THE HISTORY OF SCIENCE AND SCIENTIFIC EDUCATION: PROBLEMS AND PERSPECTIVES

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Abstract

In the past the gap between humanistic and scientific culture was much more evident than it is nowadays. After centuries of prejudice about scientific learning and discoveries, when science was underestimated as a kind of pseudo-culture; after generations of scientists considered extravagant people, or worst, outsiders, as regards such rules imposed by religious and moral beliefs and code, the primary function performed by scientific education has now become unquestionable.

In this paper we shall try to deal with the issue of scientific education from a historical-foundational perspective. We shall try to show the importance of introducing the history of science as an integrant part of the culture of scientific education to the extent of considering history of science either an indissoluble pedagogical element of culture or the basis of inter-discipline. This project-research is not finished, so we only present the outline of the problem, some hypothesis and applications. Beyond, it is based upon use of historical categories to investigate the foundations. For this reason the latter are not analysed by means of a traditional approach. Of course, the content of this study could appear potentially factious, since it cannot be the unique possible perspective.

Key words: *history and epistemology, teaching of physics and mathematics, scientific and interdisciplinary approach.*

Introduction

Teachers at any school degrees, university researchers and doctors, pupils, scholars and tutors, they all should highly mind education as the first and most general aim of a civil society. It is a common assumption that school curricula can vary according to the different education training offers, to cities and Countries but nowadays a common warning from educational agencies all over Europe is being shared: a lack in scientific education (Blezza, 1994)[1]. This emergency is witnessed at any level, by negative reports from schools, especially, in the field of mathematics, physics, chemistry, up to a dramatic cut in the registration to university departments of mathematical and physical sciences. Of course, it is not the way the world is expected to turn, especially, if we think in terms of scientific,

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1   See also: Pisano, 2008, in press.

interdisciplinary and cultural progress (Dewey, 1903).[2] Hence, the importance of introducing the history of science as an integrant part of the culture of education to the extent of considering such a discipline - in its turn - as an indissoluble pedagogical element of history and culture (Fox, 2006, pp. 410-432).[3] More in details, the history of science is a necessary component either to the process of scientific learning or to the teaching process. No doubt, a teaching strategy simply based on definitions, theorems, schemes, physical laws under a mathematical pattern should be avoided, even if it comes together with laboratory training. Thus one could notice that the students have practically an image (and sometimes teachers as well) of science just deduced by textbooks. Nevertheless,

> Inevitably, however, the aim of such books is persuasive and pedagogic; a concept of science drawn from them is no more likely to fit the enterprise that produced them than an image of national culture drawn from a tourist brochure or a language text. (Kuhn, 1962, p. 1, line 9)
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> […]. Textbooks, however, being pedagogic vehicles for the perpetuation of normal science, have to be written in whole or in part whenever the language, problem-structure, or standards of normal science change. In short, they have to be rewritten in the aftermath of each scientific revolution, and, once rewritten, they inevitably disguise not only the role but very existence of the revolutions that produced them. (Ivi, p. 137, line 23).

Obviously, we must take into account that not all the students will attend university or will become researchers though, if teaching means a source of culture to grow up world citizens tout-court, developing a deep feeling of responsibility in being a member of our community, it is morally necessary providing each student with the proper skills to leave the secondary school with specific competences to build hypothesises and choose above all the most "conventional" problem solving attitude. Certainly the large amount of numerical exercises performed at school (according to the traditional teaching) will have provided a student with a useful ability at calculations but they are not sufficient as to motivate him to enter the library of his town and look up roots or the necessary sources to draft the cultural premise of his own work project. That is why what should be aimed at nowadays in schools at any degree is a new trend in teaching in order to change the school of notions (mechanicist and *a-scientific*) into a school (e.g. Italian ones) where *choice and method* for the discovery of science itself (and not for its justification) prevail (Pisano, 2008). Therefore, what really matters under this new approach (among other things) is not the discipline in itself, though the problems brought in by it, as well as a researcher does not make a discipline but tries to solve its problems. This would be possible just thanks to the passage from a traditional teaching to one developed according to new approaches, mainly interdisciplinary, to be considered a strongly innovative cultural and teaching strategy aiming at the increase of open-minded students. The role of interdisciplinary, though commonly recommended and even abused as a key-word in teachers' school planning, has generally been neglected in practice, this is due to several factors, such as problems with school organization and timetable or simply to different perspectives and interpretations of the concept underlying the term *interdisciplinary* itself.

What we are thinking of, here, is a form of *factual* interdisciplinary, based upon school topics (i.e. scientific topics) dealt with according to a converging plan by teachers representative of different disciplines. Of course, in order to get at the result a strong cooperation is needed. This would give our students the living proof either of a *continuity* and a *consistency* among humanistic and scientific perspectives about cultural matters or of a revolutionary, multi-tasking teaching-learning approach (Hessen, 1965).[4] A major importance would be given to the learning process and the students would be more involved in the *how* than simply in the *what*.

We feel confident that a renewal in the field of science education is up to teachers and those things can change if we want to. That is why we have welcomed some really interesting proposals

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2   See also: Bruner, 1996; Id, 1964; Dewey, 1916; Id., 1940; Id., 1953; Id., 1969; Id., 1966; Laudau, 1977.

3   See also: Fox, 1996; Id. & Guagnini, 1993; Debru, 1997; Id., 1999.

4   See also: Hessen, 1979, pp. 345-353.

coming from the European Committee about projects[5] aimed at handling with the diffusion of science but, above all, with the encouragement of a renewed interest in scientific education everywhere. Let's think of the so many discoveries, inventions and problematic matters issued by science (e.g. heat machine, electricity, textile machine, the planetary effect of the over-increased population, the decrease of the natural energy resources) that can be though considered *history and culture makers.* As a matter of fact, the *discovery* banally seems re-dimensioned in its scientific value whenever it has not undergone the filter of different approaches and scientific theories, even in conflict to each other, since their foundations; so the evaluation itself of the scientific value of a theory cannot be an absolute one**.** It could seem a paradox but the evaluation very often turns to be adequate only after a historical review and rather far in time from the discovery itself.[6] As a result:

> […] the impossibility of a teaching strategy simply based on definitions, theorems, physical laws under a mathematical shape even if it comes together with laboratory training. Such a kind of science cannot [more] be taught. [In this sense] general conditions are indispensable to the teaching process as well as definitions, demonstrations and laboratory training […] it could be said that the theoretical languages cannot appeal for their build-up and their transformations to the determining role played by observation, neither can they assert their own autonomy from the direct observations. Nowadays a reasonable approach to the teaching methodology is based just on that delicate balance between the two components of the scientific method. (D'Agostino, 2007, p. 15, line 14).[7]

A bibliographical and historical *excursus.* Examples and perspectives.[8]

Technicians and artist-engineers of the 15th century (Gille, 1964)[9] were concerned with scientific matters (*Scientia Activa*) as well as with the current theoretical science (*Scientia Theoretica)*, that is they were able either to plan or to realize tools and fortifications; notwithstanding their basically empirical knowledge, through their work they were given the chance to offer their contribution to the seach for innovative scientific methods,in which the role of mathematics (and history of mathematics)[10] was growing more and more relevant. As a matter of fact, the study of mechanics was being then strongly influenced by mathematical methods. In particular, firm limits were established on that part of Mechanics, the Statics, born of the law of the lever in *Problemata mechanica* or *Quaestiones Mechanicae*) by Aristotelian school.[11] It was possible to employ it in the treatment of the centres of gravity in Archimedes (287-212 B.C.) (Clagett, 1964-1984). It had sprung out from the tradition of the principle of virtual works Aristotelian and Nemorarian-displacements) and from the theory of elementary machinery.[12] It is particularly worth considering the demonstration of the lever by Archimedes. During the Middle Age, the great mathematician did not prove highly attentive as to the indirect impact following his demonstrating techniques, his line of reasoning, as

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5   For a analyses of European situation, please see European Eurydice Project results: 2006. Science Teaching in Schools in Europe. Policies and Research, from: http://www.eurydice.org/portal/page/portal/Eurydice; http://www.observanet.it; other initiatives: http://moro.imss.fi.it:9000/echo/inizio.do; Interesting are the initiatives about history of science, cinema and education: Storia e scienza a Brera e Vedere la Scienza-*Iniziative di diffusione di cultura scientifica mediante film e documentari scientifici* by Pasquale Tucci: http://www.brera.unimi.it/storiaescienza/scuola/index.html. An interesting group of EU Projects is listed in: http://www.imss.firenze.it/istituto/iproeuro.html (e.g. Grid, Pencil et al...).

6   See, e.g., Poincaréian and Kuhnian revolutions and their logical inquiries in their way of conceiving a theory; Cfr.: Poincaré, 1968; Kuhn, 1962. See also: Planck, 1972; Nagel, 1961; Popper, 1972-73; Przelecki, 1969; Feyerabend, 1989; Duhem, 1977; Mach, 1974.

7   Our transl. See also: D'Agostino, 2004a; Id. 2004b; Id., 2005; Lombardo Radice, 1983; Marigliano, 2004, pp. 36-42.

8   The following *excursus* is based on previous works. Recently: Pisano, 2006c, pp. 934-941.

9   See also: Duhem, 1905-06, Tome I, pp. 91-151; Laird, 1986; Drake & Drabkin 1969; Galluzzi, 1970; Clagett, 1959; Id. & Moody, 1960; Clagett & Murdoch, 1958-59; Grant, 1971; Renn, 2000, pp. 25-36; Id., 2002a, pp. 258-279; Id & Schoepflin & Wazeck & Wintergrün, 2002b pp. 4-21; Id., 2003a, pp. 43-59; Id, 2003b.

10 Enriques, 1938; Further on, the first physical science affected by such influence was Renè Descartes (1625-1637) Optics in which any physical law was followed by a mathematical interpretation. Cfr.: Descartes, 1897-1913.

11 Today (for someone) seems still opened the debate. It may be attributed to Strato (about IV century. b.C.), one of Aristotle' pupil (ca. 384-322). Cfr.: Cartelon, 1975.

12   Notoriously the general problem of the medieval mechanics was trying a solution or a reduction of the matter of the six simple machines (since *Problemata* by Aristotelian school): wheel, axle, wedge, scale, lever, inclined plane and screw. One can see: Rogers, 2005, pp. 74-94.

well as the logical organization of his theory, set as a true paradigm. Archimedes is able to grasp two essential aspects of the scientific research: observing and comparing.[13] Archimedes' paradigm proves fundamental for a historical inquiry in the history of the foundations of the   centre of gravity and Torricelli's principle.[14] The great man from Syracuse was the first scientist to fix *rational criteria* for determining centres of gravity. In the first *Book*[15], *On Plane Equilibrium,* Archimedes (Clagett, 1949),[16] further than studying the rules of the Law of the Lever, defines the centre of gravity for the parallelogram, the triangle and the trapezium as well. (Capecchi & Pisano, 2007a).[17] He provides the basic elements by establishing seven hypotheses for the theory of the centre of gravity.[18] According to these hypotheses, Archimedes can cope with the definition of the *rational criteria* or *Propositions.* In order *to* "calculate" the centre of gravity of composed bodies, he starts from the knowledge of the centre of gravity of the single bodies

This way of performing science can help catch an inner intellectual nature of his reasoning process: instead of setting a general theory to deduce some rules, he built a theory based on a specific matter: studying the centre of gravity of a quantity or of two or more compounded quantities and trying to calculate it through the application of rational criteria that he properly uses according to *Reductio ad Absurdum.*

During the Renaissance (Knobloch & Vasoli & Siraisi, 2001, pp. 605-1044)[19] intrigues, homicides and destructions caused by wars were followed by the birth of *pseudo governments* and *democracies* that, though unsteady in some ways, brought somewhat favourable conditions for the image of a re-born individual, once he was able (though not completely) to get rid of the ecclesiastical dogmatism. In such a climate, not so peaceful but culturally proper, the image of the new scientist of the Renaissance, seen as a also scholar of the natural phenomena, emerged; he was seen as a new type of scientist, re-born and re-qualified, not just an interested and clever astrologer and medieval theologian; above all he looked now independent from a hypothetical and *general pre-established design*. However, the reconcilement between the divine plan and the new mathematical truths could converge into an outlined project, still divine under many aspects, considering God as the engineer who had planned a cosmological design in mathematical and geometrical terms. This new mechanist way of conceiving science, particularly physics (but also the raising geometry, mathematics), was still limited to learned and rich people with a cultural background of Latin and Greek (Kolmogorov & Aleksandorv & Lavrent'ev, 1974).

Newton and Newtonianism (Thackray, 1970) introduced a positively new image of Science (a mathematical and mechanistic one) that seems relevant even today, notwithstanding the several variations and revolutions - techniques and technology (Fox, 1996) - undergone by the well as to scientific concepts over the centuries; it still performs a basic role, especially in what the image of the education of physics presently offers; for instance, the convincement that experiment is the only valid learning tool, as well as the interpretation through an advanced level of mathematics, the paradigm of the theoretical deductive structure, the usage, even mathematical, of space and time, the absence of the study of foundations, the test phase, the lack of a deep relationship between physics and logics (Pisano, 2005a; 2006a).[20] This predominance could explain the present minor role (in the educational field, too) performed by thermodynamics and by chemistry unfairly (?) (Metzger, 2002)[21] though we can also wonder about what we mean, today, by "mechanical", a word usually related to terms like "problem", "model", "physical law" (Kragh, 1987)[22] as quantity and magnitude.

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13 Cfr.: Dijksterhuis, 1957; Id. 1961.

14 Torricelli, 1644.

15 In the *Book II,* Archimedes deals with the centre of gravity of the parabola segments.

16 See also: Cfr.: Id., 1964, Vol. I, 116-120; Id., 1981, 50-56; Dijkstrehuis, 1956. 21-33; 286-359. The *Method* is the work of Archimedes who more than anyone defines the basis "for the way to the discovery". Cfr.: Frajese, 1969. pp. 261-296; see also Id. 1964, chapp. IX, X, XII; Heath, 2002, pp. 189-219; Favaro, 1923.

17 See also: Capecchi, Pisano, 2007b.

18 The centre of gravity in Archimedes was referred to bodies which were operatively composed until they became only one, which was given by sum of all the others and for which it was attempted to define the total centre of gravity. In particular the sum of all the components may require the adoption of the method of exhaustion.

19 See also: Pisano & Di Pietrantonio, 2007c, pp. 197-219; Giannetto, 1989, pp. 261-276.

20 See also: Destousches 1948, pp. 411-417; Giles, 1970, Vol. 11, pp. 2139-2151; Id., 1979, Vol. p. 38; pp. 345-353.

21 See also: Pisano, 2006-07; Id., 2006d.

22 See also: Pisano, 2006b, pp. 279-300.

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Table 1.   The different foundations between mechanics and thermodynamics theories[23]

Burning items of the theory	Isaac Newton (1642-1727) Mechanics	Sadi Carnot (1796-1832) Thermodynamics (Carnot, 1978)[24]
Space	Infinite and absolute	Bounded-relational
Time	Absolute	Finite variations
Inertia	As a perpetual	Impossibility of a perpetual motion
Basic-concept	Acceleration	Transformation
Interaction	Force-cause	Work
Mathematical problem	$\vec{F} = m\vec{a}$	dq/t Integration
Issuing techniques	Differential Equations	Cycle
Solutions	All possible motion, from $-\infty$ to $+\infty$	Maximum of efficiency of heat machines

Nowadays the modern physics seems incline to a challenge to clear up the role and the image of new foundations, in its attempt to recover the cultural reference model previously set over two centuries of mechanicism and about 80(?) years (surely in Italy) of almost entirely mechanist education (Fox & Guagnini, 1993).[25] For example, has the Quantum Mechanics, actually, suggested an autonomous explanation of a theory or has it just rejected a too improper past (a not well outlined paradigm, some determinism…) introducing formalism *ad hoc*? Accepting the idea of "quantum" in physics would mean going back to the foundations of the classical science? Furthermore, an attempted but not completed axiomatic formalization of a limited relativity is to be remarked. (Even in the case of the isotropy of space or the propagation law there is a parameter to define…).[26]

Table 2.   Newton' and Lavoisier' chemistry foundations and their incommensurability[27]

Burning items of the theory	(Mechanicist) Newtonian chemistry	Lavoisierian chemistry
Space	Infinite and absolute	Assumed as volume on the whole
Time	Absolute	Assumed as a measure to mark a before and an after; with regard to the rate reactions).
Atom	Infinitesimal part of matter	Plurality of elements.
Fluid	Phlogiston (corporeal)	Caloric (incorporeal).
Mass	Inertial	Gravitational.
Interaction	Force-cause	Reaction and balance.

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23 Adapted by Drago, 1991. See also: Pisano, 2007a, in press; Drago, 2002; Id., 2002; Id., 2003; Id. & Creca, Gatti & De Renzis, 1976; Koyré, 1957.

24 Carnot, 1978, op. cit. For recent historical papers on Carnot' thermodynamics: Drago & Pisano, 2002; Id. 2004; Id. 2005; Pisano, 2001; Id., 2004a; Id., 2005b; Id., 2007b.

25 See also: Knobloch E. 2005. *Mathematical language and mathematical progress* http://halshs.ccsd.cnrs.fr/docs/00/03/54/64/PDF/14%20Knobloch2.pdf

26 These aspects are very well dealt in: Drago, 1991.

27 Adapted by Drago, 1991; See also: Kragh, 1985, pp. 50-67; Id., 1987; Pisano, 2007a, in press.

Burning items of the theory	(Mechanicist) Newtonian chemistry	Lavoisierian chemistry
Problem of the theory	Nature of the matter. Molecular theory: attractive and repulsive forces	Indivisibility *Chemical affinities* theory through the accomplishment of the nomenclature and chemical elements.
Arguing techniques	Differential equations	Arguing *by absurdum* proof and elementary mathematics.
Solutions	Any possible motion, for a given force, from $-\infty$ to $+\infty$	Oxygen's saturation degrees; variation of some acids names endings.

Thus

> *In a hybrid, fluid, limited world, continually and wholly transformed by science and by technology, can we keep on teaching science and avoiding the question about what the image and the cultural origin of the science we teach is?*

Let's give an example. Generally, either the force $\vec{F}$ or acceleration $\vec{a}$, each taken individually, express a physical concept initially (and historically) assumed as able to be experimented, more or less coming from the common knowledge. The second principle, as a matter of fact, does not allow to measure instant by instant neither the force nor the mass; moreover neither in that, nor in the previous law of inertia, a definition of it is set; that is to say, it is necessary first of all to define a force as a physical magnitude subdued to comparisons (therefore measurable) and then to proceed to the study of the consequences it can produce by the action over a body. For example, it could be useful setting when two forces are equal and opposite and how they can be applied and where they action; but then it is necessary to know the trend of the forces over bodies; that is but partially pointed out in the third law.[28] That is, according to Poincaré words, such a way of reasoning only produces a "trompe-l' il" effect. Furthermore, an acceleration measure does not express anything about what kind of object in motion after that acceleration, since from the only acceleration (and without the measure of the mass) of a body we cannot deduce information about the type of force; and we know that to the action of a force does not necessarily correspond a motion. Therefore the second law should not appear (didactically) as an experimental law, though as a mathematical law, that is "définitions déguisées", that is a convention. As a matter of fact, the second law is a second-order differential equation, so not subdued to any experimental test. Thus, after first analyses, it seems that two concepts, individually taken, are not correlated or not completely defined. *How can we then link up or, better say, relate (among them) different measures or the different experimental laws we reach?*

Then

> Comment une loi peut-elle devenir un principe? Elle exprimait un rapport entre deux termes réels *A* et *B*. Mais elle n'était pas rigoureusement vraie, elle n'était qu'approchée. Nous introduisons arbitrairement un terme intermédiaire C plus ou moins fictif et *C* est *par définition* ce qui a avec A exactement la relation exprimée par la loi. (Poincaré, 2003, p. 210, line 8).

Thus, laws should be written the laws (and to learn them) in such a way that the physical magnitudes involved can be put in relation among them. Let's consider, e. g., the following expression:

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28 Let's note that, just through the use of the third law, historian Ernst Mach gave an operative definition of mass not recurring to ideas linked to the concept of matter and space. Cfr.: Mach, 1974, pp. 192-195; pp. 216-222.

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$$a = \frac{k}{b} \qquad (1)$$

In short, by doubling the value of the magnitude b (e. g., given the speed of a cannon ball shot), the magnitude a (e. g., given as the time taken by the ball to fire a determined target) is reduced to the half. Given the value k (that can evidently depend on the type of cannon used), the previous mathematical expression permits, by replacing[29] (e.g.) numerical values to k and b, to calculate a. We can also apply the content of the previous passage also to the second law. We refer to the force $\vec{F}$ with the term A, to the acceleration with the term B and to the mass m with the term C. Hence, we can derive the mathematical relation between the force (A) and the acceleration (B) through the magnitude mass (C).[30] But we can also deduce a more general relation, so more *helpful*, according to which every when we study the dynamic force or the electrical force even in a different field of physics, we can assume as valid the conventional law, e.g., that among those it exists a theoretical "similitude ou plutôt ce parallélisme" (Poincaré, 2003, p. 242, line 11) allowing us to make some esteems and to frame them (in general) within a common interpretation of the forces in the physical sciences; then, in details, we can deduce the particular results for the specific physical field. Let's think, e.g., to the fact that from the generalization of the three Newtonian laws, that is from their regularity, we can reflect upon crucial consequences:[31] does an object falling down, let it alone the air resistance, increase its speed in a directly proportional to the falling time? We must underline, though, that generally not any laws occurs after evident mathematical relations. Let's think of, e.g., the affirmation according to which all the living beings are made out of cells. Surely it expresses regularity (that is a law) which is the ground of bio-medicine, but it is given after a mathematical form.

At the present it seems that the teaching of mathematics and of physics has been going on the ground of a strict criticism according to which, at the secondary high school, it is necessary to teach mainly mathematics and physics by means of experiments and principles, neglecting the possibility that a student could follow just the way round in his learning *process of scientific knowledge*; that is, he could realize that not everything can be built up according to what the formulation of principles reads. This way of conceiving teaching seems to be the heritage of the old, extremely positivist conception of science in general; a kind of science only based upon experimentation and proved facts, or upon self-standing laws, aloof from the cultural context, often even isolated from the teaching plan itself. Such a model of teaching, in a past not too far, has already strongly contributed to a kind of learning too mechanist, based upon strange mnemonic abilities and simple functions; learning strategies coming along with lots of exercises; *as if eating 1000 cakes could make me good at cooking just one!* In addition to all this, a fully reassuring model of mathematics, bringing lots of incontrovertible certainties, clashes a model of reality very often full of uncertainties and contradictions.

We dare ask: how and when that way of conceiving school and teaching originated?

Applying the previous perspective to the 21st century education would make it possible to teach science introducing reflections about relationships, burning for a critical learning style, such as the relationship between geometry (Knobloch, 2005b, pp. 25-76)[32] and physics, logics (Destouches, 1948, pp. 411-417)[33] and physics, chemistry and physics - further than mathematics

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29 Obviously the example implies that the magnitudes involved are really physical and measurable.

30   Please, note that in my interpretation, to the term C, meant as mass, it may be added the instrument used for measuring. This way the relationship between the force and the acceleration is reinforced through an operating tool allowing the measure. It also has to be noticed, though, that the instrument mentioned is a dynamometer so the force measured would not be anymore Newton's dynamic force but the static one, e.g., the force of a mechanical spring. This way, Poincaré' concept of "relation" could be deepened, to extend it further than its mathematical meaning.

31   But it is discussible, too.

32   See also: Knobloch, 2005a; Id. & Rowe, 1994; Høyrup, 1981, pp. 3-14.

33   Upon logics in the history of science: Drago, 1991; Pisano, 2005a; Id., 2006a.

and physics - (Pisano, 2005, 41-58) that the education of physics and mathematics seems not to explore completely yet, though its high acknowledgement of the scientific contents. Anyway, we could argue:

- How is it possible to keep on teaching science - mathematics and physics - being unaware of their origins, cultural reasons and eventual conflicts and values?
- How is it possible teaching and remarking contents and certainties of physics and mathematics as sciences not having first introduced the sensible doubt about the inadequacy and fluidity of such sciences in particular contexts?

Scientific teaching:
an application between English literature and physical science

The following example could be a typical teaching situation in which interdisciplinary approach and strategies converge to sort out the best results in terms of motivation and stimulus to study a scientific subject going back to its historical premises and, at the same time, adhering to its fonts in the original linguistic code. The project was directed to two classes of the scientific Technological secondary school[34] and involved mainly two subjects: Physics and English.

Teaching scientific literature in English is not generally an easy task in our schools. Average students usually find it boring, even useless; an analysis of the problem, supported by years of experience in the field of teaching, led to the conclusion that one of the main obstacles to a growing interest towards the study of science was a dramatic lack of knowledge of the proper semantic codes. Learning science through the history of science, to understand the logical and historical relationship between *causes* and *premises* before than technical *results,* was the first aim of the project and reading documents in their original language to appreciate their content and the authors' aim at the best seemed the right or one of the possible ways to a solution. The search and the use of fonts in order to go back to the fundamentals of science could be attained trough the study of the history and getting, simultaneously, the skills to decode documents while appreciating the authentic meanings through their original connotations. During this experience the pedagogical role of English as a transversal language, according to C.L.I.L. approach (*Content and Language Integrated Learning*) has been underlined. It can evidently contribute to overturn the split up of cultural environments in sectors and guarantee the *circularity* of different languages. Even burning in such a context, is to strengthen students' motivation and involvement through a teaching-learning process according to patterns. For instance:

a. Teachers' effort to a concrete cooperation
b. Teachers' effort to perform a convergence of cultural interests beyond the barriers of departments
c. A shared search for an intellectual complicity to challenge the tradition of a study by sectors
d. Use of a valid interdisciplinary teaching in order to sort out the effect of a *coincidentia oppositorum*, if by *opposites* it is meant the charge to the false dichotomy of the scientific-humanistic knowledge.

Thomas Kuhn (1922-1996) developed interesting reflections upon textbooks to an integral part of a paradigm:

> Inevitably, however, the aim of such books is persuasive and pedagogic; a concept of science drawn from them is no more likely to fit the enterprise that produced them than an image of national culture drawn from a tourist brochure or a language text. (Kuhn, 1962, p. 1, line 9).

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34 ITIS Liceo scientifico tecnologico - "G. Marconi", Latina (Rome, Italy).

[…]. Textbooks, however, being pedagogic vehicles for the perpetuation of normal science, have to be written in whole or in part whenever the language, problem-structure, or standards of normal science change. In short, they have to be rewritten in the aftermath of each scientific revolution, and, once rewritten, they inevitably disguise not only the role but very existence of the revolutions that produced them. (Ivi, p. 137, line 23).

[…] Why dignify what science's best and most persistent efforts have made it possible to discard? The depreciation of historical fact is deeply, and probably functionally, ingrained in the ideology of the scientific profession, the same profession that places the highest of all values upon factual details of other sorts.

Perhaps the most striking feature of scientific education is that, to an extant quite unknown in other creative fields, it is conducted through textbooks, works written especially for students. Until he is ready […] to begin his own dissertation, the student of chemistry, physics, astronomy, geology, or biology is seldom either asked to attempt trial research projects or exposed to the immediate products of research done by others- to, that is, the professional communications that scientists write for their peers. (Kuhn, 1963, pp. 347-369).

The warning is against a kind of knowledge favouring specialization and causing the alienation from culture in a general sense. Nowadays the paradox of a technological, global and holistic society, composed of individuals who either *know* or *can do* is being spread. According to Morin it could be possible to catch

[…] the unity and the complexity of human beings gathering and arranging all the pieces of knowledge scattered in natural sciences, human sciences, in literature and philosophy, […]. [35]

The steps of the organization of the project included a warm-up phase, when students have been stimulated and guided to the training of micro-linguistic vocabulary and to the analysis and reading of texts and documents. The teacher of physics communicated in English. The lessons were held with the aid of slides, commented and illustrated through a linear and concise Anglo-Saxon style.

Finally, the students elaborated information either in written or oral reports. They were involved in debates, arising their curiosity and questioning about the large variety of contents proposed, from the first Heron' mechanical *escamotages* to late Middle Age (opening of a temple and heat production, the birth of machines up to Sadi Carnot' heat machines. The best result of this experience has been the real motivation expressed by students, not to mention their renewed interest for university courses of physics and science.

The role of A.I.F.[36] *Latina division* in our territory proved essential. Obviously in the present situation of our schools (the problematic decrease in scientific vocations is spread all over Europe) we should not neglect the use of technology. When facing problem solving the use of computer applications is a rich resource for enhancing the learning of science. Studies conducted mainly in upper secondary education have shown that appropriate computer simulations offer pupils the opportunity to visualise theoretical models, providing a *cognitive bridge* between theory and practical experience and improving cognitive understanding (De Landsheere, 1974). However, computer simulation though providing a platform for a flexible learning, very often causes a dramatic cut in the search for autonomous study methods and in some cases can originate lack of concentration. Computer technology should never replace the role of coordinating and facilitating the learning process which concerns teachers.

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35 […] l'unità e la complessità dell'essere umano riunendo e organizzando le conoscenze disperse nelle scienze della natura, nelle scienze umane, nella letteratura e nella filosofia […]. Our transl.: Morin. E. (2001). I sette saperi necessari all'educazione del futuro, Raffaello Cortina Editore, 12, line 29.

36 AIF *Association for Physics Teaching* Latina Division: http://www.historyofscience.it For the National AIF: http://www.aif.it

Final remarks

The real motivation expressed by students, not to mention their renewed interest for university courses of physics and science, have proved the best result of this experience. No doubt it was for them an occasion to meet a new model of reading and writing reports about science, of exploiting the foreign language; above all they *started* from the history of science to rise questions and get involved in class debates as well as to search or suggest solutions to problems of physics; it was also an occasion to experiment team work and the positive effect of inter-discipline. For us teachers this experience meant the opportunity of living *optimal* teaching that is teaching as it *should be:* students'- centred, at the same time aimed at arising intellectual complicity and reciprocity between teachers. Thus to create the proper cultural environment for teachers to stimulate their own updating and even the possibility of setting the paradigm of didactic role interchange when working in team. Above all, for both of us, students and teachers, this inter-disciplinary experiment was an important and true step towards integrated learning, which we consider essential in the renewal of pedagogy and didactics in general.

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