Cambodian students' prior knowledge of projectile motion

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Abstract. Students always bring intuitive ideas about physics into classes, which can impact what they learn and how successful they are. To examine what Cambodian students think about projectile motion, we have developed seven open-ended questions and applied into grade 11 students before (N=124) and after (N=131) conventional classes. Results revealed several consistent misconceptions, for instance, many students believed that the direction of a velocity vector of a projectile follows the curve of the trajectory at every position. They also thought the direction of an acceleration (or a force) follows the direction of motion. Observed by a pilot sitting on the plane, the falling object, dropped from a plane moving at a constant initial horizontal speed, will travel backward and land after the point of its release. The greater angle of the launched projectile creates the greater horizontal range. The hand force imparted with the ball leads the ball goes straight to hit the target. The acceleration direction points from the higher position to lower position. The misconceptions will be used as primary resources to invent instructional instruments to promote Cambodian students' understanding of projectile motion concepts in the following work.

1. Introduction

Students' misconceptions are usually used as a guide in developing instructional approaches to facilitate students' learning in a given topic. Survey the students' misconception is generally the first phase of the research. It can study from both correlated previous researches and the direct target group. In this study, the target group of learners is Cambodian high school students, who are less published on their teaching and learning. Moreover, the adversity from the damage in the Khmer Rouge regime (1975-1979) still impacts on the education system in Cambodia nowadays [1-2].

To help Cambodian students in grade 11 effectively learn physics on the projectile motion as one crucial concept of mechanics, their misconceptions are firstly investigated and presented in this article. The instrument is seven open-ended conceptual questions developed from previous researches, well-known physics textbooks and personal experiences of the researchers. Students' responses are categorized based on ideas and compared with other references.

2. Design the open-ended questions

Seven open-ended questions (English version) designed in this study cover main ideas of the projectile motion for a high school level namely velocity, acceleration, and force of a projectile (Q1, Q2, Q5), travelling times (Q2), the trajectory of a projectile (Q3, Q4, Q7), the highest point, the maximum range, and complementary angles (Q6). Q1 is shown in figure 1 as an example. The questions have been evaluated the agreement between an item and its behavioral objectives by eight physics experts (more than five-year experiences in teaching at a university level) via the item-objective congruence (IOC) form. The questions were modified technical terms and contexts following the experts' suggestions. After that, the questions were translated into Cambodian version, checked the matching translation, and revised by a group of experts to reach an acceptable Cambodian version.

3. Data collection

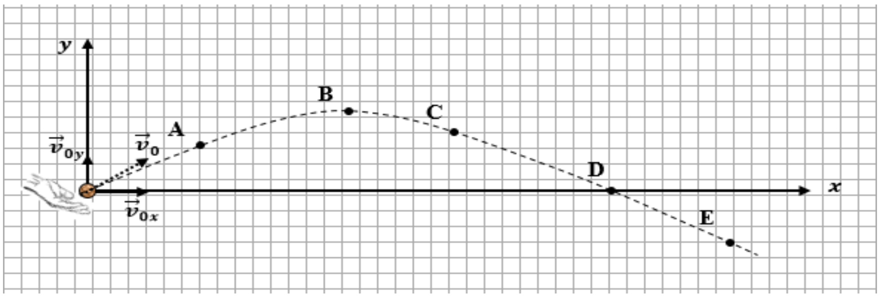
We applied the questions into 6 common classes of grade 11 students from a middle school located in Kampong Cham province, Cambodia. Data were collected from both before instruction

(N=124) and after instruction (N=131). Normally, the instruction approaches in those classes are such as reading aloud the formal books by one student and others listen, lecturing, passive problem-solving by teachers and students take note, and questions and answers method. These are general teaching methods found in common high schools in Cambodia. Approximately, teachers spend 6 periods in teaching the projectile motion. After the end of a class around 3 weeks, we asked the students to fill out the post-test. Questions on pre-test and post-test are the same questions. The responses to pre-test and post-test were analyzed and classified as shown in the following.

4. Results and discussion

This article presented results in details for only a part of Q1. Q1 consists of 3 sub-questions, as shown in figure 1.

Q1: A ball is thrown upward, at an angle, with the initial velocity $\vec{v}_0$. The horizontal component $\vec{v}_{0x}$ and vertical component $\vec{v}_{0y}$ of $\vec{v}_0$ are depicted in the figure below.



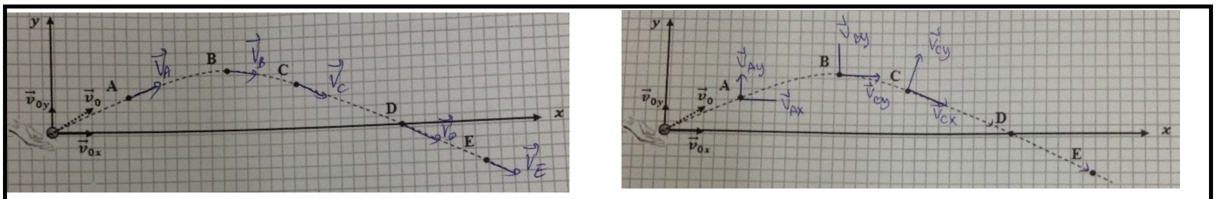
1.1 Draw arrows to indicate the horizontal and vertical components of the ball's velocity at position A, B, C, D and E. (Draw arrows into the figure.)

1.2 Mark √ in the table that agrees with the magnitude and direction of the ball's acceleration ($\vec{a}_{ball}$) at position A, B, C, D and E, and give your reasons. (Define: *g* is the magnitude of the acceleration due to gravity.) *(A table is provided for students to mark √.)*

1.3 Identify and draw arrows to indicate the direction and magnitude of the force(s) acting on the ball at position A, B, C, D and E. *(A blank and a figure are provided for students.)*

Figure 1. An example of Q1 about projectile motion used in this study.

Of about 90 students gave responses to Q1.1 in pre-and post-tests. But there were only 39 students on pre-test, and 57 students on post-test, who completely drew arrows at point A, B, C, D, and E of the ball. The others drew arrows only some points and left some. 49% (30%) of the students in pre-test (post-test) drew only one arrow at each point following the curve of the trajectory, as shown in figure 2(a). The others drew 1, 2 or 3 arrows at each point, such as an arrow following the curve of the trajectory, rightward, downward, and upward arrows. An example was shown in figure 2(b). This indicates that most students had low background knowledge not only the projectile motion but also the vector concepts, even though they were taught at a lower level. They had the misconception that a velocity vector followed the curve of the trajectory. Correctly, a velocity vector just contacts the parabolic path at a given point. Moreover, many students had the difficulty in representation the horizontal and vertical velocities with vectors, as shown in figure 2(b). They just drew upward or downward arrow, or a vector with non-corresponding components. Overall, after the passive instruction, many students still strongly held their misconceptions. It reflects ineffective of the traditional physics instruction as mentioned by several works in physics education research [3-4]. This also implies that the students have to be improved the understanding of the vector concepts before the projectile motion class.



(a) (b)

Figure 2. Examples of students' drawings in Q1.1

In Q1.1 when we considered at each point, we found that at point A, most students (63% before instruction and 75% after instruction) knew that the ball was going up by drawing the upward arrow (connecting with the rightward arrow). However, they disregarded the vector's length. Most students drew a vertical arrow at point A longer than that of the starting vector presented in the question. Many students drew a vector following the curve of the trajectory with non-corresponding xy-components. In fact, they have to draw the shorter upward arrow and the identical rightward arrow with the starting arrows. At the highest point of the projectile path (B), we found that less than 20% of the students correctly understood that the vertical velocity at this point is zero. However, they drew one longer rightward arrow than the starting vector. It displayed misconception about the horizontal velocity of the projectile motion. Responses to point C, D and E were quite similar. Before (after) the instruction, less than 20% (35%) of the students drew the downward arrow (connecting with the rightward arrow). Most drew the upward arrow (connecting with the rightward arrow), and the arrow following the path.

Misconceptions found in this study	Other references
The acceleration and the instantaneous velocity are always the same parameters.	[7]
An acceleration is a displacement.	[7]
A moving object has positive velocity if it is above xy position graph, and negative velocity if it is below the graph.	[8]
A force is in the direction of motion.	[6], [9], [10]
Released at the same level, the object falling straight will hit the ground before the object moving as a curve because the former uses shorter distance.	[10]
Released at the same level, the object having a constant initial horizontal speed will hit the ground before the object moving without the initial speed because the former is faster.	[11]
Two projectiles with different initial horizontal speeds have different vertical accelerations.	[11]
The fired ball moves as a curve because in the first phase the impetus acting on it greater than its weight causes the ball moves as a straight line, then the initial impetus slowly reduces, and the downward gravitational force gradually acts on it at the middle phase. At the final phase, there is only the downward gravitational force acting on the ball causes the ball goes straight down.	[9],[11],[12],[13]
Observed by a person on the ground, the falling object, dropped from a plane moving at a constant initial horizontal speed, will travel backward and land after the point of its release.	[9, 11]
Observed by a pilot sitting on the plane, the falling object, dropped from a plane moving at a constant initial horizontal speed, will travel backward and land after the point of its release.	-
The greater angle of the launched projectile creates the greater horizontal range.	-
Theoretically, complementary angles of the launched projectile create different horizontal distances.	-
The hand force imparted with the ball leads the ball goes straight to hit the target.	[9], [12]

For responses to Q1.2, we found that most students believed the ball's acceleration at point B was zero. Many students though at point A and C the ball's acceleration is greater than *g* (or zero) because it is above the x-axis, so at point D and E the acceleration is less than *g* (or zero). The misconception about the direction of acceleration follows the direction of motion were also found in these students, similar to ref. [5-6]. The most popular misconception in Q1.3 was that a hand force (or thrown force) and a reaction force are forces acting on the ball.

In addition, we summarized misconceptions on projectile motion and other related concepts found in this study shown in the table.

5. Conclusions

Our study disclosed some misconceptions on projectile motion from a group of Cambodian high school students in grade 11, which agreed with several references. Moreover, it indicated that the students still strongly held their prior knowledge after the conventional instruction. Students have to be revised the misunderstanding about vectors and motions in one dimension before the projectile motion class. This result will be used as a key resource to design the instructional teaching instruments to improve Cambodian students'understanding of projectile motion in the following research.

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