Innovative Methods for Science Education: History of Science, ICT and Inquiry Based Science Teaching

Olivier Bruneau / Pere Grapí / Peter Heering / Sylvain Laubé / Maria-Rosa Massa-Esteve / Thomas de Vittori (eds.)

Frank & Timme

Verlag für wissenschaftliche Literatur

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Preface

The project of this collective book results of several meetings since 2006 between European historians of science and technology. Regularly, both at national[1] and international[2] level, the six editors and most of the authors present in this publication organized symposia inside conferences about the role of history of science and technology in science education and teacher training.

In 2008-2010, the French group participated to the FP7 European group named "Mind The Gap" and the research time was ended in Brest, France, by a European Workshop entitled "Workshop "Mind the Gap" History of Science and Technology (HST): ICT Resources and Methods for Inquiry Based Science Teaching (IBST)"[3]. After the final dinner, we decided to publish a book in order to propose a "state of the art" that would point out the research activities that we leaded in France, Germany and Spain, in the domain.

We would like to underline in this preface two important facts that condition sustainably the research about HST and Education in future:

- The development of educational tools based on website, digital documents, collaborative work constitutes certainly a breaking point concerning teaching methods based on ICT as well the new interfaces between human being and machine (computer, mobile phone, enhanced reality, virtual world, etc.). A direct consequence is that new research problems in this area are strongly interdisciplinary and that mean collaborations with computer scientists.
- IBST is clearly a problem-based learning method which is considered at the European level as a good way in order to make more efficient the science education, to interest young people and to promote scientific culture in the society. History of science and technology con-

stitutes a very large "landscape" where to find examples to be used or adapted for IBST, but we would like to insist that it is important for the teacher, the teacher trainer (and of course the student) to keep safe the "gender" of HST when educational tools are designed.

Thus, the two objectives of the book are:

1. to enlighten and to discuss different research problems concerning HST and ICT, HST and IBST, HST and science education. In this way, it is dedicated to scholars.
2. to offer teacher and teacher trainer different ways to explore history of science and technology by using digital resources on-line, using new teaching method and to become more familiar with the method in HST.

The book is organized in three parts. The first one is a general approach proposed by the six editors. All the texts are based on the results of their research on HST and science education. In opening of this part, Laubé & Bruneau question the definition of a true inquiry based teaching and discuss the interest of "authentic" historical problems in science teaching. The development of new resources is one of the aspects explored by the following authors. In his text, Heering gives numerous examples on the early history of electromagnetism and raises important question about visual materials for physics teachers. In the same field, Grapí renders an account the building of an online course on history of science for in-service teachers and enlightens the potentialities of such a resource. In the field of mathematics, the contribution of Massa analyses the use of original sources in the classroom and the issues of teacher training in history of mathematics. The first part is ended by de Vittori's text in which the new didactical questions raised by the involvement of history in inquiry based classroom activities are examined.

The second part is dedicated to IBST and ICT design. In her text, Lawrence relates a work with original sources from the history of mathematics involving the video conferencing between different schools. The issues for teacher development and collaborative learning and teaching and the role the history of mathematics can play in this context is examined. This link between history of sciences and new technology is analyzed in the second text where Bruneau, Laubé & de Vittori render an account a large European project specifically on this topic. Then, Ferriére shows how the use of online resources in history of biology raises deep ethical questions, especially in a work on controversies. The last two texts of this second part of the book are from computer science specialists. Thus, with the light of this new field, Gilliot, Pham-Nguyen, Garlatti, Rebai & Laubé, explain how an inquiry based learning are fruitful for semantic web analyses. As for Kanellos, his contribution discusses the concept of accessibility to technical, scientific and generally cultural resources from a hermeneutical point of view. Let us know that henceforth, all the contributors of these last four papers are engaged in common research program on semantic web.

Varia papers constitute the third part. How can the history and philosophy of science be helpful in teaching the concept of energy? This question is the main entry point of Bächtold & Guedj's text in which they present the way they consider the connection between these two fields. All over Europe, the curricula are changing and mathematics education involves more and more history. Many ideas from the Catalonian situation are given by Guevara, and the case of Lithuania is very well described by Cibulskaite. History of science offers many resources and topics for those who want to introduce this perspective in science teaching. New examples are given in physics by Le Gars and in the rich text about Chinese mathematics by Puig-Pla. History of probabilities and its interest in teaching is the main topic of Romero Vallhonesta's contribution. Finally, as it is impossible to speak about new technology without mentioning Internet. Sucarrats & Camós explore how it can be considered as an interesting pedagogical tool for an historical approach in science teaching.

We would like to thank the international relations department of the Université d'Artois (France) for its financial support and all the persons or institutions that have made this project possible.

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[1] for example, in Spain, a yearly colloquium is organized in November by the Catalan Society for the History of Science in Barcelona (see http://schct.iec.cat/) ; in France, several symposia were proposed by the ReForEHST group in the conferences of the French Society for the History os Science and Technology (see http://www.sfhst.org/) or in different University Institutes for Teacher Training (named IUFM) (see http://plates-formes.iufm.fr/ehst/rubrique.php3?id_rubrique=3)

[2] for example, see the website of the European Society for History of Science (see http://www.eshs.org/index.php?option=com_content&view=category&id=5&Itemid=81), the 11th Conference of the International History, Philosophy and Science Teaching Group (http://ihpst2011.eled.auth.gr/) or International Conference for the History of Science in Science Education (http://ichsse.ipcd.de/)

[3] see http://pahst.bretagne.iufm.fr/?p=84

PART I

Inquiry Based Science Teaching and History of Science

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ABSTRACT: Inquiry Based Science Teaching can be considered as open "authentic" problem based learning in science. We will discuss in this paper the interest to study historical (and "authentic") problems in science in order to characterize a typology of problems to propose to the students. Some examples extracted from a paper review are proposed to illustrate our point of view.

Introduction

The *Centre Francois Viète (EA 1161)* in Brest (France) develops research works in the pluridisciplinar field of History of Science and Technology (HST), Heritage, Information and Communication based Technology (ICT), and also, in science education about the use of HST for Inquiry Based Science Teaching (IBST) and ICT tools for cultural mediation in science[1]. *Education* is taken here in the widest sense and concerns the place where knowledge in science is disseminated:

1) teaching and teacher training;
2) science and cultural mediation (museum, archives center, CCSTI[2], etc.).

In 2008-2010, our group (named *PaHST*) participated to the FP7 project "Mind the Gap" (n° 217725)[3] by producing a research report intitled "HST, ICT and IBST" (Laubé *et al*[4]*)* and organizing a European workshop *« History of Science and Technology: Resources and methods for Inquiry Based Science Teaching (IBST) »,* in *Brest, March 18th and 19th 2010.*

This paper will summarize the principal elements of this report concerning IBST and HST. It is related to three others papers in this book that will develop the part concerning the role of ICT to develop HST resources for IBST: Bruneau *et al*, Gilliot *et al* and Kanellos.

Inquiry Based Science Teaching and History of Science

At the European level, the lack of students interest in science or in the scientific careers has led to a call for research projects in science education (the FP7 "Science in Society" program) and the publication of the Rocard Report about Science Education[5]. These recommendations promoted an evolution of teaching methods toward Inquiry Based Science Teaching (IBST) and requested some international comparisons.
In the FP7 "Mind The Gap" project, Inquiry Based Science Teaching was characterized by activities that pay attention to engaging students in:

- authentic and problem based learning activities where there may not be a correct answer
- a certain amount of experimental procedures, experiments and "hands on" activities, including searching for information
- self regulated learning sequences where student autonomy is emphasized
- discursive argumentation and communication with peers ("talking science")

Many of articles in Science Education Literature that we examined refer to the definition proposed by Linn *et al.*[6]: *"we define inquiry as engaging students in the intentional process of diagnosing problems, critiquing experiments, distinguishing alternatives, planning investigations, revising views, researching conjectures, searching for information, constructing models, debating with peers, communicating for diverse audiences, and forming coherent arguments"*.
Abd-el-Khalick *et al.*[7] summarized the results of a international symposium where two kind of inquiry appeared:

- *"Inquiry as means (or inquiry in science) refers to inquiry as an instructional approach intended to help students develop understandings of science content (i.e., content serves as an end or instructional outcome)"*

- *"Inquiry as ends (or inquiry about science) refers to inquiry as an instructional outcome: Students learn to do inquiry in the context of science content and develop epistemological understandings about NOS and the development of scientific knowledge, as well as relevant inquiry skills (e.g., identifying problems, generating research questions, designing and conducting investigations, and formulating, communicating, and defending hypotheses, models, and explanations).*[8]

Several descriptors were chosen to characterize the role of inquiry in science education: "These include scientific processes; scientific method; experimental approach; problem solving; conceiving problems, formulating hypotheses, designing experiments, gathering and analyzing data, and drawing conclusions; deriving conceptual understandings; examining the limitations of scientific explanations; methodological strategies; knowledge as "temporary truths;" practical work; finding and exploring questions; independent thinking; creative inventing abilities; and hands-on activities"[9]. Furthermore, the authors specified that: "This set of descriptors also focuses our attention on the need to distinguish within our curricula what it is we wish to be the goals of science education (e.g., content, process, NOS) and how an inquiry approach to science education can (or cannot) help achieve these goals"[10].

In the FP7 "Mind The Gap" Project, we pointed out that an historical approach of "authentic" problems in science is helpful to characterize what is Inquiry in Science and what kind of problems have to be solved. From the studies about scientific theories, concepts creation, and the way how experiments are elaborated and analyzed, historians of science showed that science does not only consist in final results: the processes take also an important part of knowledge elaboration, like scholars hesitations between two, or more, models, how scientists create experiments, collect data, discuss the results, etc. In each field of science (mathematics, physics, biology and Earth science), history of science gives interesting and authentic examples that show the complexity and the richness of knowledge construction. There is no doubt that these historical data are useful to describe and analyze the investigation process. Inquiry Based Science Teaching has to be aware of this, as it underlines its own main concepts. The FP7 research report was based on examples in mathematics, biology and physics. We will here illustrate the methods by focusing about the Galileo's works that constitute a set of suitable examples in order to show what inquiry is in authentic and historical scientific situations.

Galileo's works as an example of authentic scientific inquiry

Galileo showed a remarkably appreciation for the proper relationship between mathematics, theoretical physics, and experimental physics. *Sidereus Nuncius*[11] is thus an authentic and historical example that allows *inquiry in science* to be understood. *Sidereus Nuncius* is a short treatise published in Latin in March 1610. It was the first scientific treatise based on observations made through a telescope. It contains the results of Galileo's early observations of the Moon, the stars, and the moons of Jupiter. It gives arguments against the Aristotelian "Weltanschauung" and in favour of the Copernican view where the Sun is in centre of the world. Galileo received in 1609 a report concerning a telescope constructed by a Dutchman and decide "*to inquire into the principle of the telescope*". He succeeded in constructing an instrument so good that the objects appeared magnified thirty times nearer. He explained the method to construct the telescope, some elements about the theory and physical principles and the way to use it. Concerning the moon, Galileo observed that the darker part makes it appear covered with spots. He draws several sketches in order to describe the observations. In the last portion of Sidereus Nuncius, Galileo reported the observation (made between January 7th and March 2nd 1610) of the motion of four stars that appeared to form a straight line of stars near Jupiter with illustrations of the relative positions of Jupiter and the stars.

The discovery of spots on the moon surface and of the fours stars moving near Jupiter constitute two problems that was not solved inside the Aristotelian theory. Hypothesis and models were stated in order to explain what

he observed. About the Moon, Galileo explains that the darker regions are low-lying areas and brighter regions are covered with mountains. From this hypothesis, he calculated that the lunar mountains were at least four Italian miles in height: "*We are therefore left to conclude that it is clear that the prominences of the Moon are loftier than those of the Earth*". About the four stars near Jupiter, he shows that the movement doesn't belong to Jupiter (as it was first believed), but to the stars (named then Medicean Planets). "*It can be a matter of doubt to no one that they perform their revolutions about this planet, while at the same time they all accomplish together orbits of twelve years' length about the centre of the world. […] the revolutions of the satellites which describe the smallest circles round Jupiter are the most rapid*". The Jupiter system with his four Medicean Planets appear here as a Kepler's model.
Galileo is Copernican and all his discoveries are used as "arguments" against Aristotelians and "*remove the scruples of those who can tolerate the revolution of the planets round the Sun in the Copernican system, yet are so disturbed by the motion of one Moon about the Earth, while both accomplish an orbit of a year's length about the Sun, that they consider that this theory of the constitution of the universe must be upset as impossible ; for now we have not one planet only revolving about another, while both traverse a vast orbit about the Sun, but our sense of sight presents to us four satellites circling about Jupiter, like the Moon about the Earth, while the whole system travels over a mighty orbit about the Sun in the space of twelve years.*"

The Sidereal Messenger, is totally included in the context of the controversy between Aristotelians and Copernicans. What is inquiry in the Sidereal Messenger? We can see three types of problems. First, the technological questions are linked to scientific instruments. How to construct an instrument? What theory is used to explain it? How to use it? Second, the enigma has to be well posed and to be solved by explanatory models. But modelling requires collecting data (observations, measurements, etc.) in order to obtain reference data as input for the construction/discussion of the model. Those reference data are reports, sketches, tables, numerical data, etc. Third, these enigmas are included in a larger theoretical controversy and the constructed models are participating here to a debate that will lead to the "Copernican Revolution".

This example shows that history of science could good furnish material or references for an "authentic" inquiry-based learning in science and technology. Each point can be regarded as *problem solving situations* and for this side of the scientific activity the history cannot be ignored.

As result of the FP7 research, we proposed then to consider IBST as Open Problem Based Science Teaching (in a set of activities where student autonomy is emphasized) about: 1) collecting data 2) stating hypothesis, 3) testing hypothesis, 4) experimentation/hands on, 5) modelling, 6) results evaluation, 7) argumentative communication, 8) scientific language.

A review to illustrate HST/IBST activities as Open Problems

From a paper review on the topic "HST and IBST", we selected some papers in order to give concrete examples.

Collecting Data

Dolphin[12] explains that collecting data is an important moment in IBST – first for the teacher who has to review good resources - when we are looking for a theoretical explanation and a dynamic model (here the tectonic model of earth). So, the author collects – with his pupils - data in the past (historical representation of the earth: historical texts, textbooks, patterns, maps…), data in his classroom (or maybe in museum and environment for fossils, rocks, photos…) and first visual representations of his pupils. This example is a global approach of investigation in science that integrates historical and epistemological approach in the same time.

P. Clément[13] talks about collecting different kind of cells in different times (and method of collecting from and coloring cells of plants and animals), about some instruments (optic and electron microscopes), about different ways to present (in museum, in university and school), to show, describe and symbolize (photos, texts, draws, patterns) and their consequences for understanding other phenomenon (like cellular differentiation or epithelial level of organization in an animal organism).

P. Mihas[14] establishes an account of some experiments which come from history to develop ideas on refraction. One of them starts with the editing of data with the Ptolemy's method and he notices that "*Ptolemy's Refraction experiment results can be compared with students' results. This can be done by asking students to plot their results with Ptolemy's results in Excel and try to find a relation between the angles. (…) This exercise helped students appreciate the value of planning for an experiment.* »[15]

Thus, a great diversity of data can be mobilized via historical IBST, and there are not only texts but also maps, photos, fossils, etc.

Stating hypothesis

From Ptolemy's and their proper data collection, Mihas' pupils compare their and propose a refraction law (the Ptolemy's law): "These results were presented to the students to compare with their own results. The students recognized easily the implied relation. The students also questioned the results. The author asked the students to tabulate their own results and to compare with Ptolemy's."[16]

Testing hypothesis

Students test hypothesis in order to validate, to reject or to amend this one. Testing induces a critical reflection and allows that some different hypotheses are possible. Former hypothesis depend on the finiteness of knowledge of students like historical scientist: "mathematicians" inadequate knowledge about the convergence of infinite series in the 17th and 18th century was also brought up in the class. One of the assignments was to sum up the divergent infinite series "1 + 1 - 1 + 1 - 1 + 1 …" *wherein students were given three contradictory but seemingly reasonable answers in history and asked to select the correct one. This episode reflected the unsound foundation of calculus at that time and the* *potential fallibility of superficial intuition.*"[17]. Rudge and Howe notice also the importance to test reflection: "*At this time, the instructor encourages students to discuss their answers to questions about nature of science issues that were given to them on the slip of paper during their group work. (…) The first probe invites students to indirectly consider what is commonly referred to as the subjective (theory-laden) nature of science. A conception that it often held by students is associated with a naïve-inductivist perspective, which holds that students believe scientists inevitably all come to similar conclusions when examining the same data.*"[18] The example developed by Dolphin is also very attractive because he states and tests (with his pupils) different "essential questions" ("*Questions that are not answerable with finality in a brief sentence but are used to stimulate tought, to provoke inquiry, and to spark more questions*"[19]) then some hypothesis. They are about the structure, composition, temperature, history and dynamism of Earth. But, in the same time, he does not explain why several models of earth have been proposed by scientists in different time: why several hypothesis have been well considered and some other have been immediately forgotten for different reasons (like pragmatics or empirics reasons: observations by miners by example, but we could also talk about the belief of the existence of Hell in the middle of Earth to explain the models with fire or "lavas ocean" under our feet…).

Experimentation/ hands on

In the IBST activity, the central point is experimentation. In our literature review, this part is present and relatively well explained. The Dolphin's work is also a good example in our case: his students have to build some model scale to understand the different point of view in history of Geology (to know the age, the structure and the dynamism model of Earth). In this case, there is a real hands-on experimentation with lot of sort of things that are chosen by professor: sponges, balloon, paper (so the autonomy of students – point 8 – is not so bigger than we could believe at the beginning)… In others cases, the selected investigation is more a "literature search" than the rest. But, it is also a particularity of HOS to permit to select a kind of investigation especially when replications of experimentation are impossible (for many reasons as ethic reason or the expensive cost of a replication...) or in the case of mathematics, the main source is a written one. For instance, Liu explains how pupils experiment many ways of demonstration: "*instead of introducing limited concepts at the outset, students were asked to prove or explain the area of a circle is [proportional to] r^2 by using basic mathematics at the middle-school level, followed by the introduction of historical approaches used by Archimedes, Japanese mathematician Seki Kowa, and ancient Chinese mathematician Liu Hui. This problem-solving activity aimed to increase students' experiences and understanding of infinitely partitioning processes and the sum of infinite vanishing quantities.*"[20].

One can find in history of science a lot of kind of experiments and some of them can be reproduced relatively easily in classrooms. For instance, Riess *et al.* reproduce the Galileo's inclined plane experiments: "*One of the best known experiments with respect to the discussion of free fall is the inclined plane experiment that was published by Galileo Galilei in 1638. This experiment has been analysed by the Oldenburg group with the replication method. Currently, we are working on teaching material that will give access to our experiences with this set-up for teachers and students. Moreover, we are reconstructing a demonstration apparatus developed in the 18th century to teach free fall and the superposition principle. Historically contextualised, this experiments.*"[21]

Modelling

Dolphin is convinced that modelling and discussing about modelling is a central part and allow pupils to develop critical views about science: "*An important part of the contextualized approach is the use, discussion, and critique of models. Models play an important role in teaching science content and teaching about the nature of science. (…) One major challenge was taking concepts which represent some of the major discoveries or paradigm shifts that occurred during the evolution of the theory of plate tectonics and developing different modes of representation for them. Because students often confuse a simplified model for its target, they need to be exposed to many different modes of representation in order to facilitate enrichment of their mental models and their* *understanding of the concept. (…) By organizing the models historically and allowing students to discuss and debate them, the process of how science really works is itself modeled. (…) My motivation is for students to sharpen their own critical thinking skills by separating themselves from their own mental models and analyzing those models for strengths and limitations. Critical assessment of models by students is encouraged with the use of model analysis worksheets used throughout the entire course of study.*"[22]

Results evaluation

Assessment of results is probably more effective when students have understood how they were built in the past. The historical and contextualized approach allows finding the nature and complexity of the evidence in the demonstration. Outcome evaluation is not only about the soundness of arguments and evidence but also about their efficiency and construction. Glenn Dolphin, N. Gericke and M. Hagberg[23] work show that the results evaluation is more effective when students can compare them with historical results.

Moreover, one can consider the evaluation as a good challenge and source for pupils of pleasure. For instance, Koponen and Mäntylä state about using 19th-century physical experiments that: "*Such experiments can, nevertheless, be used to help students' conceptualisation in support of learning. Students can still have the satisfaction of participating in creating the knowledge for themselves although it now becomes strongly guided by the teacher and constrained by empirical observations.*"[24]

Argumentative communication

Liu pays attention to the fact problem-solving activities product social interaction and participate to reinforce argumentative communication: "*In addition to the history-based curriculum, students were situated in a dynamic problem-solving setting. As aforementioned, several historical problems were used in serving the purpose of bringing out students' curiosity and the desire to think. Students demonstrating more elaborated thinking were invited to share their ideas and approaches. All questions and comments from peers were welcomed for developing critical thinking. Following* *whole classroom discussion, the class then learned about the relevant historical background and mathematicians' approaches. For more challenging problems, such as Napier's original logarithm and Leibniz's tractrix problem, students worked in groups to increase social interaction and motivate higher-order thinking.*"[25] Rudge and Howe put out that an inquiry-based teaching must include discussions and debates. And at this stage, "*In the remaining time for this class, the instructor answers students' general questions about the conclusions they reached for the Uganda data or answers questions students have about other curious aspects of the mystery patient already examined in a prior class. The instructor reminds students to write a reflective diary entry about their experiences in the class with the expectation that they turn in their diary entries at the beginning of the next class. Students are also reminded to consider the diary probe when writing about their experiences in the class.*"[26]

Scientific language

Introduce non-werstern history of science shows how to do science in the other way especially when pupils are not sensible to European culture. For instance, Wang declares: "*At least, the history of ancient Chinese mathematics can show us another way to do mathematics, which is very different from the western tradition and the system in modern textbooks. This way can enable us to think, to learn and to teach mathematics in a more interesting way, one that is easier to understand and more related to the reality than is now the case.*"[27]

As conclusion of this paragraph, we would like to highlight once again a citation of Abd-el-Khalick F. et al[28]: "Thus, instead of thinking of a generalized image of inquiry in science education and assuming it will allow achieving multiple goals, <u>it might be more useful to think of several images that are intimately linked with small clusters of valuable instructional outcomes.</u> What is needed is a sort of a multidimensional heuristic that defines a space of outcomes, which would facilitate discourse and streamline communication about images of inquiry between players within any educational setting (e.g., policymakers, curriculum theorists and developers, administrators, teachers, teacher educators, and students), such that the likelihood of impacting actual classroom practices related to inquiry is substantially increased. […]One dimension could include the types of knowledge and understandings that Duschl refers to, that is, conceptual, problem solving, social, and epistemic. Another dimension could include a range of inquiry-related activities, such as, problem-posing; designing investigations; collecting or accessing data; generating, testing, and refining models and explanations; communicating and negotiating assertions; reflecting; and extending questions and solutions. A third dimension could include a range of (the necessarily reductionistic but nonetheless crucial) skills, such as mathematical, linguistic, manipulative, and cognitive and metacognitive skills, needed to meaningfully engage in inquiry at one level or another. A fourth dimension could comprise a range of spheres, including personal, social, cultural, and ethical, with which any of the aforementioned outcomes could interface. When navigating through this four-dimensional space, one could think of the elements on each dimension either as possible outcomes of, or as prerequisites for meaningful engagement in, inquiry-based science education. The former would help conceive and place more emphasis on inquiry as means (inquiry as teaching approach), while the latter thinking would help gauge the level at which students could engage in inquiry and help emphasize inquiry as ends (inquiry as an instructional outcome".

Conclusions

The first conclusion that we would propose is that the paper review showed that the research field about IBST is very active. The questions linked to the use of history of science in science education are studied at the European level by historians as it is shown for example by the symposium "HST & Education" organized inside the two last Conference of the European Society of History of Science in Vienna (2008) and Barcelona (2010)[29].

As historians of science and technology, we do consider IBST as a Open Problem Based Science Teaching. We have shown that HST could contribute to produce authentic pedagogical problems well adapted to IBST. We think now that we need a European network in order to:

- publish on-line resources in history of science in different european language and well-adapted to education
- produce research results about "HST & Education"

The second conclusion concerns the research field about resources in HST with ICT tools for IBST and cultural mediation. The research field concerned three scholar communities: Computer Science, Science Education and History of Science. As it is said in the European network of excellence Kaleidoscope[30], research questions about technology-enhanced learning systems concerns the ability to reuse learning resources (learning objects, tools and services) from large repositories, to take into account the context and to allow dynamic adaptation to different learners, contexts and uses based on substantial advances in pedagogical theories and knowledge models (Balacheff[31]). The design and engineering of learning systems about IBST or cultural mediation with resources in HST must be considered as a "big" interdisciplinary research problem requiring the integration of different scientific approaches from computer science, pedagogical and/or didactical theories, education, history of science, etc. The design process leads to an artifact - the learning system - based on different scientific approaches which are related to different theories – for instance, activity theory, theory of didactic situations, computer-based theories, etc. Consequently, it is crucial to establish the relationships between theories, models and artifacts to ensure the traceability and the interpretation of phenomena related to the use of artifacts (Tchounikine *et al*[32]).

Thus, we think that a major point for the future is to work on adaptive technology-enhanced learning systems for cultural mediation using a problem-based learning approach and represented by IBST scenarios[33]. The goal of scenarios is to describe the learning and tutoring activities to acquire some knowledge domain and know-how to solve a particular problem. A scenario may depend on several dimensions which describe different learning situations: the learning domain (course topic), the learner (his know-how and knowledge levels), the tutor/teacher, the learning and tutoring activities (their typology, organization and coordination), the resources (documents, communication tools, technical tools, etc.), the activity distribution among learners, teachers and computers, the learning "procedures" according to a particular school/institution/ university and the didactical/pedagogical environment.

In other words, dimensions are closely related: changing one dimension may lead to the change of others. For instance the learning activities have to change according to the learner know-how and knowledge levels for a given knowledge domain. In other words, their typology, organization and coordination change to deal with these dimensions. *Adaptive technology-enhanced learning systems* compute on the fly the delivered courses from distributed data resources, according to the current context and the learner's needs. The resource reusability has to rely on resource interoperability at syntactic and semantic level. At semantic level, resources are described by semantic metadata and their corresponding ontologies[34]. These ontologies can be used to formalize at knowledge level the different required models of learning systems: user models (student, teacher, visitor of a museum) models, domain model (i.e. the gender of digital documents in HST[35], IBST), context model, scenario models, pedagogical and/or didactical models, adaptation models and rules, etc. New software architectures are necessary to use learning system models based on ontologies and to support dynamic adaptation and context awareness.

The results and the interest of The European "Mind the Gap" workshop organized in Brest[36] in March 2010 was to show three axis in order to develop HST technology-enhanced learning systems for IBST in the future:

- The necessity to develop Web 3.0 ICT tools[37] in order to share the resources at the european level
- The necessity to publish historical digital documents for science education at the european level and, thus, to propose a translation in the

different european languages of the fondamental historical texts or documents in science

- The interest for historians of science and computer science researchers to work together about ICT and innovation[38]

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[1] For example, see the website « Ressources en histoire des sciences et techniques pour la formation des maîtres »: http://plates-formes.iufm.fr/ressources-ehst/spip.php?rubrique18.
The item « Histoire des techniques » was realized with the help of Brest Archives and educative service of the National museum of Marine.
[2] Centre de Culture Scientifique Technique et Industrielle (Cultural Center dedicated to Science, Technology and Industry)
[3] http://uv-net.uio.no/mind-the-gap/index.html
[4] Laubé S., Bruneau O., Ferrière H., de Vittori T. "History of Science, ICT and IBST", Deliverable 5.4, FP7 Project "Mind the Gap" n°217725
[5] http://ec.europa.eu/research/science-society/index.cfm?fuseaction=public.topic&id=1100
[6] Linn, M. C., Clark, D., Slotta, J. D. (2003). WISE design for knowledge integration. *Science education,* 87, 517-538.
[7] Abd-el-Khalick F, Boujaoude S, Duschl R, et al. "Inquiry in Science Education: International Perspectives". *Science Education*. 2004; 88(3), 397-419.
[8] Abd-el-Khalick *et al.*, *op. cit*, p. 398.
[9] *Id.*, p.411-2.
[10] *Id*, p. 412.
[11]Galileo, Galilei, *Sidereus Nuncius*, http://www.intratext.com/IXT/LAT0892/_P3.HTM (Original version in Latin); Galileo, Galilei, *The Sidereal Messenger*, http://www.archive.org/details/siderealmessenge80gali (English translation, 1880); Galilei, Galileo, *Le messager céleste: contenant toutes les nouvelles découvertes qui ont ete faites dans les astres depuis l'invention de la lunette d'approche*, A Paris: Claude Blageart ..., et Laurent d'Houry ..., 1681, http://fermi.imss.fi.it/rd/bd?lng=en&collezioni=galileiana
[12] Dolphin G. Evolution of the Theory of the Earth: A Contextualized Approach for Teaching the History of the Theory of Plate Tectonics to Ninth Grade Students. *Science & Education*. 2009; 18(3-4):425-441.
[13] Clément P. Introducing the Cell Concept with both Animal and Plant Cells: A Historical and Didactic Approach. *Science & Education*. 2006; 16(3-5):423-440.
[14] Mihas P. Developing Ideas of Refraction, Lenses and Rainbow Through the Use of Historical Resources. *Science & Education*. 2006; 17(7):751-777.
[15] Mihas, *op. cit*, p. 755.
[16] Mihas, *op. cit.*, p 758.
[17] Liu P. History as a platform for developing college students' epistemological beliefs of mathematics, *International Journal of Science and Mathematics Education*. 2008;7(3):473-499, p. 477-8.
[18] Rudge and Howe, *op. cit.*, p. 571.
[19] Dolphin, *op. cit.*, p.428.

[20] Liu, *op. cit.*, p. 477.
[21] Riess F, Heering P, Nawrath D, Education P. Reconstructing Galileo's Inclined Plane Experiments for Teaching Purposes. In: *Eighth International History, Philosophy, Sociology & Science Teaching Conference*. Leeds; 2005:1-10, p. 1.
[22] Dolphin, *op. cit.*, p. 427-8.
[23] Gericke NM, Hagberg M. Definition of historical models of gene function and their relation to students' understanding of genetics. *Science & Education*. 2006; 16(7-8):849-881.
[24] Koponen IT, Mantyla T. Generative Role of Experiments in Physics and in Teaching Physics: A Suggestion for Epistemological Reconstruction ¨. *Science & Education*. 2006; 15(1):31-54, p.51.
[25] Liu, *op. cit.*, p.477-8.
[26] Rudge and Howe, *op. cit.*, p. 572.
[27] Wang, *op. cit.*, p. 639.
[28]Abd-el-Khalick F., Boujaoude S, Duschl R, et al. Inquiry in Science Education: International Perspectives. *Science Education*. 2004; 88(3), *op. cit.*, p. 415
[29]Fourth ESHS Conference, Barcelona, http://conf.ifit.uni-klu.ac.at/eshs/images/M_images/PDFs/suss.%20liste.%206.%20sept.pdf
[30] http://www.intermedia.uio.no/display/Im2/Kaleidoscope
[31] Balacheff, N. (2006). "10 issues to think about the future of research on TEL." Les Cahiers Leibniz, Kaleidoscope Research Report (147). http://www-didactique.imag.fr/Balacheff/TextesDivers/Future%20of%20TEL.pdf
[32]Tchounikine, P. and Al. (2004). Platon-1: quelques dimensions pour l'analyse des travaux de recherche en conception d'EIAH. *Rapport de l'action spécifique "Fondements théoriques et méthodologiques de la conception des EIAH"*, Département STIC, CNRS. http://telearn.noe-kaleidoscope.org/warehouse/Tchounikine_2004.pdf
[33]Laubé S., Garlatti S., Tetchueng J.-L. (2008) "A scenario model based on anthropology of didactics for Inquiry-Based Science Teaching". *International Journal of Advanced Media and Communication*, april 2008, vol. 2, n° 2, pp. 191-208.
[34]about ontologies for computer science, see: http://semanticweb.org/wiki/Main_Page
[35]Laubé S. "Modélisation des documents numériques pour l'histoire des techniques: une perspective de recherche", *Documents pour l'histoire des techniques*, n° 18, décembre 2009, pp. 37-41. http://assoc.secdhte.fr/wp-content/uploads/2010/01/dht18_laube.pdf
[36]http://pahst.bretagne.iufm.fr/?p=84
[37]http://ec.europa.eu/information_society/eeurope/i2010/invest_innov/index_en.htm
[38]http://ec.europa.eu/information_society/tl/research/documents/ict-rdi-strategy.pdf

Developing and evaluating visual materials on historical experiments for physics teachers: Considerations, Experiences, and Perspectives

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ABSTRACT: This paper discusses an attempt to develop visual materials for physics teachers on experiments from the early history of electromagnetism. In several respects, this attempt has to be interpreted as a pilot study: the number of materials that were developed is few, the field and period are very narrow, and the evaluation of the developed materials can serve only as a pilot study as the number of teachers evaluated has been very limited. Yet, it appears to be relevant to discuss some of the ideas that were conceptually important for the development of the materials. In this respect, also the results of the pilot study of the evaluation appear to be meaningful as they seem to strengthen some of our considerations.

Introduction

Various accounts have attempted to implement history of science in general and the history of scientific experimentation in particular in science education (see in particular the publications of the Oldenburg group led by Falk Rieß, but also Achilles (1996), Cavicchi (2003), Kipnis (1993), and Teichmann (1979)). These approaches aim at enabling students to redo historical experiments, either with reconstructions that are created according to the available source information, or with reconstructions that are based on the working principle of the instruments. Evidently, the experiences made in these approaches show that such a approach is beneficial in science education. However, a problem appears to be the availability of the instruments that are necessary for such an approach. The approach I am going to discuss in this paper goes in a completely different direction. I will discuss the