Acquisition of projectile motion concepts on phenomenon based physics’ experiential learning

L Yuliati1, F Nisa2 and N Mufti3
1,3Physics Departement, State University of Malang, Indonesia, 2Graduate School, State University of Malang, Indonesia

Abstract. This research aimed to explore the concept acquisition in phenomena based experiential learning on projectile motion. Through phenomenon based physics’ experiential learning, students analyze a phenomenon & link it with the existing concept so that it will be able to increase the acquisition of the concept. This research employed a mixed-method with an embedded experimental model. The data was obtained from test, interview, and observation on 26 tenth graders of Senior High Schools in Malang, East Java, Indonesia. Data was analyzed by N-Gain score and d-effect size. The students’ concept acquisition was grouped based on a cognitive level and projectile motion concept. The results showed that the improvement of students’ concept acquisition after taught with phenomenon-based physics’ experiential learning. The average score of pretest and postest is 29.96 and 77.69 with high N-gain and large d-effect size, 0.681 and 5.5 respectively. Concepts of velocity and acceleration on the projectile motion should be noticed using vector analyze in daily learning.

1. Introduction

The projectile motion was used in daily life such as basketball, javelin throw, and football. Some research studies showed that some students have difficulty understanding the projectile motion concept. Students think that thrown objects do not have forward motion [1]. Therefore, the falling object moved backward or just free-falling [2]. Physics education undergraduate students at Bengkulu are using Newtons' law of motion, Archimedes’s law, and energy conservation law to determine the objects’ distance in projectile motion [3]. The problem in linear motion concepts also causing the problem in the understanding of projectile motion concept. Students also have inconsistency while describing velocity [4], acceleration on the non-calculus problem [5], reference point [6], and instantaneous velocity at displacement to times graph [7;8]. Students think that a graph of motion is the figure of objects’ path [9–11].

Mismatch of the teaching process with concepts characteristic causes a weak student concept acquisition. The characteristic of the projectile motion concept is using multi representation [12;13]. The teaching process should be creating a suitable environment to help students understanding concepts [14;15], so it can enhance students thinking [16]. Students hands-on in the learning process can help students in building their knowledge and applying on problem-solving [17]. A good learning process is viewed from the process, not the result [18]. The learning process is more valuable if students got experience from a contextual problem [15;16].
Students need a learning process that focusing experiments to analyze daily phenomena to associate concepts they had with a new concept. Experiential learning builds knowledge with experience transformation [18]. Some research showed that experiential learning also affects undergraduate students’ quality of facing real-world jobs [19], reducing cognitive load [20], and enhance students' critical thinking [21].

Experiential learning in the education sector is widely researched [18]. The learning process that focuses on research activities showed a positive result on students' problem-solving skills and concept knowledge [23]. Problem Based Learning (PBL) process is one of the experiential learning based on a problem that enhances the concept of acquisition [24] and problem-solving skills [25]. However, a phenomenon-based learning process is more effective to enhance concept acquisition because a phenomenon-based learning process can show concepts from a different perspective [26]. Multirepresentation of physics phenomena can help students in solving a problem [27], increasing learning outcomes [28], and concept understanding [29].

Phenomenon based learning can achieve concept acquisition. During phenomenon observation, students may have cognitive conflicts [30]. Phenomenon observation and explanation help students confront and improve their concepts [31]. With phenomenon, students practice planning evidence-based scientific explanations by collecting, discussing, and interpreting data [32]. By evaluating scientific ideas, which are concepts, principles, or theories, and comparing them with the data, it will give students a deep understanding of the concepts [33].

Based on theoretical studies, experiential learning and phenomenon-based learning process gives a positive result on concepts acquisition and matched with projectile motion concept’s characteristics, so this research will explore the projectile motions concept with phenomenon-based physics’ experiential learning.

2. Method
The research used a mixed-method within an embedded experimental model. The subjects of this research were 26 students of 10th-grade Senior High School in Malang, East Java, Indonesia. The data were obtained from interviews, tests, and direct observation. Before and after the intervention, the researcher interviewed the teacher and students to find the need in the learning process. The test was done before and after the intervention. The observation was done before, during, and after intervention using the phenomenon based physics’ experiential learning process.

Phenomenon based physics’ experiential learning has four steps that are concrete experience, reflective observation, abstract conceptualization, and active experimentation. Students observe physics’ phenomena in concrete experience steps. In reflective observation, students consciously reflect back on the experience they have gained. Then, students express concepts or theories from physics phenomena in abstract conceptualization steps. The last stage is active experimentation, where students are planned on how to solve the problem from physics’ phenomena based on the physics' theorist.

The data were analyzed using the normalized gain score to check students’ concept acquisition. The d-effect size was used to check the effectiveness scale of the phenomenon based physics’ experiential learning to students' concept acquisition. The student's concept acquisition was grouped based on C1-C4 cognitive level, the vector of velocity and acceleration of projectile motion concepts, and the understanding of projectile motion concepts.

3. Results and Discussion
The learning process of projectile motion concepts split into the two-part, analysis of units in projectile motion and analysis of the position, velocity, and acceleration vector on projectile motion. An example of the learning stage is presented in Figure 1.

Pre and post-test analyses show an N-gain score of 0.77 which falls into a high category. Cohen's d-effect size is 4.6 which means that problem-based experiential learning has big impacts on students' concept acquisition as shown in Figure 2. This is consistent with other research that stated experiential
learning can enhance knowledge and ability to explain certain physics phenomenon [34–36]. Other research also shows that phenomenon-based learning can help students to understand the concepts and can be used as a learning process and material [37–41].

Figure 1. Learning Process of the Vector of Position, Velocity, and Acceleration on Projectile Motion

![Figure 1. Learning Process of the Vector of Position, Velocity, and Acceleration on Projectile Motion](image1)

Figure 2. Concepts Acquisition with Phenomenon Based Physics’ Experiential Learning

![Figure 2. Concepts Acquisition with Phenomenon Based Physics’ Experiential Learning](image2)

C2 problem is about the direction of velocity and acceleration on projectile motion. The pre-test result reveals that there is no student that able to determine the right direction of velocity and acceleration on projectile motion. Students pre and post-test answer on C2 problem is presented in Table 1. 38.5% of students stated that at the highest point of projectile motion, the direction of velocity is equal with the direction of acceleration (answer B). 57.7% of students stated in the same position that the direction of velocity is perpendicular to the direction of acceleration. The post-test result, after intervention with phenomenon-based physics’ experiential learning, 96.2 % of students were able to determine the direction of velocity and acceleration correctly. 25 students know that the direction of velocity is always sweeping the projectile motion path and the direction of acceleration is always downward. Only one student that did not answer on the pre-test and answered wrong on the post-test.

C3 problem, about the amount of speed in some positions, no student can correct before the intervention and 50% can answer correctly afterward. In the pre-test, most students believed that the minimum speed was the highest point where the speed of the y-axis was zero. In a post-test, change is where students answer that the minimum speed is at point A where the direction of speed is the opposite of the direction of acceleration of gravity. C4 problems were about diagram analysis of projectile motion and a summary of the concept of student acquisition is presented in Table 2.
Table 1. Cross Tabulation of Students Pre and Post Test Answer on Vector Analysis of Velocity and Acceleration

| Pretest*Posttest Cross Tabulation of Vector Velocity And Acceleration Questions | Posttest |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | C* | D | E | Total | % |
| Pretest | | | | | | | | | |
| A | 0 | 0 | 2 | 0 | 0 | 2 | 7,7 |
| B | 0 | 0 | 10 | 0 | 0 | 10 | 38,5 |
| C* | 0 | 0 | 0 | 0 | 0 | 0 | |
| D | 0 | 0 | 13 | 0 | 0 | 13 | 50,0 |
| E | 0 | 0 | 0 | 0 | 0 | 0 | |
| NA | 0 | 0 | 0 | 1 | 0 | 1 | 3,8 |
| Total | 0 | 0 | 25 | 1 | 0 | 26 | 96,2 |
| % | 0 | 0 | 96,2 | 3,8 | 0 | 96,2 | 0 |

Note: *= Answer key; NA = No Answer

Table 2. Summary of Concepts Acquisition on Projectile Motion

| Indicator | Pre-test | Post-test |
|---|---|---|
| Acceleration of Projectile motion | • Acceleration depends on objects height | • Objects acceleration is not dependent to object height and objects acceleration is equal to the acceleration of gravity |
| | • At the highest point, the vector direction of velocity is equal with the direction vector of the acceleration | • The direction of a vector of velocity sweeps objects path and the object's acceleration is downward |
| The velocity of Projectile motion | • Projectile motion is a combination of two uniformly accelerated linear motion | • Projectile motion is a combination of uniform linear motion on the x-axis with uniformly accelerated, motion on the y-axis |
| | • Velocity at maximum height is zero | • At the highest point, the vertical velocity is zero and horizontal velocity is constant |

Table 3 is about the shift of students' answers on acceleration on projectile motion. Students understanding about acceleration on the projectile motion is changed from “the acceleration is always changing” to “the acceleration is constant.” But, there is one student that still argues that height is affecting the rate of acceleration because visually higher the initial height faster the object fall.

At the pre-test, students think that velocity and acceleration on the projectile motion are varied by its maximum height. However, it changed at the post-test where the majority of students understand that acceleration on the projectile motion is constant and equivalent to the acceleration of gravity. Another problem is students were unable to determine the direction of velocity and acceleration because of an inability to analyze the vector of projectile motion on x and y-axis [42]. Students assume that the direction of velocity is equal to the direction of force [43]. After intervention with phenomenon-based physics’ experiential learning, students were able to determine the vector of velocity and acceleration. A problem that persists on the post-test is students still think that at highest point velocity of the object is zero. Students think projectile motion is the same with vertical motion were at its highest point the object stops for a moment [44]. The right condition is that at the highest point object that undergoes projectile motion still has speed at horizontal or x-axis [45].
The Effect of Initial Velocity on Projectile Motion

Students have difficulty determining the velocity and acceleration vectors in projectile motion. The use of phenomenon-based physics’ experiential learning with vector analysis is also needed so that students’ acquisition projectile motion concept can develop well.

4. Conclusion

Based on the results of data analysis, it can be concluded that students’ acquisition projectile motion concepts were increased. Students have difficulty determining the velocity and acceleration vectors in projectile motion. The use of phenomenon-based physics’ experiential learning with vector analysis is also needed so that students’ acquisition projectile motion concept can develop well.

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