TOWARDS HIGH QUALIFICATION FOR SCIENCE EDUCATION. THE LOSS OF CERTAINTY

Dear Readers!

«Revolution in Science Education: Put Physics First».[1]

It is known that teachers and professors at any school and university orders[2] should highly mind education as the first and most general aim of a civil society. It is a fact that many European countries and education centres are reflecting brilliantly upon higher scientific education focusing on physics and mathematics especially. The Institutions also seem to take into account full management autonomy. Accreditation has considered one of the best solutions adopted by central or high-level education authorities to guarantee quality standards in training offered by higher education. It means accrediting education results through a legislative and professional process in order to judge whether an institution or a programme meets proper quality standards. The final authorised award is corresponding qualifications. Particularly, Eurydice[3] is one of the most recent and interesting *EU* analyses. It deals with different levels of education per country and statistical results accomplishing a direct consequence of a different level of economic and cultural state:

> The way in which science is taught in schools depends on many factors related mainly to training received by teachers, and the content of both the school curriculum and standard tests or examinations. Directly or otherwise, these factors influence the content and approaches to science teaching as well as science activities in the classroom.[4]

Since the beginning of the past century, we can amount many studies by education and pedagogy students-side.[5] I focus on teachers because it sounds like the only thing to do: we have the last keys. That is to say, we need to match a new way of conceiving science according to Life on Earth which is in a continuous deterioration which is another fact. Among plenty of strategies used, maybe we should also mind another element that one more educational component should be added to the major and more affordable cultural[6] factor able to overcome hyper-specializations and laying out to support the individuals not giving up the necessary technical competences. In other words, the problem is all rooted around the attitude[7] of the teachers and young people toward science and their relationship with a new school and new scientific-technological teaching. It is a common assumption that school curricula can vary according to different kinds of formation and training depending on Cities and Countries. However, nowadays, a common warning from educational agencies all over Europe is being shared: *the loss of certainty to develop concrete scientific education*. This emergency is witnessed at any level by negative reports from schools, especially in the fields of mathematics, physics and chemistry and up to dramatic

1 Lederman L.M. 2001. *Physics Today*, Vol. 54 (9), 44; Please visit: http://ed.fnal.gov/lsc/
2 Please visit: http://education.illinois.edu and http://www.ed.psu.edu/educ/news/news-items-folder/duschl-waterbury-pr
3 European *Eurydice* Project results: 2006. *Science Teaching in Schools in Europe Policies and Research.* The study covered 30 Eurydice Network member countries available at: http://www.eurydice.org/portal/page/portal/Eurydice; see also an interesting group of *EU* Projects at: http://www.imss.firenze.it/istituto/iproeuro.html (e.g. *Grid*, *Pencil* et al).
4 Eurydice Project 2006. *Science Teaching in Schools in Europe.* 7, line 2, op. cit.
5 Cfr: Drago A., Di Maso A. (1982). L'uso delle tecniche motivazionali nella didattica della matematica. Analisi del Progetto Nuffield. Mathesis: L'insegnamento della matematica: problemi e prospettive Lucani (ed.), Roma, 250-263; Dewey, J. 1938. *Experience and Education*. New York, Macmillan; *Id*, 1916. *Democracy and Education: An Introduction to the Philosophy of Education*, New York, Macmillan; Bruner, J.S. 1971. *The Relevance of Education*, New York: Norton; *Id.,* 1996. *The Culture of Education*, Cambridge, Mass., Harvard University Press; Osborne R.J., Wittrock M.C., 1983. "Learning *science*: A generative process", *Science Education*, 67 (4), 489-508.
6 Dewey, J. 1940. *Freedom and Culture*, London, Allen & Unwin.
7 Osborne J.S, Collins, S. 2003. "Attitudes towards science: a review of the literature and its implications", in *International Journal of Science Education*, 25 (9), 1049-1079.

cut in the registration to university departments of mathematical and physical sciences. For example, applications to the faculties of sciences have dramatically decreased; same as a high percentage of temporary teachers and university researchers. A debate on the matter seems necessary from an ethic and professional point of view[8] , e.g. *what kind of scientific cultural background does it take to teach how science works?* Then, these aspects move towards a larger base of analysis which includes not only disciplinary matters but also psychology, sociology and epistemology. It is remarked that teachers regularly find crucial difficulty to teach historical, sociological, and philosophical knowledge about science in ways that their students find meaningful and motivating. It is unthinkable to learn and understand the scientific sense of a subject without deepening its intellectual and cultural background, i.e. its history and foundations. The other questions are: *how is it possible to keep on teaching sciences being unaware of their origins, cultural reasons and eventual conflicts and values? How is it possible teaching and remarking the 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?* Education needs to revaluate scientific reasoning as an integral part of human culture that could build up an autonomous scientific cultural trend in schools. *In this sense, what about the importance of introducing the history of science as an integral part of the culture of teaching education*[9] *to the extent of considering such a discipline – in its turn - as an indissoluble pedagogical element of history and culture?* 'To foresee the future of mathematics, the true method is to study its history and present state'.[10] We know this is not the only option, however cultural training is necessary for what concerns mathematics and physics. It would be moves toward particular attention to the elaboration of the *teaching-learning* process sprung out from reality observed by students (inductively) by a continuing critical[11] reflection, e.g. by means of studying the history foundations of modern physical and mathematical[12] sciences. Therefore, turning from *teaching based on principles* to *teaching (also) based on large and cultural themes*[13] would be crucial. It would mean teaching scientific education as well which is a kind of education setting *problems* and for what physics is concerned, introducing it through the historical and philosophical criticism too. It would be helpful to practically support processes cantered on a multidiscipline or even on cooperation, a kind of didactics able to re-considering, from this point of view, the relationship between theory and experience, history and foundations. Let's think about (1) lack of relationship between physics and logics, (2) when we use the term *mechanical* associated to problem, model, law et al... Rather one should also assume the logical organization of scientific theory (axiomatical or problematical) and its pedagogical aspect based on planned and calculated processes. People do not naturally and scientifically reason by means of deductive or inductive processes, only. Insofar, scientific reasoning is not a part of our common knowledge reasoning, although we often intuitively compare events, tables etc. Rather they reason mainly by the association of ideas and concepts that are very far from the scientific ones, e.g. heat and temperature, mass, weight and force-weighs, the solar system and atom orbital system in quantum mechanics, the kinetic model of gases and thermodynamics, parallel straight, material point et al. Thus, the present scientific teaching system paradoxally changes the logic basis of reasoning.

A few years ago, the teachers of mathematics and physics started developing an increased interest

8 Cfr: Debru C. 1997. "On the Usefulness of the History of Science for Scientific Education", *Notes and Records of the Royal Society of London*, Vol. 51, No. 2, 291-307; *Id*., 1999. *History of Science and Technology in Education Training in Europe*, by Claude Debru (ed.), Luxembourg, *Office for Official Publications of the European Communities, European Commission, Euroscientia Conferences*; Osborne J.S., Collins S. 2001. Pupils' views of the role and value of the science curriculum: a focus-group study. *International Journal of Science Education*. Vol. 23 (5), 441-467**.**

9 Pisano R., Guerriero A. 2008. "The history of science and scientific education. Problems and perspectives", in *Problems of education in the 21st century – Recent Issues in Education*, 145-158.

10 Julius-Henri Poincaré (1854-19121) quoted in: Klein, M. 1980. *Mathematics. The loss of certainty*, Oxford University Press, 3; *Id*. 1972. *Mathematical Thought From Ancient to Modern Times*, Oxford University Press. Poincaré, J.-H. 1968. *La Science et l'Hypothèse* Flammarion, Paris.

11 Jammer M. 1954. *Concepts of Space: The History of Theories of Space in Physics*, Harvard University Press; *Id*., 1957. *Concepts of Force: A Study in the Foundations of Dynamics*, Harvard University Press; *Id*., 1961, *Concepts of Mass in Classical and Modern Physics*, Harvard University Press; *Id*., 1999, *Concepts of Mass in Contemporary Physics and Philosophy*, Princeton University Press; *Id.,* 2006. *Concepts of Simultaneity: From Antiquity to Einstein and Beyond*, Hopkins University Press.

12 Knobloch E., Rowe D.E. (eds). 1994. *The history of modern mathematics*, vol. III: *Images, ideas, and communities*, Academic Press; Kragh H. 1987. *An Introduction to the Historiography of Science*, Cambridge University Press.

13 Dewey J. 1903. *Studies in Logical Theory,* [by Dewey and others], University of Chicago Press.

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in a kind of education including (e.g.) the history of mathematics and physics, though the result is still a minor one, considered the lack of the deepest intellectual and cultural approach to historical search, that is, a critical reflection about the history of foundations for mathematics and physics. This would permit a deeper consideration about the great themes of paradigms and revolutions in science. Thus, so many attempts that should try to break out and make criticism on usual search for that epistemological-pedagogical paradigm produced the reverse effect: a well-rooted and wide spread pain and fear among teachers to face a foundational and radical change; this suggests a kind of silent agreement not to make historical or educational hypothesis or to deal with new topics. As a consequence, debate on pedagogical and epistemological problems looks re-dimensioned and under-evaluated compared to the attention paid to only a few matters considered crucial. Certainly, it is remarkable that the historical approach should be not only an uncomfortable and out of fashion hat used only to introduce a hard subject. E.g. let's think about an introduction to mathematical and physical concepts based on historical facts. As a result, everybody knows that students find difficult to grasp the connection between techniques used to explain linear equations in mathematics and when they apply them in physics. A similar situation is the illustration of a literary work of art when students are requested to set it in a cultural, social and historical background to improve its main themes and meaning. Therefore, it could be possible to go beyond the limit of the mechanist teaching providing students with the belief that mathematical and physical sciences sprang out from nowhere, from a sudden flash or even that, given some laws, some thesis can be logically deduced.[14] Thus, it may happen that brilliant students get their degree being convinced that '[...] celebrated apple tree the fall of the one of apples of which is said to have turned the attention of Newton to the subject of gravity was destroyed by mind […]'[15] and not also from intellectual perseverance and from his/her religious and bigot convincement to build up a scientific program able to interpret any phenomena, either celestial or terrestrial, through a mathematical law the application of which caused the birth of a highly unsteady universe. A proposal, of course not the only one possible, could be the introduction within the educational plan of reading passages *ad hoc* centred on mathematics and physics to be analysed in the classroom, primary books by Aristotle[16] (384-322 B.C.), Euclid[17] (ca. 300 A.C), Archimedes (287-212 B.C.), Niccolò Tartaglia [18](1499-1557), Galileo Galilei[19] (1564-1642), Evangelista Torricelli[20] (1608-1647), Sadi Nicolas Léonard Carnot[21] (1796-1832) et al.. Such reading passages, together with pre-arranged and efficacious work shared by several subjects allow not only dealing with usual scientific contents but also giving the possibility of analysing the linguistic model setting the author in his/her historical and philosophical context, thus producing well arranged didactics based on large themes naturally leading to scientific education. This way some useful reflections on the basic role played by mathematics, physics and science in general in everyone's life could spring out. Through an educational offer enriched with the study of the foundations of physical and mathematical sciences completed with the intelligent usage of didactic computing technologies, a kind of teaching might be accomplished with the model of the prevailing teaching-learning process mainly related to and coming from reality. It would be an attempt necessary to show how paths usually chosen have not been unique in the history of science but very often an alternative way has existed, for example Jordanus de Nemore (ca. XIII century) and Tartaglia statics, Newtonian and Antoine-Laurent

14 Pisano R. 2005. "It is possible to teach the plurality of logics? [Into Italian], *Periodico di Matematiche,* (1), 41-58.

15 McKie D., de Beer G.R. 1951. **"**Newton's Apple", *Notes and Records of the Royal Society of London*, Vol. 9, (1), 46, line 17.

16 E.g.: Aristotle 1963. *Mechanical Problems*, *minor works*, Oxford, Oxford University Press.

17 Euclide 1952. *De ponderoso et levi*, in Clagett M., Moody E. A. 1952. *Medieval science of weights*, Madison, University of Wisconsin press.

18 E.g.: Tartaglia N. 1554. *Quesiti et inventioni diverse de Nicolo Tartaglia brisciano*, (1^ ed. 1546), see: *Libro I-VI-VII-VIII-IX*, by Masotti A., Brescia, printed 1959.

19 E.g.: Galilei G. 1890-1909. *Opere di Galileo Galilei*, ed. Nazionale by Favaro A., Firenze. Pisano R. 2009. "Continuity and discontinuity. On method in Leonardo da Vinci' mechanics", in *Organon*, in press.

20 E.g.: Torricelli E. 1644. *Opera geometrica*, Massa-Landi (ed.), Firenze. Please see: "De motu gravium naturaliter dscendetium"; Capecchi D., Pisano R. 2007. "La teoria dei baricentri di Torricelli come fondamento della statica", *Physis International Journal of history of science,* Vol. XLIV, (1), 1-29.

21 Carnot S. 1978. *Réflexions sur la Puissance Motrice du Feu sur les machinés propre à développer cette puissance*, édition critique par Fox Robert, Paris, Vrin J, (ed.).

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de Lavoisier (1743-1794) physics-chemistry[22], mechanics by Lazare-Nicolas-Marguerite Carnot[23] (1753-1823) et al.... In details: second Newtonian principle is not strictly a physical law and it has just a little in common with physical laws by Galilei rather than showing that the historical foundations of thermodynamics are based on five[24] principles, more than the classical ones read in a textbook.[25] In other words: 1) *the student is placed before a problematic situation and driven to realise the inadequacy of his/her basic knowledge with regards to problem solving.* 2) *When the build up of scientific education is started up, in order to overcome such difficulties.* The result will be didactics according to which science education essentially means *setting and solving problems* and teaching then, re-evaluating the relationship between theory and experience and between history and foundations. I ought to teach something but not anything about. They could come together with well-structured and practical interdisciplinary work by means of the history of science. And

> […] multiplication of interfaces between the history of science and what (for want an ideal term) I class as more 'social' or 'cultural' approaches to the study of the past. The bridge to interdisciplinary styles exemplified in the history of book, the history of collecting and taste, and the history of conservation has greatly enriched our discipline […].[26]

International debate should care about pedagogical research on foundations for history and learning-teaching science discovering as well as how science-teaching and informal-learning activities. In this way, a student is *protagonist* both formal and non-formal (*hands-on*) of his *learning*. From this point of view, an integration between science-exhibit[27] and natural phenomena is desiderable. This vision of learning that we could define as experiential forces, the construction of contrivances, *ad hoc* conceived to show unique phenomena directly controllable by the educational actor. These contrivances are usually called *hands-on* because physical variables that characterize the observed phenomena can be perceived. Interaction encourages exploration that can be considered as having fun with toys; and it is a possible basis of a modern technique of acquiring interdisciplinary information. Therefore, the use of exhibits not only gets very well into the operative mentality of time we are living in but it also distinguishes itself in the comprehensive view of educational technologies and of the propagation of scientific knowledge and an example of innovation on the equipment of the past. However, it is necessary to intend teaching toward *scientific education* which discovers the use of mathematics and physics by hands and reflects through historical criticism and philosophical close examination concretely favouring multidisciplinary teaching based on large themes and problems. It is necessary a new attitude toward scientific education and possibility of studying different formulations of the same theory. We could contribute to improve the interest in the study of mathematics and physics even through historical criticism and a widen philosophical knowledge. Therefore, scientific education re-evaluating teaching mathematical and physical science as an integrant part of human culture might be able to build up an autonomous scientific culture in schools where critical reflection about science and not a mere celebration of academic scientific results is prevailing. Furthermore, the teaching process ought to be student-centred and not built as it often happens on in-practicable institutional programs. Students should feel the main characters at school enabled to catch the opportunities that school can offer. I think the same about schools training experts as these also should provide ground favouring teaching research aiming

22 Thackray A. 1970. *Atoms and Powers. An Essay on Newtonian Matter and the development of Chemistry*, Harvard University Press (ed.).

23 Carnot L. 1803. *Principes fondamentaux de l'équilibre et du mouvement*, Deterville, Paris; *Id*., 1813. *Réflexions sur la metaphysique du calcul infinitésimal*, Courcier, Paris; Gillispie C.C. 1971. *Lazare Carnot Savant,* Princeton U.P., Princeton, 90-100; *Id*., 1976. "The scientific work of Lazare Carnot and its influence on that his son", in Taton A. (ed.) 1976. *S. Carnot et l'éssor de la thérmodynamique,* CNRS, Paris, 23-32.

24 Pisano R. 2008 "On Principles In Sadi Carnot's Theory (1824). An Epistemological Inquiry", submitted to *Centaurus* ID: CNT-OA-Jul-08-0038.

25 Please see the textbooks discourse in: Kuhn S.T. 1962. *The Structure of Scientific Revolutions*, Univ. of Chicago Press, 137-138; Feyerabend P. 1989. *Against Method*, Verso Books Paperback, Humanities Press, 21-35;

26 Fox R. 2006. "Fashioning the discipline: history of science in the European intellectual tradition", *Minerva*, 411, line 25. (The brackets are original by the author).

27 On exhibits: http://www.exploratorium.edu/ (USA).

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at the critical re-built of scientific meanings coming along with ideas, opinions and proper contents.

In the end, this fast proposed reflection, announces that it is urgent to set the bases for a debate that ethically appears rightful and professionally necessary. Maybe, operating by means different way, we could also contribute to build a school linked to the new perspectives of science, its image and teaching without limitations on specializations pushing itself over disciplinary competences. Well, a provocative hypothesis: *generally speaking, we should not lose the certainty of a critical thought on science... but if we do not do anything, then nothing changes... but if we do something (few crucial things), something could be improved.*

> « The loss of truth, the constantly increasing complexity of mathematics and science, and the uncertainty about which approach to mathematics is secure have caused most mathematicians [and scientist] to abandon science. With the "plague on all your horses" they have retreated to specialities in areas of mathematics [and science] where the methods of proof seem to be safe. They also find problems concocted by human more appealing and manageable than those posed by nature. The crises and conflicts over what sound mathematics is have discouraged the application of mathematical methodology to many areas of our culture such as philosophy, political science, ethics, and aesthetics. The hope of finding objective, infallible laws and standards has faded. The Age of Reason is gone.
>
> With the loss of truth, man lost his intellectual center, his frame of reference, the established authority for all thought. The "pride of human reason" suffered a fall which brought down with it the house of truth. The lesson of history is that our firmest convictions are not to be asserted dogmatically; in fact they should be most suspect; they mark not our conquest but our limitations and our bounds. »[28]

A revolution in science education? Put a professional teacher first: teachers that teach, research and publish... and let's help this virus spread contagion.

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28 Klein M. 1980. *Mathematics. The loss of certainty*, Oxford University Press, 7, line 12; 99, line 14. The quotation belong to the author.