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The Physics of Free Fall: Analysing the Opinions of Future Teachers

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Abstract: In this paper we analyse the opinions of students and future teachers of our Department about the Physics of Free Fall. The students practice to a free fall laboratory exercise, after having been taught the equivalent theory. The experiment is consisted of an electromagnet that releases a metal sphere, which then performs a free fall motion, and of light gates that record the transit time interval of the metal sphere through a predetermined length.

The students seem to understand the physics of free fall theoretically and algebraically, but when the questions are related to their natural intuition and, especially when they come in contrast to it, then they have a hard time or hesitate answering. In this paper, our purpose is to examine whether these students, who will have to teach, in a few years, the free fall phenomenon in school classes, have fully understood the scientific facts or whether their deeper beliefs originating from the natural intuition are strongly established.

Key words: free fall, natural intuition, laboratory exercise

1. Introduction

In recent years, there's a lot of discussion on the teaching methods of the fundamental concepts of Physics to Primary Education students and the first classes of the Secondary Education as well (Howe et al., 1990; Kruger, & Summers, 1988; Juuti, 2005; Trumper, 2006; Ohle, 2010). Exploratory learning methods (Volkmann, & Zgagacz, 2004), co-operative learning methods (Bot et al., 2005), social constructivist learning approaches (Duit, & Treagust, 2003), and other methods and techniques take precedence. Occasionally, the laboratory, exploratory, partially guided approach is projected, so that school students have the chance to discover the laws of Physics, acting like little explorers (Hatzikraniotis et al., 2007).

However, although teaching approaches have been prioritised, the necessary attention to the understanding of the fundamental concepts of Physics by teachers must be given (Johnston, & Ahtee, 2006). Free fall is a physical phenomenon that is directly related to our natural intuition, as we already notice the fall of bodies from the early years of our life. But how ready are we to deal with the fact that a feather will reach the ground at the same time as a metal sphere if both objects are dropped simultaneously from the same height? (Borghi et al., 2005; Subali et al., 2017).

These future teachers may have learnt and memorised this knowledge, but how deeply is this perception rooted in them? (Galili, 1993). But if we slightly alter this wording or if we made them conduct an equivalent experiment, will this perception be demolished over their natural intuition? (Kavanagh, 2007).

These questions triggered our interest for the perceptions and the opinions of the students of the Department

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of Primary Education on the teaching methods of physical phenomena, and especially of free fall. These students usually do not respond positively to the hearing of natural sciences courses, because, in the framework of orientation groups in High School, they were split between Humanities and Sciences courses. In general, the majority of students in Pedagogical Departments stem from the Humanities orientation group thus had neglected the natural sciences courses in the secondary education.

But having entered the University and as teachers-to-be, they must face these courses with the same seriousness and professionalism. They should be more open-minded and not guide their students towards one orientation group. Therefore, it is highly important for them to form their perspectives with innovative trends and goals, and to ensure pluralism and the freedom of expression in their class. All the above, may be achieved if students manage to deal with their "phobia", which is originated from their school years, towards the natural sciences courses.

2. Experimental Configuration

The Experimental Configuration includes: square aluminium rod, metal strap, equilateral triangle base, electromagnet, electromagnet base plate, electromagnet connection wire, light gate (or light trap), digital stopwatch, metal sphere, weight and string.

Figure 1 The Experimental Configuration of Free Fall

To conduct the experiments and to record the experimental data, we follow the steps below:

1) We adjust the metal sphere to the already activated electromagnet. The light gate is set at the height of the metal sphere and is activated as soon as the electromagnet is deactivated, marking the start of the free fall motion.
2) We let the metal sphere perform free fall motion between the two light gates.
3) The light gate is aligned at the start line 0, so that the initial speed of the metal sphere is zero when it starts to fall ($V_0 = 0$).

4) We place the final light gate 50cm lower than the initial. We mark the distance S.
5) The digital stopwatch starts as soon as the metal sphere passes the initial light gate and stops automatically when the sphere reaches the final light gate. We mark the time t.
6) We repeat the measurement at least 10 times and then we alter the distance between the two light gates and repeat the experiment.
7) By the formula $h = 1/2\ g\ t^2$ (when $V_0 = 0$) we determine the value of g.

3. Process

The current study was carried out on students, who attend the course "Introduction to Physics I" and the equivalent laboratory class. The theoretical component of this course is delivered to students in the form of lectures. The practical component of the course, i.e., the laboratory class, takes place at the Department's science lab. Students are divided into 4-person groups and conduct specific experiments based on the theory they have been taught.

Coming back to the issue under discussion, students were taught the free fall and the horizontal shot theory. Then, they attended the laboratory class and conducted a free fall experiment. After they made the necessary measurements and answered the questions in the laboratory guide, we decided to ask them some questions. We wanted to observe whether these future teachers have fully understood this physical phenomenon and also to hear their suggestions for new, more innovative teaching methods of Physics.

The interview concerned the students who previously completed the free fall experiment. To see whether they have fully understood the theoretical framework, we first asked them to characterise five sentences as True or False, without explaining why. These sentences were the following:

1) Two objects that are dropped from the same height reach the ground at the same time, without considering the air resistance.
2) The only force applied to a free-falling body is weight.
3) A metal sphere reaches the ground faster than a piece of paper, if both are dropped simultaneously from the first floor of a building, at standard atmospheric conditions.
4) During free fall there is no acceleration.
5) Free fall is an individual motion of the horizontal shot.

After finding out the knowledge level of our interviewees, we ask them suggest a teaching method to introduce this knowledge to school students, that is the motivation to make free fall more appealing to students that learn about it for the first time. It is important to mention that students knew from the very beginning that their answers would remain anonymous.

4. What Results We Expected

As mentioned before, most students come from the Humanities orientation group in High School, which means they attended natural sciences courses only on a basic level, resulting in an unfamiliar relation to Physics. Therefore, in the first part of our interview, we expect them to answer correctly 3 out of 5 questions, as one is a trick question and the other is hard to perceive. All five sentences have been analysed theoretically, but we did not expect totally correct answers.

In the second part of the interview, we were stricter, as the students had to suggest new and innovative teaching methods to gain the interest of their future students. We expected them to give innovative suggestions and fresh ideas, without relying on the school textbook. According to the detailed school programme, the course is more practical at primary school, as there are no calculations and formulas.

5. What the Students Answered

The answers of the future teachers were divided into groups, depending on the orientation group they come from.

- Group A: Second-year students who come from the second (Sciences and Health Sciences) or the third orientation group (Economic Sciences).
- Group B: Second-year students who come from the first orientation group (Humanities Sciences).
- Group C: Students who attend the course for a second or third time.

We were not really concerned about the gender of the interviewees, but we will later examine whether male or female future teachers have a way, more, with the natural sciences courses. We divided the students depending on their year of studies, as the course "Introduction to Physics I" is taught at the 2nd year. Although the laboratory class should be attended exclusively by second-year students, there are third and fourth-year students, as well, who have failed to pass this course.

To begin with, in the first sentence ("Two objects that are dropped from the same height reach the ground at the same time, without considering the air resistance.") most students answered "True" which is correct. More precisely, very few students of Group A answered incorrectly and only one did not answer at all. In contrast, the vast majority of Group B answered correctly, as they perceived the sentence well. In a nutshell, approximately 1 out of 5 students of this Group gave a wrong answer. The students of Group C had a hard time answering, since the ratio was similar as in Group B.

Additionally, in the second sentence ("The only force applied to a free-falling body is weight.") many students stated, correctly, that it was "True". Despite that this sentence was easily perceivable and anyone without any Physics background could answer correctly, there were students that gave incorrect answers. In more detail, only very few students of Group A had a hard time answering and even fewer answered incorrectly. As far as Group B is concerned, the responses of the first two sentences were quite modest. Group C answers were very optimistic, as only few third-year students failed to answer correctly. In the given sentence, incorrect answers were given due to bad instructing and comprehension on students' part who think there's another force applied besides weight.

Resuming the interview, in the third sentence ("A metal sphere reaches the ground faster than a piece of paper, if both are dropped simultaneously from the first floor of a building, at standard atmospheric conditions.") the students' answers were more certain and, to a large degree, correct. Many students of Groups A and C did not get confused on this one. The number of those who answered that this sentence was "False" was close to zero, something that contradicts their response at the first sentence. The preponderance of Group B also answered with ease, as only 1 out of 7 students did not know the answer or answered incorrectly.

The fourth sentence ("During free fall there is no acceleration.") tricked the interviewees, because of its short length, as many of them answered quickly without thinking. In this sentence, Group A had the most wrong answers in the whole questionnaire. The error rate did not increase as much, but it was not as low as in the previous sentences. This sentence troubled plenty of Group B students, as some of them answered incorrectly or did not give a response at all. Approximately half of the students knew the answer, while the other half acted with curiosity upon reading the sentence. Finally, Group C answers ranged similarly to the first sentence. The use of negative form (“there’s no acceleration”) in this particular sentence may have confused the students, as it didn’t help them answer that it was “False”. Another possibility is that they have not corresponded gravitational constant to acceleration.

The last sentence (“Free fall is an individual motion of the horizontal shot.”) troubled students the most, as it received the least amount of correct answers. To be more exact, amongst students of Group A, who we expected to answer correctly, only very few remembered the correct answer, while most of them did not answer at all. The majority of the next group of students gave an incorrect answer. Only 1 student out of 15 answered correctly, as most of them were certain that this sentence was “False”. One third of the interviewees did not answer at all. The students of Group C were in a similar situation as the students of Group B, as only few of them knew the answer.

After the True or False questionnaire, students considered themselves as future teachers giving a lesson on free fall. What was examined was students’ innovative thinking to make the lesson more appealing to their future students. Their purpose is to put their future students in a position to understand free fall in a different way. The answers given by the students vary depending on the orientation group they stem from as well as their year of studies.

To begin with, Group A students seem to have more innovative ideas. The most usual answer was to conduct an experiment. The most common experiment was the drop of two objects, from the same height, by both the teacher and the students, but each using different objects. Some of them were marbles of different weight each, school items (pencil case, rubber, pencil, ruler etc.), different types and shapes of paper, stones, and feathers. Only two answers were a little off this theme. The purpose of the first suggestion was gaining the students’ interest by using different kind of candies as objects while implementing the experiment, which the students would consume at the end of the experimental process. In addition, the second suggestion was the use of students’ toys, thus making the course more cross-curricular. Many of them suggested a video of a person jumping off a plane and performing free fall motion, so that students can understand this physical phenomenon by watching it. Very few students gave diplomatic answers such as “Using experimental configuration” or “Using examples from everyday life”.

This was not the case as far as Group B students were concerned. Their answers were so generic that seemed almost incorrect. Most of them tried to give descriptive answers, without thinking practically. Most of this group did not think like future teachers, but rather like university students who try to pass this course. The most common answer was everyday experiments, without providing any specific details. Many suggested the experiment that was conducted in the laboratory class. However, we are not sure whether a school has such a well-equipped lab. Another common answer was to watch videos of a parachutist or various objects free falling. But there was also an ambiguous answer which is the fall of an apple from the tree, clearly influenced by Newton's theory of gravitation. The above experiment was mentioned a few times, using school objects, like pencils, rubbers, paper, rock, chalk, and chalkboard eraser. There were also some more innovative variations of this answer, such as the fall of two leaves from the trees in the quad, combining in that way the course with environmental studies and botany.

Finally, the answers of Group C were not as far apart as the ones given by Group A students, as they were much more practical and could be carried out in the classroom. This is because all these students have gone on traineeships and have seen how a school class functions. Some answers were common to the ones given by

Groups A and B. One of them was the experiment of dropping two different objects from a certain height, while altering either the objects or the height, so as students can understand the phenomenon. An interesting answer was the suggestion that students visit a museum of natural sciences and the university lab in order to understand the phenomenon by watching physicists conduct such an experiment. Very few were the diplomatic answers, such as “Using the same experiment that we conducted” or “Using a routine experiment”.

6. What We Concluded

Through this process, we tried to understand whether these future teachers are ready to teach natural sciences courses properly and experimentally. We observed that only few of them have a proper educational level to natural sciences. Many of them came from the second and the third orientation group in High School, which helped them to have a more theoretical way of thinking. The students originated from the first orientation group need to invest time in studying natural sciences in order to be able to deliver classes in the future. It is unacceptable for a teacher to be unfamiliar with the courses that he/she teaches. There are many students that disdain this course and are not interested in learning how to teach it properly, because they had a difficulty understanding it during their school years. This perception should have progressively died off, because of interdisciplinarity in today’s school. However, this is not the case.

Additionally, a point that was totally made before the interview is that generally second-year students have a more overall view at the organisation of a class, because they have not taught or attended a teaching process yet. They envision the classroom as it was during their school years. Conversely, fourth-year students have a better understanding on how to make the course more appealing to students. Another interesting point is that male interviewees think more practically than female ones. That may be since the number of male students in Pedagogical Departments is relatively small. Male students of Pedagogical Departments would make a rather interesting social research that cannot be analysed in this paper.

Concluding, we cannot ascertain whether the difficulty that students face at natural sciences courses is due to themselves or the way that these courses are delivered at all levels of education. However, it seems that a large percentage of students have understood the free fall phenomenon. Admittedly, they can impart this knowledge to their future students with new, more contemporary methods, if they so desire.

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