PHYSICS EDUCATION AND HISTORY OF PHYSICS. A RELATIONSHIP OF HATE OR AFFECTION?

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1 BRICKS ON THE WALL!

After twenty years of teaching physics I think that the answer to the question that comes to the mind of all of us when we enter a class for first time is more than crystal clear. I think that everybody is wondering about the image we present to our students when we step in. And the answer is just like Vampires?!

Some of you may think that we do not deserve to be perceived by our students as monsters ready to suck their blood, though this is still the situation despite the numerous efforts to improve the image of the physics teacher among the more or less fearful students pondering what lies ahead for them in the new school or academic year. Though the above picture is somewhat exaggerated it is not too far from reality.

Yet another question arises, which is also central if one wants to do serious work in physics teaching. I mean, that we have to consider how capable our students feel to learn science. I think that, due to a series of factors having to do with their families, friends, school, the mass media and, generally, with their everyday cultural environment (which I would dare compare with the darkest ages of human history), the answer is not encouraging.

In fact the most accurate answer to the above question is given not in a sober scholarly paper but in a classic rock song composed by the famous group of Pink Floyd during the eighties. The youth of that period, of our times and probably of the generations to come consider themselves just like “another brick in the wall”.

Henry Nielsen and Paul Thomsen have proved that for Denmark, but we have no reasons to believe that elsewhere the situation is any different. As Nielsen and Thomsen have pointed out: “the majority of secondary school students find Physics to be difficult, unrelated to other school subjects and with very little connection to real life” [1].

Thus, any attempt at teaching physics productively should focus firstly on changing the two negative images we have just described in the conscience of the students. According to many serious researchers and educators there is not a simple method, one that could be used as a panacea for this problem. “Basic instinct” would be a two-word directive if one were to give advice to a desperate teacher, followed by the well-known statement that he or she should use “speculative imagination and controlling evidence in good balance”.

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Speculative imagination and controlling evidence are also two crucial compounds of what we call "history of science".

2 OLDIES BUT GOODIES!

If we go back, in the early days of non-Aristotelian physics, which began to be systematically taught in the eighteenth century, we will find that the authors of various textbooks of that time, like the Newtonian "Elementae physicae" or the Cartesian "Traite elementaire de Physique" expressed their concern about the way these textbooks had to be written. In their texts they tried to include experiments, mathematics, rational reasoning and elements from the history of physics, all these in the right proportions. Even in the margins of the European scientific milieu, for example in south-eastern Europe or the Iberian Peninsula, in countries of the so-called scientific periphery, like Portugal and Greece, teachers of physics expressed their concern on the way this "new" science should be taught.

Let me present here some interesting examples from the history of education in Greece, as today we still teach the 18th century physics and paradoxically enough the situation has not been considerably improved.

Most Greek authors of the 18th century mention in the introduction of their textbooks that they tried to avoid the extensive use of advanced mathematics, deeming that their students did not have the required level of mathematical knowledge to respond to this way of teaching [2]. However, they considered a minimum level of mathematical literacy as a necessary and adequate precondition for those who would like to delve into natural philosophy. Nikephoros Theotokis, the author of the first printed Greek Physics book of the 18th century [3], writes in the introduction of his book:

"The path towards Natural Philosophy (e.g. Physics) becomes easier and more direct if we are well versed in mathematics. Without such knowledge we could not properly educate students so that they understand the theorems of mechanics, hydrostatics and optics".

Another scholar with interesting views on physics education was Dimitrios Darvaris. Darvaris chose to supplement his teaching with some intricate experiments. He starts his textbook *epitome of Physics* [4] with a very interesting statement:

"We know that not everyone can become a scientist, because for that he must posses several characteristics which are very rarely found in an individual. But everyone can be a friend of the sciences."

This is something that we, as teachers and educators must always bear in mind. We are not coaches of a professional NBA team, but we train the minds of young people so that they can understand Nature and to acquire a general idea of what physics is. Therefore, the first thing we must do is to inculcate in our students a fondness for physics.

Darvaris was well aware of that and he mentions it in his book:

"I included several funny demonstrations, which, although not directly related with the theory of physics, give a lot of pleasure and arouse students curiosity to learn more about nature."

All of the above-mentioned scholars suggested the extensive use of experiments in the teaching of physics. One of these teachers, the Greek scholar Konstantinos Koumas, wrote characteristically [5]:

"I refer the simplest and easiest to be performed experiments. The instruments used for these experiments are common and inexpensive, which can be bought by every school in the Greek speaking lands."

Koumas was also among the first to creatively use the history of science in his textbooks (due to the fact, however that he wrote in Greek, his work is still rather unknown to the community of those who studied history of education).

3 THE EARLY DAYS

During the last third of the twentieth century the discussion about the use of history of science in science education was rekindled. This discussion, which actually never disappeared, had already begun in a formal way in Western culture as early as in last quarter of the nineteenth century. Ernst Mach in the first issue of the *Zeitschrift fur den Physicalischen und Chemischen Unterricht* and in his classic Science *of Mechanics* (1883) claimed that "to understand a physical term it is necessary to understand its historical evolution". Sir Oliver Lodge's (1851-1940) classic *Pioneers of Science,* published in 1893 is considered by some scholars as the turning point for the use of the History of physics in the educational process.

Still, we have to recall that during these "heroic" years, physics was not generally accepted as a subject in the curriculum even in countries like England, as other lessons including ancient languages, knitting and sketching were considered more necessary for the basic children's education. The discussion started then, is still continued, and will continue in the years to come; several interesting arguments have been formulated in favour or against the use of the history of science in the educational practice.

Being a physicist, a teacher of physics, and historian of science at the same time, I should admit that I reflectively disagreed with the theorisation of the educational process. I considered that there are no specific recipes that can be applied with guaranteed success in the classroom. I believed that such a success, in the rare cases it is achieved, is a result of the good chemistry between students and teacher, of the ability of the teacher to adapt or to completely alter the educational methods depending on the conditions he meets in the classroom. Naturally, being of the opinion that no methodology of didactics should be rejected outrightly, without being previously tested and properly evaluated, I believe that the discipline of the history of science has its own definite role and potential for contributing in physics teaching. I would argue, however, that even though it is not completely useless as certain theoreticians of science teaching maintain, it is also not the sole reliable method for good results, as others believe.

As in most situations, we have to follow the golden mean and to avoid extreme positions. In fact, as history proves, there is no *per se* right or wrong methodology in physics education. What exists is the right or wrong application of a specific procedure at a given moment.

4 HISTORY OF SCIENCE, SOCIETY AND SCIENCE EDUCATION

A basic element of our approach is the elucidation of the precise nature of the history of science. Even today there is confusion and misunderstandings prevail with regard to this discipline, mainly among the circles of the scientists working in research and development centres. Those that do not consider history of science to be completely useless believe that it merely amounts to a collection of anecdotes from pensioner scientists. However, certain steps of rapprochement have already been made. The history of science as a discipline has its own history. For many of us, the founding father of this field is undoubtedly the Belgian George Sarton (1884-1956). Since the early days of the History of Science, with publications like Herbert Butterfield's famous *The Whig interpretation of History* (1931) and *The Origins of Modern science* (1949) where he claimed that it was "hardly possible to doubt the importance which the history of science will sooner or later acquire both in its own right and as the bridge which has long been needed between the Arts and the Sciences", much water has already gone under the bridge, and history of science has matured enough to be regarded as one of the most dynamic academic disciplines in Universities around the world. The list of international journals devoted to the subject is indeed lengthy, while thousands of relevant entries can be found in useful tools like the yearly *Isis Bibliography* or by a simple search in the popular internet search machines. On another note, it is perhaps commonplace to state that science itself and its public image are in a state of crisis. Generally politicians find applications for scientific achievements without any humanist dimension; the mass media present them in obscure ways, often failing to distinguish true science from pseudo-science. All of us have had such experiences: physicists or other scientists are invited to television panels to discuss on issues such as extraterrestrial life, the possibility of time-travel, the likelihood of meeting dead people… These facts not only ridicule science but also insult the reason of any human being. Furthermore, science is attacked hard as many consider it responsible for many of the environmental and social problems the planet faces nowadays. Though knowledge is neutral, its use is not. But it's unfair to criticise and to blame science in general, and physics in particular, for our improper use of their achievements. This total scorn of science further complicates its teaching, at the moment when most students seem to be at best indifferent to the scientific achievements, and this lack of interest is exacerbated by boring and unimaginative way of teaching.

It is common knowledge that a great number of physics teachers lose their zeal for teaching and behave like public servants after some years of working in educational institutions, having to battle against bureaucracy, narrow-minded supervisors and inadequate salaries.

Therefore, a question arises: If properly used as an educational tool, can history of science reverse this displeasing situation? Obviously, the answer to this question is not obvious. Still a very informative review on the use of history of physics in physics education has been published by Seroglou and Koumaras [6]. Intersting points have also presented by Stuewer [7].

Though one would think that historians of science would be enthusiastic about such an eventuality, this was not –and still it is not– always the case. A large part of the community of the historians of science maintained a cautious position; some were even hostile to the prospect of employing the history of physics as an educational tool.

Two of the most vocal sceptics in this issue were Martin Klein and M.A.B. Whitaker. Martin Klein was a research physicist who later became a historian. In a 1972 paper titled "Use and Abuse of historical teaching in physics" among other things he claims:

"One reason it is difficult to make the history of physics serve the needs for physics teaching is an essential difference in the outlook of physicist and historian … it is hard to imagine combining the rich complexity of fact, that the historians strives for, with the sharply defined simple insight that the physicist seeks".

Michael Matthews, a well-known promoter of the use of history in physics teaching and founder of the International History and Philosophy of Science Teaching Group retorted as follows [8]:

"Klein suggested that there was a basic difference in the very enterprise of science and history that makes their marriage most improbable and where it does occurs, makes the union short and stormy".

Whitaker's views were mainly contained in his 1979 paper "History and Quasi –history in Physics education". Matthews has defended history of physics against the Klein-Whitaker arguments considering them "serious but not fatal". He actually attacked the core of Klein's arguments as he denied the empiricist accounts of history supporting that "A historian is not an archivist".

Secondly, he criticized the statement "that the history used in science courses will be quasi-history". Matthews accepts that there is an "internal" methodological problem which has to be addressed, but still, he argues, the use of a 'simplified' history for educational purposes does not amount to the creation of a pseudo-history of science.

Finally, he demonstrates that historical study is not corrosive of scientific commitment. The corrosive impact of the history of science in science teaching was supported, among others, by Stephen Brush in his "Should the History of Science be Rated X?" where he claimed that "history of science could be a bad influence on students because it undercuts the certainties of scientific dogma seen as necessary for maintaining the enthusiasm of apprentices on a difficult task".

Sharing Matthews's view, I think that Brush's fears are not well founded. Several well documented studies, and our everyday-school experience indicates that quite the opposite is the rule.

In the 1950s, several tried to connect the internal history of science approach, which at that time was prevalent among the historians of science, with the teaching of physics. The better known of these efforts took place in the University of Harvard. In the framework of the aforementioned approach, in 1952 G. Holton published his classic book *Introduction Concepts and Theories in Physical Science*, and in 1970 F.J. Rutherford and F.G. Watson published *The Project Physics Course*. According to the adherents of this project, the main objective was to plan a curriculum for teaching physics with emphasis on humanitarian values; attract more high calibre students in the field of Physics; and investigate the factors which influence the process of learning science. According to the published evidence [9] the PPC was relatively successful in the USA compared with other, similar proposals and was used in about 15% of the schools. In addition, it became popular and was also extensively employed in Europe. With some delay, the philosophy of the PPC project was introduced in Greece too, during the early 80s. The pioneers of the creative use of the history of physics in physics education were Nikos Dapontes and Andreas Kassetas, still active teachers of physics today. The majority of the educational community received their book with great hostility, as it called for a different approach by teachers, advocating their more careful and thorough preparation before entering the classroom. Though it was proven that students who have been taught that book could better understand and appreciate the basic framework of Physics, the book was finally withdrawn due to political reasons. This proves the widely held belief that teachers are a very conservative social body, which very hesitantly accepts any new or radical idea. Going back to PPC, according to the relevant evaluations reported by Brush, its use considerably altered the opinion of the students on Physics and pushed forward its historical and philosophical character. On the other hand, the students who were taught Physics through PPC had generally the same rates of success in the evaluation tests with the students who had been taught physics through other approaches like the famous Physical Science Study Committee (PSSC). As David Quattropani already noted in 1978 [10] "historical approach of the science should be explored further as a method of increasing student understanding of the relationship among science, technology and society".

A different approach is the one that proposes the use of the external history of science in physics teaching. This approach is described in articles like those by Salmon and Aikenhead [11] and Solbes and Vilches [12]. According to them, emphasis must be given mainly to the import of social parameters on the formation of the scientific theories. It can be applied chiefly in educational programs that bring to the fore the so-called 'meta-cognitive' dimension of science, which includes the comprehension of the nature of science and the interaction between the society and the science [13].

In this case, history of science can be used in a complementary way so that the basic relations shaping the so-called scientific method, as for example the role of observation and experiment in the development of a theory is understood properly. In addition, one could propose a reasonable explanation of the fact that to a large extent the prevailing theory determines the focus of the research projects, and that, eventually, through a complicated process a new theory supersedes an older one.

As it has been argued [14], scientific knowledge reflects the cultural and environmental conditions in which it is developed. However, science should rise above these conditions and function as conduit between different cultural environments, when and where this is feasible. This bridge should be based on the respect for distinctiveness of others and should not be structured in an 'imperialistic' spirit – this is a political term, coined to accurately describe the way Westerners behaved to the people belonging to other cultures. The difficulties of such a process are described in a stimulating article by Eva Krugly-Smolska [15]. Jurai Sebesta has published also an interesting article on the use of "national" history of science in science education [16].

Following the above framework of ideas we may argue that physics textbooks can have an introductory chapter discussing indigenous or ancient science as part of a nation's cultural heritage.

In the main part of the books any contributions by 'local' scientists could be presented as well.

These references, set within a wider liberal education concept, could inculcate in students the feeling that they are active citizens of what many call the "global village" thus minimising any sense of isolation.

External history of science in physics teaching could also prove that women played a very important role in the development of Physics either conspicuously or inconspicuously. Several examples since the 18th century, like Maria Gaetana Agnezi, Anna-Maria Sibilla Merian, Marie Curie and many others could be used to disprove the prejudice that science and physics is suitable only for men. Thus, in the hands of a capable teacher science history could fulfil an important role not only in the context of an interdisciplinary approach but also of a multicultural approach.

Several theoreticians of education, Piaget being most prominent in that group, noticed analogies between the historical development of science and the ability of students to assimilate contemporary scientific knowledge. For example, in 1996 Selley mentions [17] the fact that the ideas of children concerning the nature light and vision correspond to pre-scientific theories expressed mainly by ancient Greek Philosophers. This similarity has also been discussed by Gunter Lind in an article on the use of models in Physics [18]. He mentions that our ability to see objects according to the ancients "may lie in the attribute of the eye or in an attribute of the object, or in an attribute of the transparent medium between the eye and the object". And students actually give answers similar to the above when asked to explain the mechanics of vision. Impressed by these similarities, a number of researchers argue that the use of the historical dimension in the teaching practice might aid students to recognize their misconceptions and to accept the need to adopt more developed theories as they have a superior explanatory ability. Still, this is not a view supported equivocally. Others maintain that even though the analogies between the ideas young children and the early notions on the nature of several physical phenomena are obvious, it is not necessary that the passage from the one cognitive stage to the next one be simulated precisely by the process of development of natural sciences [19], as there are serious differences between these two processes.

By the 1980s a new idea had been formulated: the history of physics can offer useful evidence on the conceptual and other difficulties that should be overcome so that a new scientific term can arise and be properly understood. Two interesting papers on the subject were these by Heering [20] and Jenkins [21]. The history of electricity or energy can offer several pertinent examples. At the same time, the application of the history of physics in the classroom can assist students to recognize in some outdated theories their own opinions for various phenomena. Knowing that these theories have been proven inaccurate they could more easily be convinced of the truth of the prevailing theory [22]. For instance, a theatrical play where Aristotle, Newton and Einstein discuss the nature of the physical laws could be part of such an approach.

Using this method, students can understand that our everyday experience may lead to false conclusions and that there is the need of a concrete process of analysis and synthesis of the available data in order to discover the truthful description of a physical phenomenon and consequently its logical interpretation. In the same framework the reproduction of historical experiments in the class has been proposed. These experiments, however, have been chosen to be mainly ‘good’ experiments e.g. experiments, which give results that, advance science forward. The experiments that failed, and all we know there are many such, are usually ignored, mainly because of an unconscious fear of the teachers who probably think that the presentation of such experiments would decrease the admiration of the students for physics, as most of them hold a completely positivist view of the evolution of science. This being the case, we must admit that the ‘good’ experiments can increase the interest of students, mainly if we try to make the experiments in conditions that are similar to the original ones and to keep the students unaware of the conclusions we expect to be drawn from the experiments. Thus we have to let students "discover" the supposed results under the minimum possible guidance. For example, such experiments are those of Galileo (where the inclined plane is used) as well as those of Faraday. Employing this methodology as well as a historical approach to the formulation of a physical theorem and its solution may prove valuable to students, as in this way they can realize the nature of a physical problem and the process one has to follow to establish its solution. This is important because one must first properly formulate the question before attempting to tackle the answer. Otherwise, by focusing attention on the wrong statement, one will never come upon the answer that will explain the physical problem. In this way students are freed of the tedious "accountant" type of exercises that comprise most part of the educational handbooks and offer very little in the construction of knowledge in physics [23].

On the other hand, though this type of exercises is considered sterile, empty of any physical meaning, nothing but a proof of mastery of mathematics they may be favoured by teachers and students who prefer what is already known if somehow inadequate, than something unknown yet fresh and innovative.

Through the history of science students may come to comprehend the way in which a certain opinion prevails, though it is contemporary to alternative ideas which at the outset have equal chances at becoming established. An often-cited example is the eventual predominance of the Newtonian concept of force over the Cartesian notion of the dynes.

In addition, history of physics may assist the students to realize that scientists are ordinary persons too. They have their likes and dislikes. When the figure of the scientist becomes demystified he is no more considered as someone above the norm, not only cognitively but also ethically. At the same time the self-confidence of students is bolstered and they may think that after all they do not differ substantially from an eminent scientist. Thus they may realize that they are capable of becoming actively engaged with science. The debate between Newton and Leibniz can prove a most excellent occasion to initiate a discussion on the moral dimension of famous scientists. Nowadays, one of the objectives of science education it is not just to inculcate sterile admiration for the giants of science in order to motivate the further engagement with physics but also to make students to realize that physics is a science which progresses only through collaborative work, and the input from each contributor, irrespective of its relative significance, may prove decisive. Certain examples of what we call nowadays Big Science, describing the way big research centres like CERN operate, can illustrate this argument.

5 A NOT COMICAL USE OF COMICS

We have already mentioned that the history of science proves science is an important cultural constituent. This can be further established by referring to the universal character of the natural laws; they have a common, universal language – that of the mathematical symbols that exceeds any national boundaries.

On the basis of the thoughts concisely outlined above, it should become obvious that now, more than ever the time is rife for a multidimensional application of the history of physics in physics teaching. In order, however, to avoid the errors and the failures of the past we have to be aware all the time, be armed with patience, seeking to couple this educational proposal with other more 'traditional' ones, and use attractive means to increase the interest of students (for instance, comic strips and computer graphics) instead of the classic methods which revolve around the use of textbooks.

In science education, cartoons could be used to make the history of science more lively and attractive. The relevant discussion started in the motherland of comics, the United States of America [24] as early as after the end of World War II. A very informative article was that of W. Sones' titled "The comics and instructional method", 1944.

This progressive, even radical for that period, idea was supported by educators like Sidonie Grumberg [25], but was finally defeated by the hysterical cries of the conservative circles expressed mainly by Fredrick Werdham (1895-1981) in his characteristic *The seduction of the Innocent* (1954).

Almost a quarter of the century later this discussion came to the fore again, although in a more moderate form as the title of K. Koenke's paper "The careful use of comics" indicates [26].

During the 90s Art Spiegelman with his influential *Maus* published in 1992 gave fresh impetus to the utilization of comics in physics education signalling that this form of expression has entered a mature stage.

We argue that even pages from comics not intentionally designed for physics education could have a positive impact on the interest of young students towards science and the study of nature. Many parts of the classic Mickey Mouse magazine created by Walt Disney illustrate exactly this possibility. Most recently, in 2005, James Kakalios published a very interesting book entitled *The Physics of superheroes*.

6 SOME CONCLUSIONS

1. History being a cyclical process we are again at the point where we have to re-introduce physics to society, because we live in an era where science and its products are around us, are developed for us –as they say– but not with us. And this situation leads –contrary to the core values of any scientific enterprise– to less freedom, humanism and happiness for the people in the world.

2. Every curriculum reform is bound to fail unless it coupled by incisive political and bold social changes, in the context of which teachers in general and teachers of physics in particular will have greater self-esteem, will be more open-minded, better paid, convinced of the necessity of reforms, respected for their work by the society.

3. We have to see the forest, not the trees.

4. We have to understand that the history of science in general and history of physics in particular is not only the history of the past but also the history of the present and, why not, the history of the future. And for the proper physics education **discipline-based**, **liberal** and **technical** approaches are needed in commensurate amounts. Yet, like in all recipes we have to modify the relative proportions of the parts and add a secret ingredient and a personal touch to create a most delicious cocktail.

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