The Role of the History of Science in Science Curricula

Manuel Sequeira / Laurinda Leite
Universidade do Minho

Introduction

Nowadays, science and technology play a major role in many aspects of our daily lives both at home and at work. As consumers or decision-makers, individuals need to understand the powers and the limitations of science so that they can live more safely and happily with it. There are many ways through which individuals can both learn science and about science. Some common informal ways of doing so are reading newspapers, books and magazines, listening to the radio, watching movies and TV programs, and visiting museums. However, all of us must agree that the image of science conveyed by the mass media is not always the one accepted by the scientific community. Anyway, individuals have the right to get information on and about science. The best way to grant this right is through an adequate school science teaching. In fact, the most important objective for science teaching in schools should be to give students the understanding of science which they need in order to be able to live more happily in the modern technological society. This understanding of science requires both the acquisition of scientific concepts and the construction of a correct image of science. The acquisition of scientific concepts is needed to comprehend what things are made of and how they work. The construction of a correct image of science is essential to understanding how scientific knowledge is created and developed and, moreover, to developing, as far as possible, correct attitudes towards science and scientists.

However, individuals are naturally mentally active and develop sets of constructs based on their experiences of the real world when they try to make sense of it (Kelly, 1955). An important consequence of this natural individual process is that when children go to school, they have already developed many meanings and interpretations about the world and therefore they already possess ideas on scientific concepts and topics (Driver, 1983; Driver et al, 1985). It is convenient to stress here that these ideas are usually different from those accepted by the scientific community and that, until the last decade, they were ignored by science educators both in science curriculum development and in classroom practice. However, for the last ten years or so, an always growing number of science educators came to realize that they were failing in the effective teaching of scientific concepts due to the interference of children's science with the science taught in schools. In fact, several studies undertaken by cognitive scientists (Driver, 1983; Driver et al, 1985; Gilbert et al, 1982; Osborne and Freyberg, 1985) have shown that some ideas acquired by children in their own efforts to understand the world either remain uninfluenced despite the science teaching to which children are submitted or are influenced in unwanted ways. If it is true that children's ideas are not coherent models, it is not less true that these ideas are the result of a long period of daily qualitative observations which impose certain ways of interpreting the natural phenomena both consequently and unconsciously. If we look back to the history of science we will realize that some past scientists were using a methodology for scientific knowledge constrution which is similar to the children's one (Perez and Alis, 1985). This is probably the reason many researchers (Erickson, 1979; Andersson, 1985; Terry and Jones, 1986; Saltiel, 1987), working in various science topics have found that children possess some ideas which are in some ways similar to those once held by past scientists and today recorded in the history of science.

In this paper we will address children's ideas which have some kind of parallel with scientific concepts throughout the history of science as "Aristotelian ideas."

Although children's "Aristotelian ideas" are respectable they must nevertheless be changed by school science teaching. This paper aims

a) to discuss how much science teaching has been able to change students' "Aristotelian models" for natural phenomena towards the scientifically accepted ones;
b) to give some insight into the role of the history of science in a more accurate science education for conceptual change;
c) to discuss how and when the history of science should be introduced in the science curricula in order to get both better scientifically educated citizens and more efficient science educators.

To attain the first objective, a pilot study was carried out by the authors on the topic "free fall," to investigate whether or not science teaching succeeds in changing students' "Aristotelian ideas." Relative to the second and third objectives, the authors will base their arguments on a review of literature concerning those issues.

Description of the Study

The pilot study described here was carried out by the authors in the spring of 1987. The sample is constituted of 10 prospective Physical Sciences teachers on their fourth year of undergraduate study and 17 tenth grade students from a secondary school in Braga. The prospective teachers had already studied the topic "free fall" both at school and at university and they would not look at it again in any course before going to school to teach Physical Sciences. The 10th grade students had not yet been formally taught on "free fall."

The data collection was done in a class of the course on Physics and Chemistry Teaching Methods for prospective teachers and in a class of Physical Sciences for 10th grade students. All the students were asked to answer individually and in writing two questions: one on free fall in the air and afterwards one on free fall in the vacuum (see Appendix 1).

The students' and prospective teachers' answers were classified in categories according to the alternatives for the questions asked or according to the justifications given for the phenomena. The justifications were clustered in three categories based on: a) weight/mass; b) air resistance; c) some other factors. No test of significance was performed due to the small size of the sample.

Results of the Study

On answering to the question on free fall in the air, 80 % of the prospective teachers and 94 % of the 10th graders stated that the metallic sphere (the heaviest object) is the object which takes a shorter time to fall down. This result would be quite acceptable if the reasoning done by children had been scientifically correct. The problem is that none of the students gave the correct explanation (based on the effect of the air resistance) and only a 10th grader stated "I think weight does not matter."

The 10th grade students pointed out the weight either as the only factor responsible for the shortest falling time of the sphere or the weight as a cofactor with gravity, force with which bodies are released, shape of the objects, volume of objects, and force of wind. On analysing these students' explanations we found that they still hold an unclear concept of mass, weight, and gravity and that they cannot relate these concepts properly to each other. In fact, in concluding that the sphere is the first object to reach the ground due to the fact that it is the heaviest object, a student stated: "I think that I should take into account the factors which have an influence upon the bodies, as for example its gravity in relation to the earth, among other factors."

For other students the weight is a characteristic of the bodies, and it is due to the fact that bodies have some weight that they are attracted by earth which has a force - the force of gravity. The following examples taken from the students' answers illustrate their reasoning: "The sphere has more mass, more weight, and therefore it will be more attracted by the force of the earth because the more weight a body has the bigger the attraction for the earth." "If the earth has the force of gravity, the heaviest object is the one which is most strongly attracted to the earth."

In general, we can say that for these students (10th graders) the force "inside the objects" or that acts upon them (attributed to the fact that objects have weight and/or earth has a force) varies directly with the speed of the falling object in such a way that the more intense the force is, the higher is the speed, and the less time the object takes to fall.

Although prospective teachers try to give more elaborate explanations these are not really better than those given by the 10th graders. Once again, nobody referred to the effect of the resistance of the air upon the falling objects and the falling time. Some justifications contain quite elaborate mathematics but they proved something which does not justify the shortest falling time for the sphere. These prospective teachers recalled Newton's second law, but they either forgot Newton's first law or drew wrong conclusions. An example of this is given below. A prospective teacher, after demonstrating that he/she could write 1/2 mv 2=mgh, concluded: "...We already know that the potential energy is higher for heavier bodies. From the above relationship (1/2 mv 2=mgh) we can conclude that the speed will be higher in the case of the sphere because it has the highest mass. Therefore, the sphere is the object which will reach the ground more quickly."

On answering a the question on free fall in the vacuum, 53 % of the 10th grade students and 70 % of the prospective teachers stated that three objects with different weights take the same time to fall down in the vacuum.

In what concerns the explanations given by 10th graders, some of them stated that "there is no air and therefore the speed will be the same for the three objects" but nothing is said about how the air affects the speed. One student wrote: "The objects will fall at the same time because if there is no air in the tube, there is nothing pushing the objects down; the weights do not matter because the air is the only factor influencing the falling speed of the bodies."And only one wrote "since there is no air inside the tube there is nothing preventing the objects from falling." An interesting explanation is this one: "Without air there is no gravity, and therefore all the objects will fall at the same speed." What, then, is the reason for the bodies to fall in the vacuum? It would be worth while to investigate it.

28 % of the 10th graders who stated that the sphere would be faster in falling than the other objects pointed to its higher weight as the cause for the different falling times. One of the other students said that the objects do not fall in the vacuum because "if there is no matter inside the tube, there cannot be either attractive or repulsive forces, nor even gravity. Therefore the objects would be flying."

In what concerns the prospective teachers, the justifications given by them include some ideas which are similar to those referred to above in regard to the 10th graders. In fact, some prospective teachers (3 out of 10) still believe that in

vacuum there is no gravity and one of them even added: "Then the weight is the cause for all the objects taking the same time to fall in a vacuum. Thus the weight is the force exerted by the earth upon the objects. As g=0 the falling times are equal."

There is no doubt that this student is not clear in his/her mind as to what is meant by weight and by gravity. It seems that a vacuum puts some kind of barrier between the objects and the rest of the world, preventing the last from acting upon the objects. In fact, a student considered that when the objects are in the tube without air they are "in the absence of any external factor." Although another prospective teacher believes that the objects are under the action of gravity and concludes "a=F/m; F=mg; then a=mg/m=g the same for all objects," we do not exactly know how this conclusion affects the falling time, or whether the absence of the air is important. One of the prospective teachers who stated that the sphere would take a shorter time to fall down believes that vacuum exerts a force upon the objects. He/she explains it as follows: "The force that the vacuum exerts upon the objects is the same, but the falling time depends on the weight of the objects. If the sphere is heavier than the button and this is heavier than the feather, then the falling times are those referred to above (t feather>t button>t sphere)."

The best of all the prospective teachers' answers is probably the following: "The falling time is the same for the three objects in the vacuum because, as there is no friction, the objects fall as if they really had the same mass."

This is the only answer which makes an explicit reference to friction (although we do not know what friction he/she refers to). But it seems that this prospective teacher is still a bit confused. In fact, when he/she says that the objects fall "as if they had the same mass" it seems that what is obvious for him/her is that objects with equal masses take equal times to fall down. Therefore some ideas are not yet properly integrated in his/her conceptual framework.

Discussion of the Results

Although the present study intends to be only a pilot study, and despite the fact that the sample is very small, we would like to express our concern about the effectiveness of science education, based on the results we have gotten. In fact, even if it were not expected that 10th graders give fully accurate explanations for the free fall phenomena, it was expected that prospective teachers would perform much better than they did. It is a matter of fact that the students participating in this study can observe falling objects every day. The general "rule" constructed from these experiences by individuals seems to be that the heavier the object is, the faster is its fall. However, this "rule" is valid only in very specific situations, and prospective teachers, who had already been taught on the topic, were supposed to be aware of that. However, the study suggests it is otherwise. In fact, roughly speaking, we can say that 10th graders performed as well as prospective teachers did, and that both groups performed poorly. It seems that something is not working properly.

If prospective teachers still held "Aristotelian ideas" after having learned about a specific topic in science, not only in school but also through their experiences in everyday life and university, we must conclude that the kind of science teaching they were exposed to failed to change their "Aristotelian ideas" and therefore did not achieve its objectives.

Implications of the Study

Although children's "Aristotelian ideas" are not as coherent models in children's (and even in adults') frameworks as the historical ideas were in scientists' frameworks (Driver et al, 1985; Saltiel, 1987), they are strongly held in children's frameworks, and resistant to science teaching (Driver, 1981). It has been argued (Driver, 1983) that to be effective, science teaching should build upon children's ideas and enable students to make a journey from the old to the new and from the known to the unknown. To feel like initiating this journey, children should be made aware of a lack of consistency of their own ideas, and afterwards they should be submitted to a science teaching strategy capable of promoting conceptual change. In what concerns the change of "Aristotelian ideas" and due to some kind of parallelism between the intellectual growth of a child and the growth of science, many people believe (Strike and Posner), 1982; Gilbert and Zylbersztajn, 1982) that the history of science seems to have a particular value in changing these "Aristotelian ideas."

According to Lind, "the history of science offers fitting material to illustrate the modification and revision, the rejection and reinstatement of models, their relativity and dependence on the spirit of the age... (and)... pupils can critically view historical models more easily than their own." (Lind, 1980).

There are several ways to introduce the history of science in the school science curriculum. Roughly speaking, we can consider four ways of doing so:

a) as an independent subject;
b) as independent modules in science subjects;
c) as illustrative material in the science modules;
d) as a specific part of each science module.

It is true that the history of science can be an independent subject in its own right. However, it would require mental abilities and a range of knowledge of other subjects which, we believe, cannot be found at least in the majority of the secondary school students. At this level, the history of science should therefore be introduced as a specific part of each science module rather than as an independent subject. The same does not apply to the university where the history of science should not only be an independent subject, but also a compulsory one in most undergraduate science programs. We do believe that university students taking this kind of programs would be better prepared to use history in their science classes not just as an illustration, but as a serious and important content through which one can learn many valuable things. If the prospective teachers in our study had taken a course in which they had studied the history of the interpretation of the free fall phenomena throughout the centuries, and if they had integrated that knowledge in their conceptual frameworks, they would certainly have given different and better explanations to the questions asked. However, looking at the curriculum of their undergraduate program, we notice that it does not contain any course either on the history or on the philosophy of science.

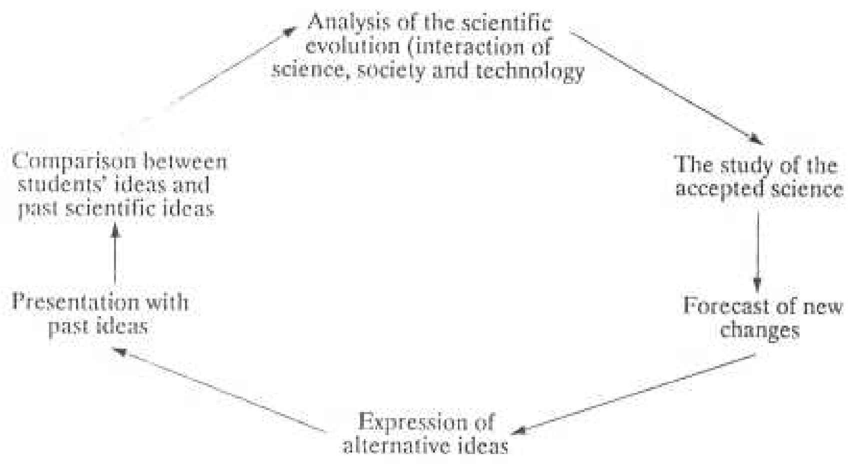

Fig. 1 – Historical generative learning cycle

A possible strategy to implement a sound historical approach to science teaching and to build upon children's ideas could be through the historical generative learning cycle (Leite, 1986). As illustrated in figure 1, the teaching of each topic would start by students making explicit their own ideas related to the topic. Then, students should be presented with ideas from the history of science containing some resemblance to students' ideas. Students would compare their own ideas with the historical ones and would analyse the way the knowledge on the science topic developed. When reaching the present stage of science, students would explore it in order to acquire the accepted scientific concepts and models. The cycle would end with the forecast of new changes in science and in the world, from a scientific point of view. This cycle can be repeated again and again at different levels and can have a variable starting point which depends on children's current ideas.

In Portugal, like in many other countries, the history of science is not integrated in science subjects and does not exist as an independent subject in some undergraduate programs, as well as in most science teacher education. On one hand, action must be taken in order to give the history of science the status it deserves by introducing it in science curricula. On the other hand, research is needed in order to assess both the extent to which the history of science can help children's conceptual change and the teaching strategies to enable science education to take more advantage of the history of science.

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Appendix 1

Questionnaire

1. A feather, a metallic sphere, (diameter = 1 cm) and a plastic button are released, at the same time, from the same level above earth.

1.1 The ground is reached: A - first by the feather. B - first by the button. C - first by the sphere. D - by the three objects simultaneously.

1.2 Please describe the reasoning followed to answer to question 1.1.

2. A feather, a metallic sphere, and a plastic button are introduced into a glass tube where a *vacuum is created (air is removed). Afterwards the tube is inverted in such way that the three* objects can fall vertically, from the same level.

2.1 Please tick the appropriate alternative for the falling times of the three objects. A - t feather *> t button > t sphere. B - t sphere > T button > t feather. C - t sphere = t button = t* feather. D - other (please specify).

2.2 Please describe the reasoning followed to answer question 2.1.

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