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The Analysis of Implementation Project-Based Learning Model of Teaching Integrated with Computer Programming in Improving Computational Thinking Skills in a Classical Mechanics Course

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Abstract: This research aims to explore student computational thinking skills in implementing a project-based learning model of teaching integrated with computer programming in classical mechanics course in projectile motion topic. The research design uses one group pretest and post-test design. The computational thinking skills have five indicators: abstraction, generalization, decomposition, algorithm, and debugging. The computational thinking indicator was analyzed from the result of Pretest and post-test scores and a comparison between manual solution and numerical solution from computer programming. The instruments used in this study were tasks, rubrics, and questionnaires. The result shows the average score of the Pretest is 53.05, and the post-test score is 80.22. The student computational thinking skills in algorithm and debugging in Pretest are 29.70% and 24.30% and 59.00%, and 54.00% in the post-test stage. This result indicates the implementation of PBL model of Teaching integrated with computer programming has a significant impact on student computational thinking skills.

Keywords: Project-based learning; Computer Programming; Computational thinking skills; Classical mechanics

Introduction

In this research, we analyze the implementation of the project-based learning model of Teaching and the integration with computer programming to improve computational thinking skills in a classical mechanics course. Classical mechanics is given at the college level. Mechanics is physics that studies the object's motion (Young, 2020) both object stationary (static) or moving (dynamic) objects. The existence of mechanics has existed since ancient Greece and continues to grow until now. In its development, mechanics is divided into two sections, classical mechanics and quantum mechanics (Takahashi, 1989). The discussion of classical mechanics focuses on objects with a velocity less than the velocity of light (Vilmala, 2020). This mechanics learning requires students to understand the process of solving a problem and suggests students understanding the concept of physic. Now mechanics learning still uses the conventional method. It makes students think that classical mechanics is complex, and they focus their attention and mind on learning a concept and a lot of formulas (Sabaryati & Isnaini, 2018). One of the topics of classical mechanics is projectile motion. To learn about it, we combine a classical mechanics course with project based-learning model of teaching for the college level with computer programing. The criteria is the students can operating a computer skill and can make simple computer programming to solving a problem in projectile motion.

In this century, science and information technology are the primaries of education so, teachers and students

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are important to learn about technology. In the modern world, it does not only involve computer scientists. Still, it has become a fundamental skill for everyone need to find their way in the world of technology and solve problems effectively (Palts & Pedaste, 2020). Introduction of technology and make the student have critical thinking. Critical Thinking is an activity of analyzing ideas more specifically, differentiating, choosing, identifying, studying, and developing them into perfect ideas (Ridlo et al., 2020) So, at the college level, students have to know about operating a computer skills. The basic skill is operating a computer than necessary know about started from thinking about the way computer scientists think (Palts & Pedaste, 2020). In other, students need critical thinking skills in this era (Fitriani,2021), students need computational thinking skills too (Tabesh, 2017).

Computational Thinking (CT) is important for a student in this era, Century 5.0 that more technology and information. Computational thinking skills can help humans to take a complex problem and fix a problem (Hunsaker, 2020). CT is a cognitive process that involved logic in a problem and makes a procedure or system easier to understand (Csizmadia et al., 2015). The emphasis on such a skill was raised several decades ago, suggesting its strong relevancy in people's daily lives, in which problems of sorts abound (Saad, 2020). Computational Thinking is "solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science." Computational Thinking also involves "using abstraction and decomposition when attacking a large complex task of designing a large complex system." (Yadav et al., 2017). In this regard, assert that students in this century need to possess sound CT skills in dealing with more challenging problems compared to those in earlier centuries (Saad, 2020). With Computational Thinking (CT), students at the college level can analyze, identity, and have a solution for a problem.

Computational Thinking Skill is told about processes and methods that we use in the operating system. The focus of computational thinking skills is how to complex problems use a computer (Anistyasari, 2020). Learning activities must ensure that students have (1) learning and innovation skills, including critical thinking skills and problem-solving, communication and collaboration, creativity and innovation; (2) information, media, and technology skills; and (3) life and career skills (Anazifa & Djukri, 2017). Technology skills in students can improve implementation with computational Thinking. In particular, they suggested that several activities could be developed and applied to public schools for students of different ages. Through such activities, teachers could teach their students to solve problems in a systematic manner that helps improve students' CT skills (Saad, 2020). Computational thinking skill is a cognitive process that involves logical reasoning in problem-solving and making a procedure or system easier to understand and computational thinking skill through the stage of abstraction, generalization, decomposition, algorithm, and debugging (Csizmadia et al., 2015).

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

Element	Definition	Indicator
Abstraction	The skill to decide what information about an entity/object to keep and what to ignore (Wing, 2010).	The student can identify and decide the important information to analyze Projectile Motion
Generalization	The skill to formulate a solution in generic terms so that it can be applied to different problems (Selby, 2014)	The student can combine the concept of trigonometry and Projectile motion
Decomposition	The skill to break a complex problem into smaller parts that are easier to understand and solve (National Research Council, 2010)	The student can derive the formulation from Projectile Motion related to finding angle (θ) and maximum distance, maximum height, maximum potential energy, and maximum kinetic energy.
Algorithms	The skill to devise a step-by-step set of operations/actions of how to go about solving a problem (Selby, 2014)	The student can make a computer program to solve Projectile Motion related to maximum horizontal and vertical lines.
a. Sequencing	The skill to put actions in the correct sequence (Selby, 2014)	
b. Flow of control	The order in which instructions/actions are executed (Selby, 2014)	
Debugging	The skill to identify, remove, and fix errors (Selby, 2014)	The student can find, identify and repair error syntax from computer programming.

A project-based learning or PBL model can implementation at classical mechanics not only equip the students with knowledge but also improve their problem-solving skills, critical and creative skill, lifetime learning, communication skill, teamwork, adaptation to changes, and self-evaluation (Anazifa & Djukri, 2017).

The project-based learning model is a method to organize a project for learning has syntax as planned learning. Syntax of project-based learning is 1) introduction and team pla¬ning the project; 2) initial research phase in terms of gathering information; 3) creation, develop¬ment, initial evaluation of presentation, and pro-totype artifacts; 4) second research phase; 5) final presentation development; and 6) publication of product or artifacts (Anazifa & Djukri, 2017).

Based on research results at classical mechanics learning applies computational thinking skills at the college level can increase scientific character by 86 % (Sabaryati & Isnaini, 2018). According to Thomas (2000), that project-based learning is focused on a question or problem that pushes students to encounter the central concepts and principles of a discipline. The students must be crafted to connect between conceptual and activities from students with making a computer programming. The stage of computational thinking is decomposition, pattern recognition, abstraction, and algorithm design (Hunsaker, 2020) Table 1 below shows the element of computational Thinking related to the indicators that are used in the implementation of the Project-based learning model of the Teaching in Mechanics course.

Method

Research Methods

The method used in this research is quasi-experimental research, and the purpose of this research is to describe the effectiveness of problem-based learning model of teaching integrated with computer programming in classical mechanics courses. The Quantitative methods are used to analyze student worksheets in solving some problems regarding the mechanic's course in projectile motion topics integrated with the PBL learning model and software for computer programming. The design of this research uses the one group Pretest-Postest design shown in the Table below.

Table 2. Design of research using mixed methods.

Class	Pre-test	Treatment	Post-test
Classical Mechanics Class	O_1	X	O_2

O_1 = Pretest

X = The Implementation of Project-Based Learning model with Computer Programming

O_2 = Posttest

Procedures

The Pretest and post-test were given in the classroom The quantitative data was analyzed with paired t-test The results of the test (Pretest and post-test) were used to analyze the increase of students' computational thinking skills in projectile motion courses. The information presented in the data, i.e., frequency, mean, std deviation, and sig (2-tailed) are used to describe the inferential data statistically. Statistical results represented the impact of the implementation of PBL model of Teaching using computer simulation. The significant value was confirmed by the difference at 5% (0.05). The Interviews and questionnaires also used in this study to determine students' computational thinking skills.

Participants

The population of this research is college students of the fourth semester in the department of Natural Science Education, University of Jember. The sampling technique uses cluster sampling that randomly selects one class. The total number of participants is 36 students, with ages ranging from 20-21 years. Data is collected from February to July 2021.

Instruments

There are several instruments provided to support the data. These instruments are tasks, interviews, and questionnaires. The instruments in the form of the task are used to find out the profile of students' understanding of the concept of the Projectile Motion. Interviews and questionnaires are used to determine students' computational thinking skills. The three sample student interviewed from three level of computational thinking skills in low level, medium level and high level. The low-level category if the student computational thinking skills reach Algoritm skills in sub section sequencing. The medium level category if the student computational thinking skills reach Algoritm skills in flow control. The high-level category if the student computational thinking skills reach all computational thinking skills. The instruments used in this study were tasks, rubrics, and questionnaires. The student computational thinking sheet uses rubric in Likert scale Excellent (Score 5), Good (Score 4), Average (Score 3), Fair (Score 2), Poor (Score 1).

Data Analysis

The data analysis method used statistic inferential analysis with SPSS software to determine whether there is an effect of the implementation Project Implementation Project-Based Learning Model of Teaching Integrated with Computer Programming In Improving Computational Thinking Skills In a Classical Mechanics Course.

Projectile Motion

An important aspect of projectile motion is linear motion on the x-axis and accelerated linear motion on the y-axis (Kuntari et al., 2019). On the topic of projectile motion, first, we study gravitational force, which only works on the y-axis and has no gravitational acceleration on the x-axis (Dilber, 2009). The concept of projectile motion on the x-axis applies for uniform linear motion and on the y axis applies for accelerated linear motion (Kuntari et al., 2019). Projectile motion is a parabolic motion depend on gravity (Halliday, 1985). In the explanation about projectile motion, we must include velocity and acceleration (Pradhana, 2019). We must find components along the x-axis and y-axis. The component of acceleration is a gravitational force (Moebs et al., 2016). Then in this velocity projectile motion, there are Vx and Vy. Where Vx is the speed on the x-axis and Vy is the speed on the y-axis. The projectile motion is shown in Figure 2.

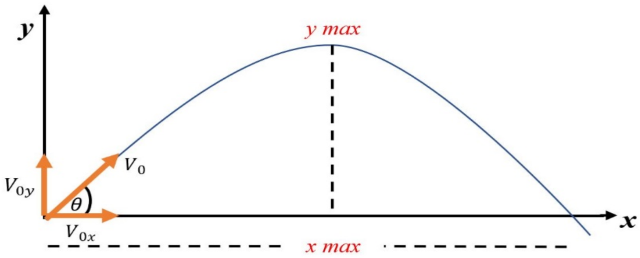

Figure 1. Picture of Projectile Motion

The analysis in horizontal vector

$$V_{0x} = V_x \text{ and } x = X_0 + V_x \quad (1)$$

The vertical analysis vector

$$y = y_0 + \frac{1}{2}(V_{0y} + V_y)t \quad (2)$$

$$V_y = V_{0y} - gt \quad (3)$$

$$y = y_0 + V_{0y}t - \frac{1}{2}gt^2 \quad (4)$$

$$V_y^2 = V_{0y}^2 - 2g\,(y - y_0) \quad (5)$$

We can find a *y*-axis maximum and *x*-axis maximum with this equation. First, we can find maximum height or y maximum with this formula 6.

$$y\ maks = \frac{V_o^2\ sin^2\theta}{2g} \quad (6)$$

And for maximum range or *x* maximum, we can find with this formula 7.

$$x\ maks = \frac{V_o^2\ sin^2\theta}{g} \quad (7)$$

The student task is about task as a problem in projectile motion which compare the manual solution with a computational solution to analyze of position of object according to time, maximum height, maximum distance, maximum potential energy and kinetic energy.

Result and Discussion

The result shown Pretest and post-test scores of the implementation PBL model integrated with computer simulation analyzed using paired t-test. The Table 3 shows mean score of Pretest is 53.05, and the post-test score is 80.22, with number of students is 36. The standard deviation score from Pretest and postest is 6.76 and 2.81 with std error mean 1.127 and 0.469.

Table 3. The mean. Std Deviation and Std Error mean pretest and postest score

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pretest	53.05	36	6.76	1.127
	Postest	80.22	36	2.81	0.469

The relation between Pretest and post-test explain with correlation coefficient value is 0.085 with significant value 0.623 shown in Table 4.

Tabel 4. The correlation value between Pretest and post-test

		N	Correlation	Sig.
Paired Samples Correlations				
Pair 1	Pretest & Postest	36	0.085	0.623
Paired Samples Correlations				
Pair 1	Pretest & Postest	36	0.085	0.623

Table 5 shows a significant value between Pretest and post-test score is 0.00 with a standard value of significance is 0.05. That means implementation of PBL integrated with computer simulation improves post-test score related to student computational thinking skills.

Tabel 5. Paired Samples Test

Mean	Std. Deviation	t	df	Sig. (2-tailed)
-27.16	7.10	-22.941	35	0.00

The distribution of student computational thinking skills in Pretest explain in Figure 2 below. Most students are excellent in abstraction, generalization, decomposition, and weak in algorithm and debugging.

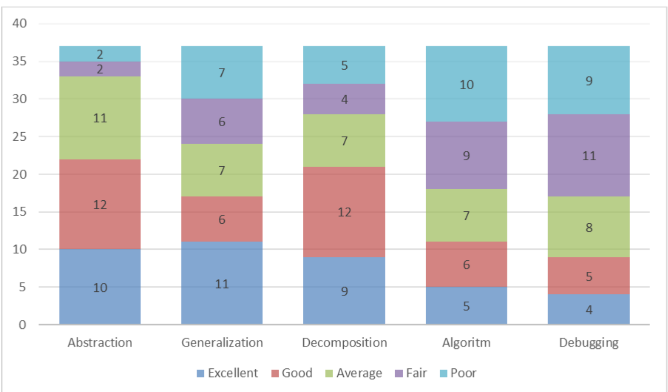

Figure 2. The profile student computational thinking skills in Pretest

The distribution of student computational thinking skills in Pretest explain in Figure 2 below. Most of the students are excellent in abstraction, generalization, decomposition, and weak in algorithm and debugging. The profile of student computational thinking skill is posttest is better than pretest shown in Figure 3 with any improvement in algorithm stage and debugging.

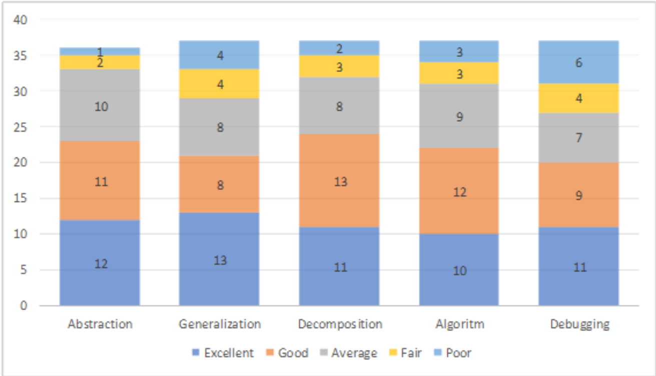

Figure 3. The profile student computational thinking skills in Postest

This research analyzes the implementation of PBL integrated with computer programming in classical mechanics course with the specific topic in projectile motion to improve student computational thinking skills. The computational thinking skills are relevant and related to the industrial revolution 4.0 that important to develop student 21-century skills. The activity of learning based on the problem in projectile motion related to analyse the concept, formulation, and solve the problem using the manual solution and numerical solution using computer programming. The study using Pretest and postest to make sure the initial competencies and improve computational skills. The computational Thinking in projectile motion is divided into five steps namely abstraction, generalization, decomposition, algorithm, and debugging shown in Figure 4.

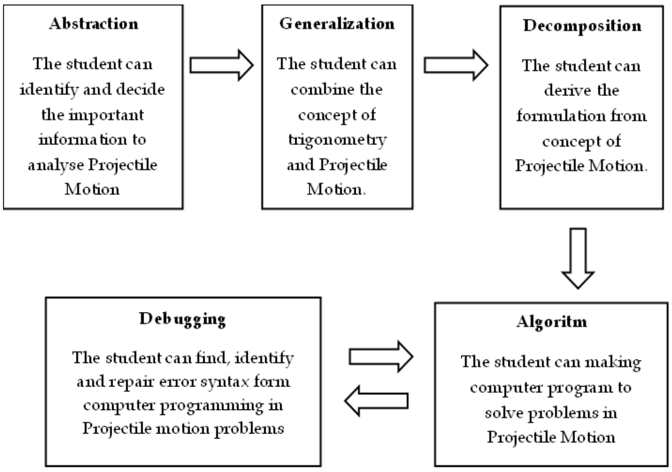

Figure 4. The computational thinking skills in projectile motion

The abstraction is related to identification skills to gathering some important information to analyze the projectile motion. After the student collects the important simulation, for the second is generalization step is to combine the concept of trigonometry in projectile motion, the trigonometry identity is important to make a maximum distance, and maximum height is parabolic motion. The third step is decomposition activity, related to the proofing formulation of maximum height and distance. The main important activity is two last steps, namely algorithm and Debugging step. The algorithm step student should making computer program to solve the projectile motion related to solving maximum distance, maximum height, maximum potential energy, and maximum kinetic energy. While the student is making computer programming in the algorithm stage, student should check the information in task and make sure all of the information is already input in the syntax of a computer program. The final stage is debugging. This stage is related to student competencies on how to understanding the symbol in computer programming to avoid the error mistake in the computation process.

The average pretest score from data analysis is 53.05, with the good and excellent student computational thinking skills in the algorithm and debugging stage is 29.7% and 24.3%, which caused the student to be confused about how to make an algorithm and check the error syntax in computer programming. After the implementation of PBL integrated with computer programing, the score of post-test is 80.22 and the ability of the student in making algoritm and debugging is 59% and 54%. The observation of student presentation about analysis of projectile motion using manual solution and compare with computer programming most of student Based of this information it can be seen that students' computational thinking skills are making an improvement after the implementation PBL model of teaching integrated with computer simulation. Based on research results, incorporating computer-simulation modelling into project-based learning may be effective but requires careful planning and implementation. Teachers, especially, need pedagogical content knowledge which refers to knowledge about how students learn from materials infused with technology (Eskrootchi & Oskrochi, 2010).

Conclusion

Implementing the PBL model of Teaching integrated with computer programming has a significant impact in improving student computational thinking skills. It is proven to have an effect on student learning outcomes. The improvement of student computational thinking skills was increased based on the paired t-test value, which shows the 2-tail sig. value is 0.00. The mean the average score of students in the postest was 80.22, while in the Pretest was 53.05. Based on the score of student tests in postest compared with the Pretest, the postest showed better results than the pre-test for all indicators of computational thinking ability. So it can be concluded that implementation of PBL integrated with computer programming has a significant effect in improving students' computational thinking skills.

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