( \frac{34\pi}{5} \cos \left( \frac{2\pi}{5} \cdot t \right) \) |
| \( (\psi_1(t) + \psi_2(t))'' \) | \( - \frac{16\pi^2}{5} \sin \left( \frac{2\pi}{5} \cdot t \right) \) | \( \psi_1''(t) + \psi_2''(t) \) | \( - \frac{12\pi^2}{25} \sin \left( \frac{2\pi}{5} \cdot t \right) \) - \( \frac{68\pi^2}{25} \sin \left( \frac{2\pi}{5} \cdot t \right) \) |

In table 9, the results of the student's work about combining two wave functions are shown. Students are required to solve these problems using two ways. The two wave functions used has a different amplitude. The first wave function is symbolized by \( \psi_1(t) \) with amanplitude smaller than second wave function. The second wave function is symbolized by \( \psi_2(t) \). On this issue, students do two ways to solve it. In function \( \psi_1(t) + \psi_2(t) \), the first way student completes function is by directly summing it up. Where as in second way, students do not do summing first. Furthermore, both first and second ways are carried out second the derivative and same the results are obtained.

| Table 10. The fourth task for wave different wave function and amplitude |
|---------------------------------------------------------------|
| **First Way** | **Equation** | **Second Way** | **Equation** |
| \( \psi_1(t) \) | 3 sin \( \frac{2\pi}{5} \cdot t \) | \( \psi_1(t) \) | 3 sin \( \frac{2\pi}{5} \cdot t \) |
| \( \psi_2(t) \) | 17 cos \( \frac{2\pi}{5} \cdot t \) | \( \psi_2(t) \) | 17 cos \( \frac{2\pi}{5} \cdot t \) |
| \( \psi_1(t) + \psi_2(t) \) | 3 sin \( \frac{2\pi}{5} \cdot t \) + 17 cos \( \frac{2\pi}{5} \cdot t \) | \( \psi_1(t) + \psi_2(t) \) | 3 sin \( \frac{2\pi}{5} \cdot t \) + 17 cos \( \frac{2\pi}{5} \cdot t \) |
In table 10, the results of students' work about combining two wave functions are shown. Students are required to solve these problems using two ways. Two wave functions used have different trigonometric functions and amplitude. The first wave function is symbolized by $\psi_1(t)$ as a sin function with a smaller amplitude than the second wave function. Second wave function is symbolized by $\psi_2(t)$ as a cos function. Just like the previous assignment, this task does not resolve using a trigonometric identity. Both first and second way use algebraic addition. Because solution using algebra for this problem is easier. Next, the second derivative is carried out in both ways and same the results are obtained.

3.2 Integration Cloud Classroom into wave and vibration course

Cloud classroom (CCR) construct in HTML 5.0 and works in every device like PDA, PC, Computer tablet, FDAs, and smarthphone based on android program or IOS device. CCR can be used without installation, it’s very easy to used because CCR. CCR has many feature that are more interactive with teacher and student including response student, direct questions and direct answer, multimedia presentations, quiz and exercise, and role play swapping (teachers and student) [12].

In this research, researchers use CCR for efficient to carry out formative assessment. The teacher construct curriculum design, planning teaching programs, explain the main course of vibration and wave (combination of wave functions), before class use CCR, teacher should be inform to student four dimension of teaching and learning process, Precondition (collect the information as basic concept to develop process combination of wave function). Organizing (making mind mapping, relation between mathematic concept and physics concept). Thinking (proof the formulation process of superposition wave functions). Simulation (making M-File program to simulated three wave functions, 2 initials wave and 1 superposition wave functions).

Teacher can ask several types of question into students using CCR like open ended question, true and false questions, and multiple choice questions. Teachers ask to student about time to do exercise on CCR. In this study teacher use a question about how to combine new wave function according to combination of trigonometry function, amplitude, and phase angle.
Integration of CCR into wave and vibration course display on Figure 9 and 10. The procedure phase of simulation is the difficult process for students, because student should be constructs M-File and plotting graphics of wave functions, each instruction in M-File should be match to general process of superposition process, for example: value of amplitude, periods, and types of wave functions. After students answer the question included with Matlab simulations student should be upload on their CCR.
Finally, to know the students’ perception about the implementation of Research-Based Learning in a combination of wave function problem, the researchers conducted interviews with students. In order to address ethical issues, the researchers made the student’s name anonymous, as they were simply represented by “Researcher” and “Student”. The data obtained from interviews are discussed below.

Researcher : After finish learning wave and vibration subject about, what have you understood?
Student : I understand about the characteristic of the wave function, superposition of the wave function, and the combination of the wave function.

Researcher : was there any new information you gained after creating M-File?
Student : Yes, I found that any relation between the process of superposition of wave function into Matlab programming, both of them should be correspondence for each other.

Researcher : You as a student of the mathematics department, what is the advantages learning by using RBL methods?
Student : It’s fun for me because I try to explore research capability to further research on next semester.

Researcher : What about the integration of HIC (Highly Interactive Cloud Classroom) in class?
Student : I think cloud classroom is good to integrate into this course because it’s more efficient and stable.

Researcher : On the post-test, what appeared to be the difficulty?
Student : The difficulty steps in combining different patterns in one table. It was confusing when I need to expand the

Researcher : How about your opinion integration study with cloud classroom?
Student : I’m very satisfy, CCR hepl us to good communications with teacher by using feature dialogue, and good information bacuse can integrated with youtube channel.

All the task of students compress into one file and sent to teacher email (Google Drive or Dropbox) to record the final result of wave and vibration course.

4. Conclusion

Research-based learning can improve student learning outcomes and can also train students to think higher. In addition, RBL can also increase activities and make students more interested in learning. This is evidenced by an increase in learning outcomes and active categories in the data collection table. Virtual classes combined with RBL models make physics learning easier to understand.

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