Free fall misconceptions: A comparison between science and non-science university majors

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Abstract

The study was conducted to find out the conceptual understanding and misconceptions of students in objects undergoing freely falling motion. Open-ended questions are utilized and are given to one science and three non-science classes to assess students' understanding of the most basic concepts in free-fall. Results showed that majority of the students in both classes were able to correctly describe the motion of an object in free-fall in terms of velocity. Similar to previous studies, misconceptions were mostly on the acceleration of the object when it is at the highest point of its flight. Further analysis showed that there is no significant difference between the answers of science and non-science majors. Regardless of their concentration, students have the same general misconceptions on free fall. Science and non-science majors equally share the 17% of the population who described the acceleration and velocity in the same manner. However, only 12% of the entire student population answered perfectly and contrary to expectation, only 4% of this are science majors.

Keywords: Misconceptions, Free-fall, Velocity, Acceleration.

Resumen

El estudio fue conducido a descubre la comprensión y las ideas falsas conceptuales de estudiantes en los objetos que experimentaban el movimiento libre-que caía. Las preguntas ampliables se utilizan y se dan a una ciencia y a tres clases de la no-ciencia para determinar entender a los estudiantes el' de los conceptos más básicos de la caída libre. Los resultados demostraron que la mayoría de los estudiantes en ambas clases podía describir correctamente el movimiento de un objeto en caída libre en términos de velocidad. Similar a los estudios anteriores, ideas falsas estaban sobre todo en la aceleración del objeto cuando está en el punto más alto de su vuelo. El análisis adicional demostró que no hay diferencia significativa entre las respuestas de la ciencia y los comandantes de la no-ciencia. Sin importar su concentración, los estudiantes tienen las mismas ideas falsas generales en caída libre. Los comandantes de la ciencia y de la no-ciencia comparten igualmente el 17% de la población que describió la aceleración y la velocidad de manera semejante. Sin embargo, los solamente 12% de la población entera estudiantil contesta perfectamente y contrariamente a la expectativa, el solamente 4% de esto son comandantes de la ciencia

Palabras clave: Ideas falsas, caída libre, velocidad, aceleración.

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I. INTRODUCTION

The concept of free-falling motion is often introduced to students as part of natural science courses in university level Physics classes. Physics classes traditionally begin with classical mechanics, with freely falling bodies discussed in both high school and universities. The range, breadth and depth of the topics discussed in the entire course vary according to instructors' area of expertise.

Undergraduate students, who took part in this study, are classified into science (SC) and non-science (NSC) students. Almost all students are familiar with the concept of free-fall, as required by the Basic Education Curriculum. The non-science students, mainly first year college students, have taken Physics classes in the previous year, as it is part of the Basic Education Curriculum. Science students, who are graduating non-Physics students, had their last Physics classes at least four years prior. They are required to take Physics classes in preparation for medical school. The non-science classes are made up of students from various disciplines with class size of at least 30 students while the science class is a large class with a class size of 60 students.

II. METHODOLOGY

To establish the level of conceptual understanding of the students, a test was given prior to classroom instruction on the concepts of free-fall. Six open-ended questions were given with specific instructions that explanations given by the students should not exceed 3 sentences. Results were classified and tabulated based on the responses of students. Each correct response was given 1 point while incorrect responses were given 0 point. The incorrect responses were also classified and tabulated to get the common misconception of students about the questions.

The test was administered to 158 students in four Introductory Physics classes to determine their level of understanding; 60 are from the science class and 98 are from the non-science classes.

It is important to note that the students being examined are senior Biology majors who took their high school physics four years ago. On the other hand, the freshmen non-science majors from various disciplines have taken their high school physics just a year ago.

III. RESULTS AND DISCUSSION

The test administered describes the motion of a ball thrown upward with an initial velocity and with specific instructions that air resistance is to be neglected. The trajectory of the ball's path was divided into three segments: (1) Motion of a ball moving upward, (2) Motion of the ball at the top of its flight and (3) The motion of the ball as it moves downward. The students were instructed to describe the motion of the ball in each segment in not more than 3 sentences in terms of its velocity and acceleration.

The distribution of the students' answers in the three segments of the ball shows that both classes can correctly describe the motion of the object with regards to velocity. A careful analysis of the students' velocity responses for each segment also shows that the percentage of correct answers from NSC students is higher than that of the SC students.

In Q1, 83% of the NSC students correctly answered that the velocity decreases as the ball moves upward compared to the 75% of the SC students as shown in Fig. 1.

As for the velocity of the ball at the top of its flight (Q3), 99% of NSC students correctly answered that velocity is zero compared to the 92% of the SC students.

It was only on the third segment of the motion (Q5) did the science students score better than the non-science students as shown in Fig. 2. These results show that the students, whether science or non-science majors, possess a good conceptual understanding of the velocity of an object undergoing free fall.

However, in terms of the acceleration of the ball, the percentage of correct answers for both classes decreased significantly. For the first part of the motion (Q2), the percentage of correct answers for NSC students is only 30% while 38% for SC students. Similarly, for the downward motion of the ball (Q6), the percentage of correct answers is only 30% and 35% for non-science and science majors', respectively. As for the acceleration of the ball at the top of its flight, the correct answer for both classes is alarmingly much lower; 17% for non-science majors and 9% for science majors.

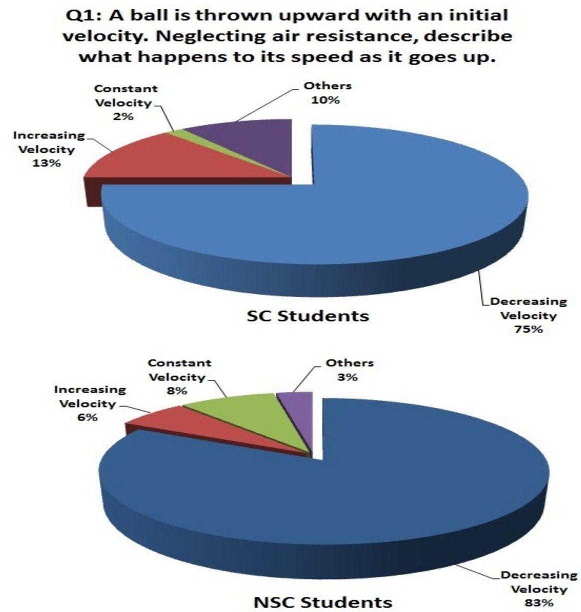

FIGURE 1. The chart shows the distribution of the answers of SC and NSC students for the velocity of the ball moving upward.

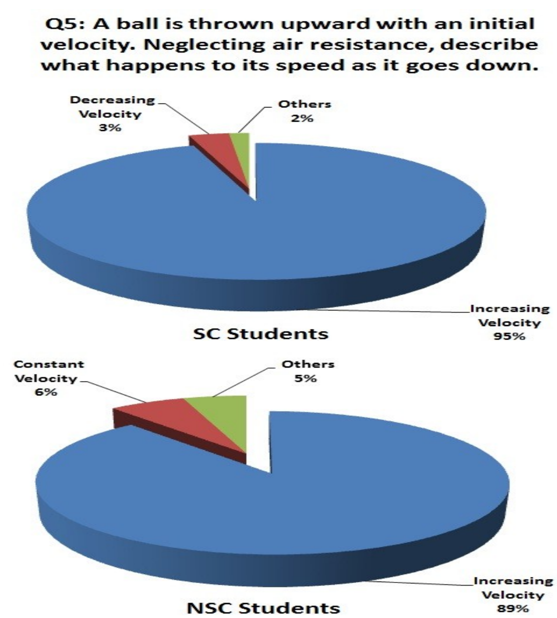

FIGURE 2. The chart shows the distribution of the answers of SC and NSC students for the velocity of the ball moving downward.

Some answers of students that acceleration is – 9.8m/s^2 were not considered to be correct as it does not depict what happens to the acceleration as an object moves upward.

Some students associate and limit the description of acceleration to just $-9.8m/s^2$ without truly understand what it means. Another basis for not considering their answer is that after a close inspection of student responses for each segment of the motion, most of the students believe that the acceleration vector changes from moment to moment as evident in their responses in Q2, Q4 and Q6. The acceleration varies from $-9.8m/s^2$ to zero and back to $-9.8m/s^2$.

These results show that even after a year of comprehensive instruction in Physics during high school, the proper conceptual understanding of acceleration is still difficult and ambiguous for the students.

It is interesting to note that in each segment of the ball's motion, the next popular answer to the question of acceleration is similar to the description of the motion of the velocity. For instance, in the first part of the motion (Q2), about 29% and 27% of non-science and science students, respectively, answered that acceleration decreases as the velocity decreases. It also shows that the students are relating the decrease in the velocity of the ball with a negative acceleration. Another interesting response is that acceleration is $+ 9.8m/s^2$ as shown in Fig. 3. It proves that students' conceptual understanding of acceleration is dependent on the motion of the object. Since motion of the ball is moving upward, acceleration must also be moving in the same direction, thus, $+ 9.8m/s^2$.

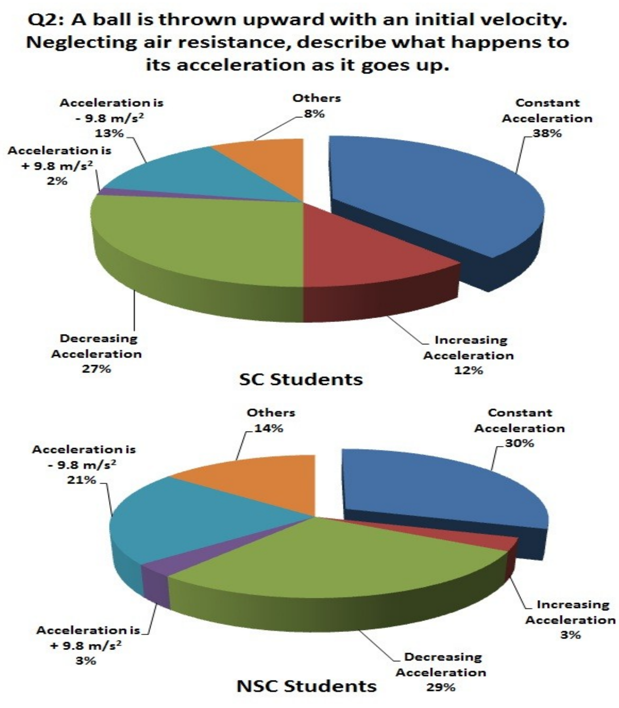

FIGURE 3. The chart shows the distribution of answers of SC and NSC students for the acceleration of the ball moving upward.

As for the acceleration of the ball at the top of its flight (Q4), about 59% of NSC students answered that acceleration is also zero like its velocity while 80% of SC students answered similarly as shown in Fig. 4.

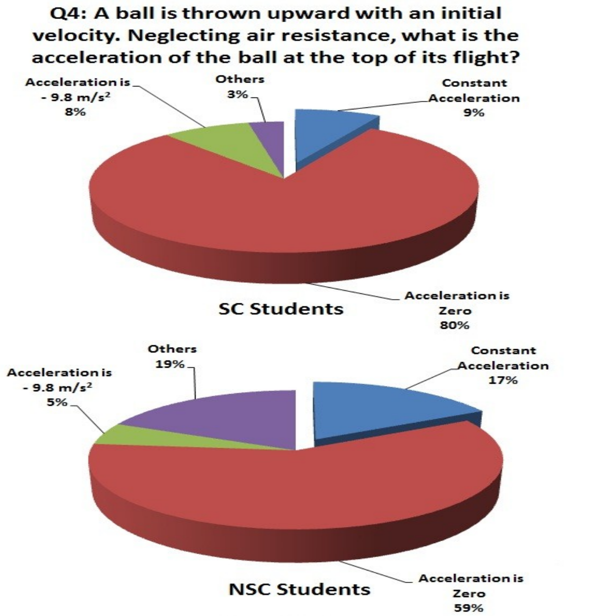

FIGURE 4. The chart shows the distribution of answers of SC and NSC students for the acceleration of the ball at the top of its flight.

The same trend is observed in the downward motion of the ball (Q6) where 27% and 39% of NSC and SC students, respectively, answered that acceleration increases as the velocity increases. It is evident that students' understanding of acceleration is synonymous to velocity. Similar to the results in Q2, a significant increase is observed in the number of students who answered that acceleration is $+ 9.8m/s^2$ as shown in Fig. 5. The students are relating that an increase in the velocity is accompanied by a positive value of the acceleration. For any object speeding up, it must have a positive acceleration regardless of its direction.

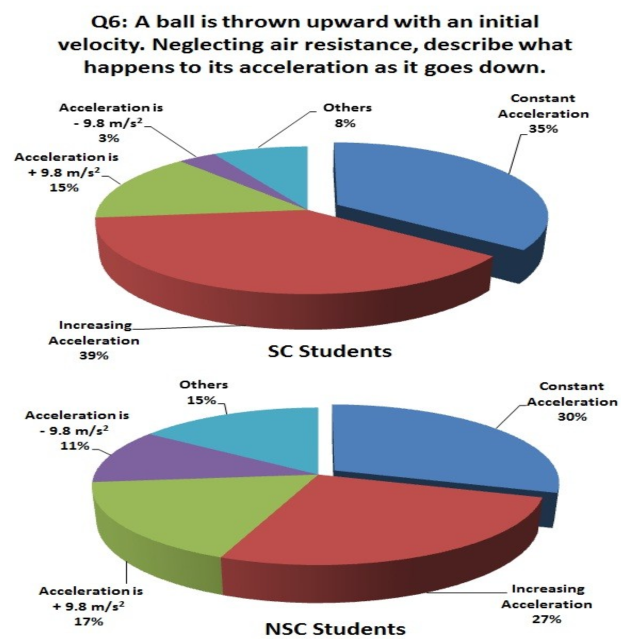

FIGURE 5. The chart shows the distribution of answers of SC and NSC students for the acceleration of the moving downward.

A careful study of the responses for the entire motion of the ball revealed that 17% of all the students answered velocity and acceleration behaves similarly, while only 12% of the students correctly answered both the velocity and acceleration for each segment. Of these correct answers, contrary to expectations, only 4% are science majors.

IV. CONCLUSION

An open-ended, free response pre-test was used to determine the conceptual understanding of science and non-science students on the concept of free fall. It is noted in the methodology that the freshmen NSC students had their last physics class only a year ago, while the senior biology students had theirs 4 years ago. With their physics class still fresh in their minds, freshmen NSC students performed slightly better than the SC students, contrary to what is expected; that science students should know more about the sciences.

However, regardless of the differences in the number of years when they took their last physics class, the results show that most students still fail to have the proper conceptual understanding with regards to freely falling objects. Students tend to resort to just memorizing the value of acceleration and not truly understanding its meaning. Most of the students equate whatever is happening to the acceleration is similar to whatever is happening to its velocity. However, since the velocity vector of freely falling object changes from segment to segment, students mistakenly assume that the acceleration will behave in the same manner. This observation really shows their misconception about acceleration. To correct this behavior, the vector nature of both velocity and acceleration must be reviewed to reiterate that acceleration can either speed up or slow down the motion of an object depending on the direction of the velocity, and not behave similar to velocity.

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