The projectile tube experiment for improving high-school physics conceptual understanding

S Rachniyom1, T Sujarittham3,4 and S Wuttiprom2,3*

1 Ph.D. candidate in Science Education program, Faculty of Science, Ubon Ratchathani University, Warin Chamrap, Ubon Ratchathani, 34190, Thailand
2 Department of Physics, Faculty of Science, Ubon Ratchathani University, Warin Chamrap, Ubon Ratchathani, 34190, Thailand
3 Thailand Center of Excellence in Physics, Commission on Higher Education, Bangkok 10400, Thailand
4 Department of General Science, Faculty of Education, Bansomdejchaopraya Rajabhat University, Dhonburi, Bangkok 10600, Thailand

* E-mail : sura.w@ubu.ac.th

Abstract. This research aimed to design the simple apparatus to improve students’ conceptual understanding in projectile motion. The projectile tube experiment was a simple apparatus that consisted of a one-meter PVC tube, a 1200-watt hair dryer, a hard sheet of paper, and a ping pong ball. The participants were 30 grade 10 students who were selected by non-random sampling in the second semester of the academic year 2018. The research tools consisted of learning lesson plans and a multiple-choice learning achievement test. The class activity was conducted by using the Interactive Lecture Demonstrations (ILDs) method with Tracker Video Analysis. The results showed that the experiment set worked perfectly and could be used for learning the projectile concept. The students’ achievement score was significantly increased at a statistical level of .05 and the average of students’ normalized gain was in a medium gain regime.

1. Introduction

Projectile motion, the motion of a body in the air, is an important fundamental topic [1]. In daily life, we can see the motion by playing sports such as basketball, volleyball, golf, and others. Understanding projectile motion is necessary for students in middle schools, high schools, and universities. It is therefore important that students have some knowledge of the mechanical characteristics of projectile motion [1].

Recently, there were researches about the projectile motion apparatuses which were made for demonstration and instruction including Increasing Student Engagement and Enthusiasm: The Projectile Motion Crime Scene, Teaching Physics with Basketball, Easy Projectile-Motion Demonstrations, and [2-4]. The aim of the instruction in the projectile motion is to minimize students' misconceptions and portray the tangible aspect of the motion to students. Teaching methods can provide students with a better understanding of physics content. Physics education researchers agree that the instructional pattern considered to encourage students and correct misconceptions in physics is Interactive Lecture Demonstrations (ILD) [5]. ILD instruction has three steps: 1) Predict the outcome of the demonstration. Individually, and then with a partner, students explain to each other which of a set of possible outcomes
is most likely to occur; 2) Experience the demonstration. Working in small groups, students conduct an experiment, take a survey, or work with data to determine whether their initial beliefs were or were not confirmed; 3) Reflect on the outcome. Students think about the reasons for their initial beliefs and in what ways the demonstration confirmed or contradicted these beliefs [6].

From the previous researches, their apparatuses were limited to only one specific topic which could not be adapted to other content in physics. In this research, the equipment is designed to be used in three topics including kinematic energy and motion, projectile motion, and pressure. The design of the equipment emphasizes the philosophy of physicists referenced from MPEX test in the cluster coherence that determines physics as a holistic view [7]. However, the purpose of the study is to design the simple apparatus for ILDs in order to improve students’ conceptual understanding in projectile motion.

2. Methodology

2.1. Participants
The participants in this research are tenth grade students in the second semester of the 2018 academic year. The group of thirty students are registered in the Physics I course. The participants were selected by non-random sampling from the mathematics-science program. The students in this program were medium and high performing students of science knowledge – considered by their achievement. Every student was originally resident in Bangkok.

2.2. Force concept inventory (FCI)
The force concept inventory developed by Hestenes [8], is a multiple choice test which is designed to monitor students’ understanding of conceptual field of force and related kinematics [9]. The researcher selected 3 items from the FCI which related to projectile motion and adapted them into two-tier questions. The first tier was five choices, and the second tier was the confidence level and supported reasoning. The questions were given before and after the intervention.

2.3. ILDs scenarios
The researcher designed the experiment by using general materials that were cheap and accessible. The materials were a half meter of transparent PVC tube, a ping-pong ball, and a 1200-watt hair dryer. The questions were given before and after the activity which was conducted by Interactive Lecture Demonstrations (ILDs). The activity was divided into two sub-activities.

2.3.1. The first sub-activity. Making a prediction from the situation; A ping-pong ball is loaded in the PVC tube at position A in figure 1. Then, a 1200-watt hair dryer is used to blow the ping-pong ball into position B. Students have to make a prediction about what the motion will be after the ping-pong ball leaves the tube. Finally, students write the answer in the prediction sheet.

2.3.2. The second sub-activity. Hands-on experiment; Students set up the experiment and test the experiment following the first sub-activity. In this activity, students need to record a video clip of the projectile motion. Then, students write the result in the result sheet. The result in the first and second activity needs to be compared using the Tracker program. Students report the comparison by drawing and describing it in the result sheet. In addition, students need to answer 1) the velocity in various positions after a ping-pong ball is released from the tube, 2) the velocity in X-axis and Y-axis, 3) The amount of time for moving in both axes and 4) the result of the comparison of the horizontal velocity and the vertical velocity by cooperating the Tracker program with calculation.
3. Results

The results were analyzed into two sections.

3.1. The result of students’ learning gain

The average score of students from pre-test and post-test was 35.55% and 77.77% respectively. The result determined that the students' score increased significantly at the level of .05 by $t = 7.64$ ($t_{0.05, 29} = 1.69$). By analyzing with a normalized gain by Hake [10], the result confirmed that teaching with ILDs improves students' learning gain in average gain ($<g> = 0.67$). In addition, there was 56.67% in high gain, 23.33 % in medium gain and 20% in low gain.

3.2. The result of students’ confidence level

From the FCI test students will be awarded points according to the confidence levels in the second tier that are divided into three levels including lowest (one point), moderate (two points) and high (three points). The researcher analyzed students' total scores from the first tier and the second tier by using the Pearson Correlation Coefficient [11]. The study found the correlation coefficient for pre and post-test equal to 0.52 and 0.96 respectively. The result showed students had a moderate level of confidence and conceptual understanding before the class, however; the post-test score obtained from students determined a high level of confidence and conceptual understanding from students.

4. Discussion

From the pre-test score, the result informed that the students had a misconception in the projectile motion by analyzing students' answers. From question I - the researcher found 16.67% of students chose option A because vertical ($v_y$) and horizontal ($v_x$) velocities were equal as figure 2 questions from FCI [8]. 23.33% of students chose option C, because there was no vertical acceleration ($a_y$) the first time the object fell out. 16.67% of students answered option D because there was no horizontal velocity ($v_x$) when the object falls to the ground. 43.33% of students selected B which was the correct answer, yet; there was no one that answered option E. Surprisingly, every student was able to give the correct answer after the activity.
Question I

Figure 2. Motion diagrams in the question from FCI [8] that were used in the study.

From question II the student’s answers for figure 2 were analyzed as follows: 20% of students chose option A though there was only the horizontal velocity \( v_x \), 20% of students answered option B though the bowling ball had more mass which did not affect the horizontal velocity \( v_x \), 40% of students selected option C because the velocity in both axes were constant all the time. 20% of students picked the right answer which is option D due to the projectile trajectory being curved by gravitational acceleration vertically \( v_y \) that makes the velocity difference in both axes, there were no students that chose option E. After the activity, the number of students that chose the right answer increased to 56.67%. From the given situation on question III for figure 3 questions from FCI [8]. The students should choose the best answer for the problem and they must give reasons for their answer. The researcher analyzed the students' reasons; 1) the weight of the ball did not affect the horizontal distance 2) The heavier ball falls to the floor and goes far from the base of the table. 3) The lighter ball falls to the floor and goes far from the base of the table. Before doing the activity, the number of students that answered correctly was 36.67% and after doing the activity, the students that answered correctly increased to 76.67 %.

Two metal balls are the same size but one weighs twice as much as the other. The balls roll off a horizontal table with the same speed. In this situation:
A. both balls hit the floor at approximately the same horizontal distance from the base of the table.
B. the heavier ball hits the floor at about half the horizontal distance from the base of the table than does the lighter ball.
C. the lighter ball hits the floor at about half the horizontal distance from the base of the table than does the heavier ball.
D. the heavier ball hits the floor considerably closer to the base of the table than the lighter ball, but not necessarily at half the horizontal distance.
E. the lighter ball hits the floor considerably closer to the base of the table than the heavier ball, but not necessarily at half the horizontal distance.

Figure 3. A question from FCI [8] that was translated in Thai and used in the study.

From the analysis of the relationship between the student's confidence levels and mastery in the content of projectile motion was at a moderate level. After being taught by ILDs with simple apparatus cooperated with the Tracker program, the confidence levels and mastery in the content were raised to a high level. The result confirmed that teaching ILDs with simple apparatus cooperated with the Tracker program visualized the overview of the projectile motion and other components and the ILDs as a source of real experimental data can be used to prompt new understanding of physics concepts, students have to discuss and communicate in small groups or with their nearest neighbors [12,13]. In addition, the activity encouraged students to construct knowledge and to raise the level of confidence.
Acknowledgments
This work was supported in part by Thailand Center of Excellence in Physics (ThEP). The authors thank Khandhi Toeddhanya for assistance with English and Woottichai Worachin (The director of Mahannaparam School) and the students.

References
[1] Chow J W, Carlton L G, Ekkekakis P and Hay J G 2000 A web-based video digitizing system for the study of projectile motion Phys. Teach. 38 37–40
[2] Bonner D 2010 Increasing student engagement and enthusiasm: A projectile motion crime scene Phys. Teach. 48 324–5
[3] Chanpichai N and Wattanakasiwich P 2010 Teaching physics with basketball AIP Conf. Proc. 1263 212–5
[4] DePino Jr A 1999 Easy projectile-motion demonstrations Phys. Teach. 37 266
[5] Sokoloff D R and Thornton R K 1997 Using interactive lecture demonstrations to create an active learning environment Phys. Teach. 35 340–7
[6] Rachniyom S, Toedtanya K and Wuttiprom S 2017 J. Phys.: Conf. Series 901 012124
[7] Redish E F, Saul J M and Steinberg R N 1998 Student expectations in introductory physics Am. J. Phys. 66 212–24
[8] Hestenes D, Wells M and Swackhamer G 1992 Force concept inventory Phys. Teach. 30 141–58
[9] Savinainen A and Scott P 2002 The force concept inventory: A tool for monitoring student learning Phys. Educ. 37 45–52
[10] Hake R R 1998 Interactive-engagement verus traditional method: A sixth-thousand-student survey of mechanics test data for introductory physics course Am. J. Phys. 66 64–72
[11] Hinkle D E, William W and Stephen G J 1998 Applied Statistics for the Behavior Sciences 4th edition (New York: Houghton Mifflin) p 118
[12] Tanahoung C, Chitaree R, Soankwan C, Sharma M D and Johnston I D 2009 The effect of interactive lecture demonstrations on students’ understanding of heat and temperature: A study from Thailand Res. Sci. Technol. Educ. 27 61–74
[13] Thornton R K, and Sokoloff D R 1998 Assessing student learning of Newton’s laws: The force and motion conceptual evaluation and the evaluation of active learning laboratory and lecture curricula Am. J. Phys. 66 338–52