Teaching to Reason

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Abstract

The objective of Physics courses is that the students learn how to use what they know to solve problems in the real world (competencies), but no one learns to do that seeing as the professor think in the blackboard. The program of a course uses topics as examples of reasoning. Reasoning involves the ability to use their knowledge. If we precisely define the objectives of a lecture *before* actually presenting the material to the students, the lecture will have better chances to hit the desired target. Having these objectives in mind we will be able to find a concatenated series of questions, which may help the students to discover and learn what we want to teach (thus improving the students´ competencies). In doing this we will be recreating the Socratic Method, which has evolved as constructivism.

Keywords: teaching aims, competencies, real life problems, car crash.

Introduction

Research on the learning and teaching of physics is essential for cumulative improvement in physics instruction (McDermott 2001). A teacher uses books, experiments, simulation and web resources; its success is measured against the class objectives with standard testing (Wörner *et al*, 2010). The solution of problems may increase the learning efficiency (Ganina and Soord, 2011) if the problems induce reasoning. Great emphasis has been placed on teaching science by a well-designed series of questions (Hadzigeorgiou *et al*, 2010). So the idea of learning related to a topic is taken as the student being able to successfully answer some questions related to the topic, often those questions being presented in the assessment. Most of the tests encourage memorization and rote learning, which is of little use in a world connected to many sources of information through the Internet. So perhaps the first question we need to answer is why we want to teach sciences to students. For college students, they need to be able to solve the problems that they are expected to solve, according to the title of the corresponding degree. But for students from primary or basic education to high school, they need to understand the changing world in which they live, and the science that is part of their culture. Students need to learn how to apply their knowledge in real life, which is often interpreted as "being competent". Since 2003 the Project PISA evaluates how students deal with problems that they have to read and understand, and afterwards they have to reason in order to get correct answers (PISA 2003). More generally, we can say that we are teaching to reason, so they can understand the information around him. It is difficult to find questions to measure that.

Objectives and Testing

A course very often consists of several topics or chapters of the textbook being used. Each topic can be used as an example of deductive or inductive reasoning, or both. We can also motivate students through stories about the history of science or its relevance in real life. How their new understanding is going to be used by the student gives an even better motivation. The best teaching tool that I know is the pleasure that comes with understanding, and what is learnt with pleasure is not soon forgotten. Physics is a science which has relationships with few variables, so that it has more clear and concise reasoning; it is, in my opinion, the best subject to teach students to reason. Given the large number of tendentious adverts circulating in the media and on the Internet, it is necessary to be able to reason to distinguish frauds (as healing crystals, pills or drops for losing weight, etc) from good ideas.

The chapters of the book and the weeks of classes are, in this case, around the same number, forcing us to use one or two weeks per chapter. We can distribute the time of each chapter according to the relevance that we give to it. In the past I first presented the lectures, and afterwards I chose the questions to be applied in the exams.

Now, when I prepare a chapter I first define all the relevant questions (around 25-30 with inductions or deductions including a few numerical problems), which will allow me to verify that the student have learnt the relevant topics (Riveros 1998). This helps me to prepare lessons designed to encourage student to reason, (and for the student who study only to pass the test, they are encouraged to try to understand and reason the subject through). It is difficult to find good questions that measure reasoning skills and test the student's new knowledge. An exam covering 3 chapters may have 75-90 possible questions, but only about 5 appear on the exam.

Classroom activities

One way to motivate learning is to present discrepant events to students, the question "What happens if" helps to induce relationships. The issue of collisions can be highlighted by dropping together a table tennis ball held together over a solid rubber ball. It is surprising that the light ball shoots off at several times the height of the initial fall. Complete explanation of this simple experiment requires the student to understand potential energy, kinetic energy, linear impulse and its conservation in collisions. A qualitative explanation, assuming conservation of energy (elastic collisions) has three stages:

1. Consider the collision of a light ball with a very heavy ball. The solid rubber ball dropped on the floor of the classroom (the larger ball being the Earth). In an elastic collision the balls rebound up to the same initial height. A "superball" rebounds to about 90% of the original height. The Earth appears unmoved.
2. Collision of a heavy ball with a light ball at rest. We can do this by launching the heavy ball against the light ball on a horizontal table. Or the two balls supported as pendulums. Experiment shows that the light ball rebounds with twice the speed, if the mass ratio is very small [$v = 2V/(1+m/M)$]. Or to reason that out, from the point of view of the heavy ball (changing the reference frame) it is the light ball, which hits the heavy ball, and rebounds with speed V. For an observer on the ground, he adds the speed V of the heavy ball, so the light ball moves with speed 2V.

3. Collision of both balls with the same speed V. This is what happens in the original demonstration. Falling from the same height both arrive with the same speed at the floor. The heavy ball hits the floor first and inverts its velocity, from the point of view of the heavy ball (changing the reference frame) it is the light ball, which hits the heavy ball and rebounds with speed 2V. For an observer on the ground, he adds the speed V of the heavy ball, so the light ball moves with speed 3V.

A quantitative explanation requires consideration of the transformation of potential energy to kinetic energy in the fall, the conservation of kinetic energy and linear momentum in the collision and solving the system of equations.

It is obtained for the light ball thus: $V_1 = (3m_2 – m_1)\ V / (m_1 + m_2)$

Where V is the speed of the fall and the subscript 2 indicates the heavy ball. If the light mass object m_1 tends to 0, the speed V_1 tends to 3V. Because the kinetic energy is proportional to V^2, the height of the rebound would be 9 times the height of the fall. The experiment gives a result that is 5-6 times the height of the fall, because the energy is not conserved.

Solving the equations produces another result for the speed of the heavy ball:

$V_2 = (3m_1 – m_2)V/(m_1 + m_2)$.

This equation predicts that if $3m_1 = m_2$, the heavy does not rebound, stays on the floor. This prediction can be verified by experiment.

Real life applications associated with this topic are those in which colliding with some greater mass implies rebound, with the greater change in the velocity of the light object. Although the forces of action and reaction are equal, these are applied to different masses producing very different accelerations. When a heavy truck collides with a car, the truck has little damage but the car is destroyed. If you want to stay alive, it is necessary to avoid colliding with objects of greater mass.

Another topic with real life applications is car collisions, so students can feel physics is important in their lives. So we may also use data published in journals such as the data taken from a car crash. These data measure the deformation of a car as a function of time, taking t = 0 when the car touches the post with which it collides. We assume the obstacle is very thin to be able to disregard the shift in the centre of mass of the car during the deformation. This allows using the deformation as the movement of the centre of mass, using the approximation of a point mass.

In a collision reported in Popular Science (Oct 1992, p60), a Saab 9000 car traveled with a speed of 35 mph (15.6 m/s) at t = 0, it's speed was zero at t = 0.09 s with a total distortion of 30" (0.762 m); the safety belt on the driver stops the driver at t = 0.12 seconds.

Table 1. *Car crash data*

Time s	*Def in*	*Def m*
0	0	0
0.015	8	0.203
0.018	11	0.279
0.035	20	0.508
0.04	22	0.558
0.05	26	0.660
0.09	30	0.762

Using only the initial speed and the fact that the velocity is zero for t = 0.09 s, it is quickly understood why there is a need for a safety belt. Although the speed is relatively small (15.6 m/s) the average acceleration during the collision (=15.6/0.09 = 173 m/s^2) gives 17 times the acceleration of gravity. If the car weighs 10 000 Newton (one ton), the post applied a force of 170 000 Newton (17 ton)]. Before I saw these numbers, I had always thought that in the event of a collision by putting my hands on the dashboard I could stop my body colliding with the car interior; but it is clear that I don't have enough strength to take a load 17 times my own weight. If the arms keep rigid, the torso will be separated on the shoulders and the head should hit the frontal surface. The only nice thing about is that I will die in 0.1 seconds. The safety belt increases the duration of the collision (to 0.12 s), reducing the necessary acceleration to 13 times the acceleration of gravity. This greatly increases the chances of surviving the crash.

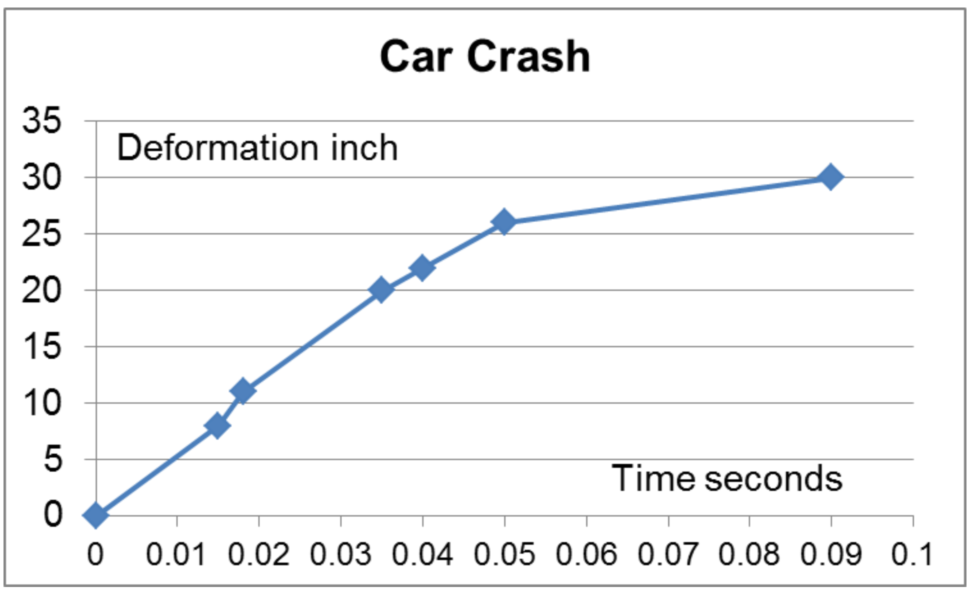

Figure 1. *Deformation against time, with the data of table I*

The data for t = 0.015 s and 0.05 s are not on a smooth curve that fits all points; Excel was asked to join the points with straight lines. A more detailed analysis, taking into account all the data, allows calculation of average speeds in each measured time interval. Those values appear as the column Vel in Table 2, this speed corresponds to the average time in <time >.

Table 2. *Modified car crash data*

Time s	Def inch	Def m	Vel m/s	<Time>
0	0	0		
0.015	8	0.203	13.55	0.0075
0.018	11	0.279	25.40	0.0165
0.035	20	0.508	13.44	0.0265
0.04	22	0.558	10.16	0.0375
0.05	26	0.660	10.16	0.045
0.09	30	0.762	2.54	0.07

		0	0.09
35 mph	= 56.6km/h =	15.6 m/s	

With this data we can plot an average speed and average time for each interval. Changing two deformations in inch: 8 to 9.2 and 26 to 25.5 figure 1 changes to a more credible graph.

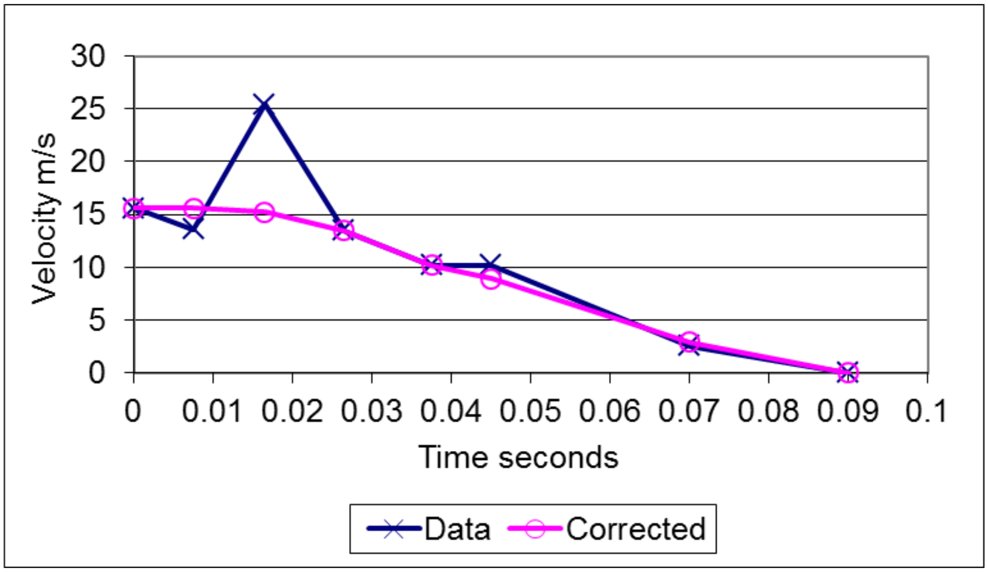

Figure 2. *The crosses mark the original data and the circles a credible approach. It is impossible that the car has increased his speed to 25 m/s*

On the graph of average speed against time, we note that the deformation of 8" is wrong because it is not possible that the car has accelerated to 25 m/s with an initial speed of 15.6 m /s. Assuming that the experimental data has some uncertainty, we adjusted the two mentioned points, tempering the blue curve, and getting the red curve. While the defenses (crumple zones) and the radiator deforms, the speed is almost constant, the plastic deformation of the engine produces the straight line, i.e., the force and acceleration during the shock can be approximated by a constant. Using the initial velocity and total time an acceleration of - 173 m/s^2, a fitting of least squares for the straight line gets - 242 m^2.

Real life applications associated with this topic are:

- The use of graphics in the interpretation of data, Experimental data having uncertainty and not all data being reliable.
- Even in a collision at low speed (35 mph) deceleration is deadly, people survive by using seatbelts.
- If we are going to collide, we must reduce speed prior to the collision as quickly as possible, to reduce the speed at the time of impact; the lower this speed the less damage will be done.

Finding student preconceptions is a very time consuming procedure, if students are passed to the blackboard. But if we ask the same question to everyone, so they respond writing at his desk, we can read several replies walking through the room. We can correct errors, without mentioning who is wrong.

In the published test we can find good questions, especially good are those of the PISA test, which are designed to measure competences. The PISA tests have been applied for several years, so it is possible to have items included in regular courses.

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