Project no. 217725

Project acronym: Mind the Gap

Project title: Mind the Gap: Learning, Teaching, Research and Policy in Inquiry-Based Science Education

Dissemination level: PU

Thematic Priority: Science in Society

Funding scheme:

Deliverable N° 5.4

Deliverable title Report on ICT/HST tools

Due date of deliverable: Month 20
Actual submission date: 01/12/09

Start date of project: **01/04/2008** Duration: 24 months

Name of Coordinator: Professor, Doris Jorde, University of Oslo, Norway
Name of lead partner for this deliverable: Ghislaine gueudet

History of science, ICT & IBST

Report

Introduction

The initial aim of this report is to show that History of Science and Technology (HST) could play a role at several levels for dissemination of IBST in Europe :

- in the understanding of what is Inquiry Based Science Teaching (Chapter 1). Thus, we will propose historical examples taken in biology, mathematics and physics. From the analysis of the examples, we will show that historical inquiries in science could considered as open problems linked to data, theory and models, experiments and historical methods
- by proposing historical and authentic problems to be solved in the classroom as the paper review will show it (Chapter 2)

The second aim will to discuss the issues related to HST resources and ICT tools for IBST. Based on research works in a) computer science about modeling digital documents ; b) ICT tools for history of science, we will focus on the definition of the gender of the digital document in history of science and guidelines in order to analyze/design websites based on historical resources (chapter 3)

As results of the "Mind the Gap" project and as conclusion, we will show that a European network of historians of science exists now about "HST and Education". Several research works are in progress (Symposium in international Conference, collective book, etc.) as well the project of publishing/sharing HST resources for Science Education in Europe.

1. History of Science to characterize IBST

The purpose of this chapter is to point out that an historical approach of authentic problems in science is helpful to characterize what is Inquiry in Science. 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 (mathematics, physics, life and Earth science), history of science gives lots of interesting and authentic examples that shows 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. Here are a few examples.

1.1 Life and Earth sciences

Controversies are numerous in Life and Earth sciences, but the experiments on spontaneous generation by Louis Pasteur and Felix-Archimedes Pouchet in 1863 and 1864 are undoubtedly the most famous[1]. Over their historical interest, they are also very useful in a global research approach with students or pupils (student misconceptions about the nature of science, student interest and motivation).

Text of the lecture and debate between the two protagonists illustrates key points of scientific process of investigation. This example shows that this kind of investigation is primarily based on knowledge of the historicity of the concepts of evidence, technical tools and experiments. The scientific problem consists in testing the central hypothesis of heterogenists - the existence of spontaneous generation - and testing hypotheses derived from knowledge of the conditions of life, survival, resistance, propagation (or release) and reproductions of microscopic living beings. The hypotheses are made in light of their verifiable consequences in a conventionally defined experiment.

One the one hand – for Pouchet - knowledge of the time on micro-organisms is construed as a zoological and philosophical vision of Nature as a large ensemble and "Life" in general. On the other hand – for Pasteur – these micro-organisms can be considered in a vision already heavily marked by “hygienism” and willingness to control technologically the human environment. It is interesting to note that the philosophical materialism seems to be the Pasteur’s enemy when he uses the argument of the rigor, and that he claims that his approach is not based on any assumption idealist. Pasteur presents himself like a hardliner reductionist – he uses only material objects and he looks for disqualify Pouchet who in his earlier writings has attempted to demonstrate that his theory heterogenists was not antireligious.

The various levels of the two discourses intertwine around to show the strengths typically notified of a process of investigation (problems, hypothesis, testing hypothesis...). Many different kinds of arguments are developed to consolidate their argumentation. The nature of arguments can be questioned in this text. The construction of scientific language is before our eyes in a real show of the two great scientists as we can see them “in action”. In order to collect data, the phenomena are discussed with clarity, and then mounts and experimental devices are described, reported and sometimes diagrammed. The technical instruments and devices (balloons, mercurial trough, heating condition, transport mode...) are extremely interesting because they show the experimental methods in modern way of construction and validation of scientific argumentation and conclusion by the scientific community of the time. The narrative of experiment itself is also very rich: we see the

[1] *Revue des cours scientifiques de la France et de l’étranger*, Première année, 1863-1864, pp. 257-270. http://gallica2.bnf.fr/ark:/12148/cb34411109f/date

connection with the discovery of supposedly more healthy environments (like mountain or campaign) and the construction of a true scientific view of nature (ordered, detailed, scrutinized in every details even insensitive part or "inaccessible" directly without instruments or mediator as a microscope). The terms and conditions of the experiments are various: their presentation is explicit. It is possible to represent them as mathematical models or schematic. And the experimental results are presented in the following statistical form and essentially comparative way.

The observations made in "live" (as in the text of the Pasteur’s conference) are interesting and show the diversity of approaches that can be envisaged. Quotations from other works or references to other past and contemporary scientists can also show the scientific way of working. The different times and rhythms of both speech can be identified and show how to build a process of investigation and how scientist relate it thereafter. Both scientists' references are explicitly mentioned.

The added value of these texts lies in the presentation of such items provided to the public by the speaker. In fact, the text is not a simple transcript of their statement. It’s a real lesson that maintains their methodological process. We can observe the techniques used. There is a whole set of systems implemented to demonstrate and, in the same time, to convince. The "journalist" who tells the lecture given by Pasteur gives many details about the staging of the lesson without affect the scientific rigor of the presented arguments. But telling all the fact, objects and technical tools that Pasteur shows to his public, and not only transcribe his words, gives extra weight to his argument. Thus, we can know also the rhetoric used, the self-staging of the speaker, their pedagogy and their technical methods of presentation (projection, lighting...).

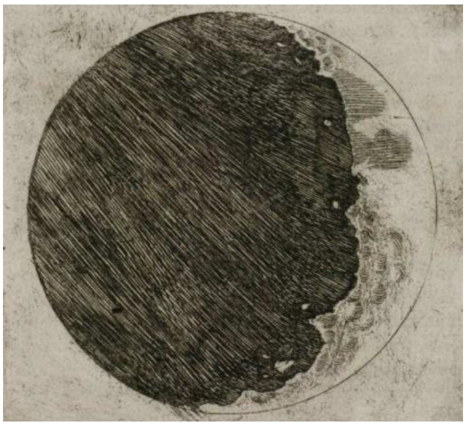
Besides, we should first remind that the Pasteur’s works were effective in medicine and veterinary medicine to understand the role of microorganisms in the spread of diseases. His works are still economically and technically profitable (for industrial production of beer or wine...) and are ideologically and politically useful. They are used to control the environment in the context of industrial revolution and to control the urban population behaviour (with hygiene measures).

The role and nature of the audience - which are highlighted at the end of Pasteur’s speeches - are important for two reasons: first to discuss the construction of the evidence and, second, to show the use of an argument of authority in a scientific presentation. Political context of this demonstration has to be mentioned because the Empress is in the conference room when Pasteur talks. This is an explicit political support from the government. This is a religious support too because the second empire is clearly conservative and Catholic. But Pasteur attacks his opponent on two aspects: the scientific and the philosophical aspects (the belief in God). The last sentences of his speech are so clear. They answer to the first sentence which declares that the subject of the controversy is not so important than the “origin of life” or the “proof of the existence of God”. Pasteur says in an excess of false humility that his speech is only about a secondary issue: the spontaneous generation. The purely transmissive of two educational devices implemented shows that both scientists know this kind of pedagogy.

The final value of this study is the non-settled debate about the "origin of life" and not only about spontaneous generation. Because it seems that microscopic living creatures don’t appear on Earth today ex nihilo. This text is of considerable wealth through a training process of investigation in science. It shows that understanding the process of investigation in science needs a look at its past implementation.

1.2 Physics

Galileo's works constitute another set of suitable examples in order to show what inquiry is in authentic and historical scientific situations. Galileo showed a remarkably appreciation for the proper relationship between mathematics, theoretical physics, and experimental physics. *Sidereus Nuncius*[2] 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 system Jupiter 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

[2] 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 eté 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

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”.

1.3 Mathematics

In mathematics as in the other fields of science, inquiry takes up a large part of the research process. Favouring the results to the reasoning, ancient times mathematicians rarely express themselves on their relationships to the experiments. However when they do it, they give us the opportunity to see the complexity of the links between theory and the use of technical instruments. The history of science assures it: mathematical theories never emerge from nothingness. The scientist describes, builds and explores multiple examples before proposing an analysis or a system. On this subject, the work of the Arabic scholar al-Sijzī is a model of such a process. Ahmad ibn Muhammad ibn `Adb al-Jalīl al-Sijzī was born and lived in Iran. Son of mathematician, he has been working between 969 and 998 and he wrote exclusively books on geometry. In all, he has written approximately fifty treatises and lots of letters to his contemporaries. Al-Sijzī was working in a specific context. Since the ninth century, the development of algebra in the Arabic world creates a new type of questions on the fundaments of this field. In the majority of cases, the equations can be solved by intersecting conics curves (ellipsis, parabola, and hyperbola). The point-by-point construction of conics is well know since Antiquity (see the Apollonius' book entitled the Conics, for example), and this method is efficient enough for the analysis of the main properties of these curves. But during the ninth century, the necessary taking in account of the intersections creates new difficulties. Indeed this possibility is based on the continuity of the different curves. The solution that has been chosen was to associate the curve with a tool that allows an effective construction to be done. As the rule or the compass allow straight lines or circles to be drawn and so justify their continuity, a new tool has to be invented to draw all the conics. Note that interest is not only mathematical because the conics are also useful in technical areas such as construction of astrolabes and sundials.

After the evocation of the works of his predecessors (Banū Mūsā brothers, Ibn Sinān...) in a book about the description of the conic sections, al-Sijzī engages himself in another treatise specifically on the Construction of the perfect compass which is the compass of the cone[3]. In this second book, he studies a new tool, made-up a while ago by al-Qūhī: the perfect compass. As he announces it in the first pages of his treatise, al-Sijzī wants to “build a compass by which we obtain the three sections of the cone.” He notes first that all the conics can be obtained from a right cone (depending on the position of cutting plane), and then proposes three possible structures for the

[3] The texts are available in a French translation in *Œuvre mathématique d'al-Sijzi. Volume 1: Géométrie des coniques et théorie des nombres au Xe siècle*, Trad. R.Rashed, Les Cahiers du MIDEO, 3, Peeters, 2004.

perfect compass. Here is an extract of the first, the other two are based on the same principles. “We must now show how to shape a compass by which we can trace these sections. Shaping a stalk or AB. We put on the top tube, or NA. We link at the end of it another tube. [...]”

The beginning of the study is technical. The reader should be able to build such a compass. But for al-Sijzī, the aim of his work on the perfect compass is not just to draw conics. The end of the text shows that this compass is also a theoretical tool and a tool for the discovery of new concepts. The link between the circle and the ellipsis is quite obvious. The construction of the ellipsis by orthogonal affinity and the formula for the area are well known. But what are the links between the circle and the parabola or hyperbola? The approach of the author takes on another dimension in that it is now oriented towards exploring and solving new problems. The practical tool becomes an instrument of discovery and as stated by al-Sijzī himself: “I always thought that there was a relationship between these two figures and the circle and their similarity and tried to get it but the knowledge of this has become possible to me once learned how to turn the perfect compass following the positions of the plans.” In this example, the comings and goings between theory and practice appears clearly. Confronted with the theoretical problem of continuity of curves, the scientist suggests an instrument. Experimentation with this instrument creates new theoretical results and so on. The approach implemented by al-Sijzī clarifies the role of mathematical instruments. They are as much objects as models and this dual status facilitates the theory-experiment passage.

According to Pr. Martin Andler (University of Versailles – France), a contemporary mathematical research activity comprises: 45% devoted to observation, 45% for experiment and only 10% for demonstration[4]. In the field of mathematics learning, the epistemology and history of mathematics can help to explain and to overlap the inquiry-based style.

Pierre de Fermat (1601-1665) is a French lawyer who works during his free time on mathematics. His name is associated with his famous theorem which has been only demonstrated in 1990’s. His mathematical works are focused on number theory even if he had not published any treatise on this subject. The only sequel can be found as quotation of his Diophantus’ book and in his correspondence especially with Marin Mersenne, Huygens or Carcavi. Now, we can find in the web[5] some parts of this.

In a letter Fermat send around august 1659 to Pierre de Carcavi (1600-1684), another French mathematician amateur, he tries to demonstrate some properties with, according to him, a new kind of demonstration he called “la descente infinie ou indéfinie”. This kind of demonstration is yet used in the margin of his Diophantus’ volume to prove that the area of rectangular triangle with integer sides (i.e. ones which are measured by integers) can’t be a square. But here, he uses it not only to prove some negative results but, too, a positive result: all prime number like 4k+1 is the sum of two squares, and this representation is unique. For instance, $5=2^2+1$, $13=3^2+2^2$, …

The nature of the demonstration is based on a reduction per absurdum. For instance, to prove the above proposition, he supposes that this king of triangle exists. He shows that it’s still true, that we can find another triangle with shorter sides which validate the assertion, and so on. Since the sides must be integers, by the method of infinite descent, he arrives to a contradiction. So, it’s quite easy to prove negative assertion, but to show positive assertion, it’s harder. He only announce that he demonstrate that any prime number which write as 4k+1 can be decomposed as the sum of two squares of integers and this decomposition is unique, But, unfortunately he doesn’t give any demonstration. A priori, the first one of this assertion which is known now is due to Leonard Euler (1707-1783). In Latin written, the title is *Demonstratio theorematis Fermantiani omnem numerum primum formae 4n+1 esse summam duorum quadratorum* [Demonstration of the Fermat’s theorem

4 Colloque Mathématiques, Sciences expérimentales et d’observation à l’école primaire, Table ronde « La démarche d’investigation en mathématiques », Chairman : P. Léna, École Normale Supérieure de Paris, September 28th 2005 : http://www.diffusion.ens.fr/index.php?res=conf&idconf=882

5 http://www.archive.org/details/oeuvresdefermat942ferm

“All prime number like 4n+1 is sum of two squares][6], it strictly follows the Fermat’s method. The “infinite descent” method has profoundly renewed the number theory. Moreover, as usual, Fermat doesn’t give a demonstration of what he announces, but he suggests others mathematicians to find the demonstration of properties he gives. For instance, in the letter already cited, in the case of the rectangular triangle with integer sides can’t have a square area, when he supposes a such triangle exists, he affirms that another one smaller must be exists, he doesn’t give demonstration which is known by him but he is asking for “je serai bien aise que les Pascal et les Roberval et tant d’autres savans la cherchent sur mon indication” (*op. cit.* p. 432).

In this Fermat’s letter, we show two aspects of mathematics field. First, some kind of demonstrations is not able to resolve problem and it must invent newer which is effective here and could be reuse to solve other mathematical enigma. The creativity can go through a new methodology and new approach. Secondly, this letter participate at the research of mathematics because it invites others mathematician to treat this kind of problems. It shows how mathematical progress can be transmitted.

1.4 Conclusion

From the above examples, the historical approach demonstrate that science and investigation are very close in different ways. As Pouchet-Pasteur controversy and Galileo's telescope point it out, one of the elements of science is the *collecting of data*. But these examples also show that observation is not enough. In every scientific field, the scholars have to elaborate a way to question their object. This is not only concerning science of Nature : the work of al-Sijzī shows that mathematics has to be considered too. In each case, new instruments have to be build, and news experiments have to be elaborated in order to be able *to ask the good questions* and finally answer them. This first part of scientific activity is very similar to a second that is dealing with theories and models. The *modelling process* is very clear in the examples given above. Physicists, biologists, and mathematicians elaborate new concepts that, together, become new theories. As we have seen it in Pasteur's, Galileo's and Fermat's work, new notions are always created to make possible the analysis of new problems. This is an important second facet of science. When their pertinence has been proved, the news concepts are applied to others situations or fields and the become part of the common knowledge. The theories newly born have always been discussed and this constitutes the last part of scientific activity we want to underline. When scientists talk about new concepts, they give themselves a way to understand them. The *communication between scholars* is a large part of knowledge building as it often needs to create *a suitable language*. The creation, or the choice, of the good words to name a scientific object is more than a linguistic problem; it is a scientific one.

In this part, we pointed out that if we consider the criteria that we have established and noticed in the introduction, examples issued from history of science could 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.

Thus, we propose 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.

Abd-el-Khalick F *et al*[7]summarized the results of a international symposium where two kind of inquiry appeared :

[6] http://math.dartmouth.edu/~euler/docs/originals/E241.pdf

[7] Abd-el-Khalick F, Boujaoude S, Duschl R, et al. Inquiry in Science Education: International Perspectives. *Science*

i) "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);

ii) "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 pointed out 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]

Hereafter, we will illustrate each point by some articles from *Science & Education*, *Educational Studies in Mathematics*, *International Journal of Science and Mathematics Education*.

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.

2. History of Science and Technology and IBST : a paper review

2.1. Collecting Data

G Dolphin[11] explains that collecting data is the first 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 (like 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. We can discover with this example an global approach of investigation in science which integrate historical and epistemological approach in the same time. ICT are not used in this case to search data because teacher makes the choice of resources before their using in classroom and he puts the emphasis on models and scales made by students.

P. Clément[12] 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[13] 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. »[14]

So, one can see that the great diversity of data can be mobilized via historical IBST, and there are not only texts but maps, photos, fossils,… After collecting, the second stage is to put up hypothesis.

2.2. Stating hypothesis

Rudge and Howe[15] begin their activity with the elaboration of some hypothesis by students and teacher validates this hypothesis or asks for more explanations. And for the case on mutagen of the allele, teacher puts together in a list which includes: "(a) the possibility of a mutagen in the environment increasing the rate of mutation of the allele, (b) the idea that gene flow (intermarriage) contributes to high numbers of carriers in certain locations, and (c) that racial pre-determination must play a role (i.e., those tribal members characterized as more traditionally African or ''black'' were more likely to be diseased). The instructor refrains from validating any of these explanations and rather asks the students to comment on their relative strengths and weaknesses. When the discussion begin to wane, the instructor reveals that scientists during the late 1940s also came to similar explanations to account for the frequency anomaly, and moreover that the scientists did not

[11] 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.

[12] 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.

[13] Mihas P. Developing Ideas of Refraction, Lenses and Rainbow Through the Use of Historical Resources. *Science & Education*. 2006;17(7):751-777.

[14] Mihas, *op. cit*, p. 755.

[15] Rudge DW, Howe EM. An explicit and reflective approach to the use of history to promote understanding of the nature of science. *Science & Education*. 2007;18(5):561-580.

share universal agreement about the relative importance of their theoretical positions"[16]. 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."[17]

2.3. Testing hypothesis

After elaborate hypothesis, students must 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. Furthermore, former hypothesis depend on the finiteness of knowledge of students like historical scientist: "Furthermore, 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."[18]. 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."[19] The example developed by Glenn Dolphin is also very attractive because he states and tests (with his pupils) different "essentials question" ("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"[20]) 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…).

2.4. Experimentation/ hands on

In the IBST activity, the central point is experimentation. So in our literature list, this part is present and relatively well explained. The Dolphin's work is also a good example in our case: his students have to do 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 which 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

---

[16] Rudge and Howe, *op. cit.*, p. 571.
[17] Mihas, *op. cit.*, p 758.
[18] 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.
[19] Rudge and Howe, *op. cit.*, p. 571.
[20] Dolphin, *op. cit.*, p.428.

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 πr^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.”[21].

Furthermore, using historical mathematics allows manipulation, for example, Wang asserts that “The style and content of Chinese mathematics is very unique, especially the wonderful style of doing mathematics by hands-on manipulation. (…) any teacher in mathematics can gain useful insights from ancient Chinese mathematics. For instance, the principle of congruency by addition and subtraction provides what may be considered formal proofs that are more eloquent than formal Euclidean ones. In addition, these formal proofs reconstructed may well have great pedagogic value for any mathematics classroom. For example, by encouraging the logical intuition required in constructing a knowable geometric object from a given that ability is the power to see geometrical properties detach themselves from a figure so as to solve a problem related to that figure. In some ways they different geometries, but they muster similar logical intuitions that may be necessary for learning of any abstract.”[22]

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, Falk Riess, Peter Herring and Denis Nawrath 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”[23]

[21] Liu, *op. cit.*, p. 477.

[22] Wang Y. Hands-on mathematics: two cases from ancient Chinese mathematics. *Science & Education*. 2007;18(5):631-640, p. 639.

[23] 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.

2.5. Modelling

In some fields of science, it is useful to make models and to debate on this. But to do that, it must be rearrange models. Dolphin' pupils elaborate a table in which different models are classified by their degrees of abstraction (fig. 1):

Modes of Representation

Atributes of Representation		Concrete	Visual	Gestural	Verbal	Mathematical
Qualitative	Static	Geographic landscape models of volcanic, domed, faulted and folded mountains	Aristotle's "Meteorologica" model		Hutton's "vertical igneous forces" Neptunist "precipitation" model	
Qualitative	Dynamic: Deterministic	Wet sponge model after Aristotle	TASA. "Plate Tectonics" "Paleo Map" CD			
Qualitative	Dynamic: Stochastic	Balloon "thermal contraction" Table cloth deformation Lava lamp (plumes)				
Quantitative	Static		Scale drawings of volcanoes Ocean bottom profile			
Quantitative	Dynamic: Deterministic					
Quantitative	Dynamic: Stochastic		"Seismic Eruptions" computer plots of epicenters and eruptions through time.			

Concrete ------------------------→ Abstract

Fig. 1: Figure extract from Dolphin (2009), p. 427.

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 (Fig. 1). 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 based on "goodness of Wt", 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."[24] (p. 427-8)

2.6. 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

[24] Dolphin, *op. cit.*, p. 427-8.

soundness of arguments and evidence but also about their efficiency and construction. The example of "egg-cell" model developed by P. Clément is also a good example. There are three kinds of reason to keep this model. Glenn Dolphin, N. Gericke and M. Hagberg[25] 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."[26]

2.7. 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."[27] 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."[28]

2.8. Students autonomy

Test ancient models or historical representation are interesting for promoting critical and an independent thinking in students. Some kind of argumentative communication and scientific language are illustrated in all already mentioned articles included strategies informed by research (like telling stories, using originals historical texts or patterns, narratives, dramatizations and period literature). The author encourages discussion and reflection, while respecting differences of opinion.

2.9. Scientific language

In the other hand, 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

[25] 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.

[26] 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.

[27] Liu, *op. cit.*, p.477-8.

[28] Rudge and Howe, *op. cit.*, p. 572.

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."[29]

As conclusion, we would highlight once again a citation of Abd-el-Khalick F. *et al*[30]

"Thus, instead of thinking of a generalized image of inquiry in science education and assuming it will allow achieving multiple goals, it might be more useful to think of several images that are intimately linked with small clusters of valuable instructional outcomes. 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. Even though I do not claim that articulating such a heuristic is an easy undertaking, it is not very difficult to imagine one possible configuration for it. 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".

[29] Wang, *op. cit.*, p. 639.
[30] 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

3. Online sources in EHST for IBST

When we navigate on the web, it is easy to find websites, pages or documents related to the epistemology, history of science and technology (EHST). Moreover, some sites have been created to orientate users to find "good" resources like "Internet Resources for History of Science and Technology"[31]. More and more primary sources are also available by for instance, "Google books" or the French project, "Gallica"[32]. So it is relatively easy to read and to study ancient texts about science and technology. But, to avoid mistakes or misinterpretations, these texts must be introduce and contextualized for one hand, and the second hand, they must be judged as good examples by historians of science.

From the research in history and technology and about the applications for IBST for pre-service and in-service teachers that we lead in our lab PaHST at the University of Brest, we will propose to define what is an electronic document gender for EHST[33] and we will give a list of criteria to judge if then it is a good electronic document for EHST in order to be used for IBST.

3.1. Numerical documents for history of science and technology

The first example concerns the history of engineering with the website on the swinging bridge of Recouvrance in Brest, France (1861-1944). This bridge has two parts which rotate and allow big ship to pass. It is a unique item by his length (more than 175m) and by their mechanisms. It is a good example of the French Second Empire knowledge on bridge construction and it was shown several times during Universal Expositions. Some aspects of this bridge have been published in a website dedicated to IBST in pre-service and in service teacher[34].

To allow the opening of the bridge in the middle of the Penfeld the rotation around the axis of the pile is given by two capstans per part, diametrically opposed relative to the axis of the pile. One of these mechanisms is sufficient to turn a fly when the weather is calm. The parts then rotated to a position parallel to the docks. Our research has highlighted five mechanical systems including:

- a rotation mechanism operated by hand by capstan
- a locking end of the two stolen
- a mechanism for attachment to docks (one pair of jaws per round)
- a system of screw jacks, which prevents deformation of the bridge

Figure 1 shows an example from a 3D kinematic modelling as result of the research: it concerns four mechanisms identified in the research and several animations clarify the kinematics. The sources used for understanding the mechanisms as historical contexts of use are derived from various archives available[35]. The reference planes for modeling are those published by Mr. Aumaître in 1867[36], engineer of bridges serving in Finistere.

---

31 http://www2.lib.udel.edu/subj/hsci/ (last accession 16th November 2009)

32 http://books.google.com/ and http://gallica.bnf.fr/

33 This part is recently pubished in a research paper : Laubé S (2009),

34 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's municipal archives and educative service of the National museum of Marine.

35 http://archives.mairie-brest.fr/4DCGI/Web_DF/ILUMP4763

36 M. Aumaître, « Note n°167 relative au pont tournant construit sur la Penfeld pour la traverse de la route impériale n°12 dans la ville de Brest » *Annales des ponts et chaussées*, 4ème série, tome 14, 1867, pp. 265-276. the digital journal can be found here : http://gallica.bnf.fr/ark:/12148/bpt6k408508k.r=.langfr

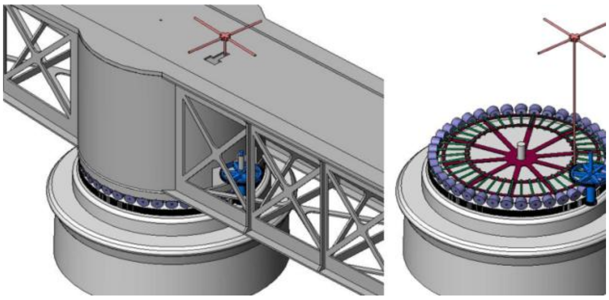


Fig. 1

Fig. 2

The figure 2[37] arises from a website which presents some different views of this bridge and video includes cards and maps of the rotation mechanics, but sources are not referenced. The 3D kinematic view shows the mechanism and a view of the bridge rotation. A first reading of these two images (without prior knowledge of the production context) indicates a very high similarity and the second figure has a greater aesthetic quality, due to the coloring and textures that creates a reality effect.

The question of the historicity of these two images arises now. The citation of sources is the first step. Figure 1 is inserted in a historic speech and a reference corpus consisting of research (briefly described above).

If the web page which is published in Figure 2 (with its animation) is presented as a historical iconography, references sources are absent, but it can easily be found: first, the site of the City Archives of Brest for the postcards; second, on the website "Digital Bridges" for two maps[38].

The image is a 3D model resulting from the critical analysis of historical sources. Two items taken from our examples will show. Each of the models shows a single mechanism for rotating a fly bridge. Historicalc sources say that two similar mechanisms were located symmetrically about the axis of rotation of each part. Depending on conditions (eg climate), one operated from one or two mechanisms with teams up to eight men capstan. The 3D model of Figure 1 does not therefore constitute a desire to replicate more closely the historical reality as we know, but a mechanism to explain the perspective of the history of technology (which is indeed the production context of image). Similarly, plans from historical sources have only one mechanism for the sake of facilitating understanding of the reader and avoid redundancy harmful.

We can assume that the 3D model of the figure 2 ensues from the direct interpretation of the unique source already quoted which show only one rotating mechanism without any critical analysis. Even if this figure has some qualities to explain mechanism, it is not a historical image[39].

One can already say that with the comparisons between these two figures, it is relatively difficult to determine *a priori* when a 3D model or more generally electronic documents is historically based. So one must define what the “numerical documents” gender is for EHST.

---

37 See Roger Yven, http://www.brest3d.fr/pont.php, site partly devoted to the « historical reconstitution ».

38 http://digital.lib.lehigh.edu/cdm4/bridges_viewer.php?DMTHUMB=&CISOPTR=3124&ptr=3168 last consulted 16th November 2009.

39 This hypothesis seems to be confirmed, for instance, by the fact that the Saint-Andrew’s cross are not present in the metallic structure inside the part. Moreover, this figure has been made by a private team in order to promote their competency in 3D model making.

3.2. Necessary condition to be a digital document for EHST

According to Michael Shepherd and Livia Polanyi[40] quoted by Ioannis Kanellos[41], one can characterises the genre of digital documents with three constitutive elements:

- The *contents* (information, …) organised following a *material* structure (disposition, page setting,…) which is often sufficient in first and quilky reading to feel gender, and a *logical* structure (title, author, date, abstract,…) which brings information on the intellectual organisation of this document.
- The *container* (support, medium) which determines the manner to access, to appropriate information.
- The *context of production* which relates the publication design in given frame or given activity. Played an essential role in the reading process of the document, context can be found in the content so such in the container.

If we apply this characterization at our examples (figure 1 and 2), according to us, the contexts of production are clearly presents: the first is framed in a historical approach, the second is a commercial activity around 3D modelling. On the other hand, the containers (digital images with animations) are both similar. Contents as well containers as such can't allow easily to decide the context of production and therefore the gender (historical or not). Only published information in the frame of the digital document identifies and determines the context of production and the gender.
We just see to define the context of production is sometime extremely difficult, so the best way to do that is to refer to a community of practice[42] (here historians of science and technology) which defines the context of production and shows the logical organisation of knowledge.

Another example interesting to analyse is the "Plan de Rome, restituer la Rome antique" website[43]. In the case of digital document (including 3D interactive and kinematic model), this website is a good example of restitution project. Based on a plaster model representing the 4th-century a.d. J.C. Rome, the ancient sources were essential to make a "truly" virtual restitution. In the website, the content, the container and the context of production are well established and one can see the wish to develop a new kind community of practice at the intersection of computer artist and researchers (and more generally between historians and computer scientists).

If we trust this definition of the digital document, the context of production reveals the gender and shows the quality of the documents for the EHST. We will thus give some criteria:

---

[40] Michael Shepherd, Livia Polanyi, « Genre in digital documents », 33rd Hawaii International Conference on System Sciences, Volume 3, 2000, pp.3010, http://doi.ieeecomputersociety.org/10.1109/HICSS.2000.926693.

[41] See Ioannis Kanellos, Thomas Le Bras, Frédéric Miras, Ioana Suciu, « Le concept de genre comme point de départ pour une modélisation sémantique du document électronique », *Actes du colloque International sur le Document électronique (CIDE'05/*, Beyrouth, Liban, avril 2005, pp. 201-216

[42] Community of practice is defined in order three aspects: the frontiers of their application field, the social existence such as community and tools, language history and documents used and shared by the members of this community. It's also a group which interacts, learns together, constructs relations and through that develops a belonging feeling and a mutual engagement. See, for instance, Etienne Wenger, *Communities of Practice: Learning, Meaning, and Identity*, Cambridge University Press, 1998 or his website: http://www.ewenger.com/theory/

[43] http://www.unicaen.fr/services/cireve/rome/index.php

- The first and the major one is the availability of primary sources. If there is not primary source, one can have some doubts about veracity and it's not the frame of history of science perspective. It's better if this sources are contextualised and explained.
- The second one is the using of secondary sources. These may help to contextualise and to understand the problematic.
- The kind of media : texts, pictures, audio, video, …
- The possibility to have simulation, to create experiments
- The opening to another view and to other historical facts or problems (with hypertexts, links,…).

These criteria are to connect with the aims of EHST digital documents. One can summarize in some great fields a list : the aim is to show the nature of science, or it refers on the macro or micro history, it's based on a history of a concept, it tries to link science and society, it shows scientist biography or controversies…

3.3. Guidelines for digital documents in HST for the use in IBST

We could now propose steps in order to analyze if a resource in a website could be characterized as historical and could be then to be used to build a Open Problem Science Teaching from authentic historical examples.

3.3.1. General description of the digital document

This part is to identify the electronic document by their authors, his destination, and his goal.
Items :

- *Who is the author?*
  Is he a professional (researcher, in history of science and technology, in education, educator, …) or an autodidact or an unknown person?
- *Who are the targets ?*
  for EHST specialists, for the researcher or practitioners in education, or simply a «websurfer»?
- *What is the aim of the document?*
  Is it devoted to research, scientific culture or for teaching?

3.3.2. Description of the historical resources

To work with the document as an historical one, it is extremely important to define what kind of sources is used. We can split in two categories the sources : original and secondary ones.
The first one concerns the science in acting in creation, in which the science is the main and central subject. This is mainly printed texts or manuscripts, images (sketch, diagram, representation of curves, photography, movies, technical objects, instruments, mineral collection, herbarium, etc).
The second one is mainly a view on the science (more or less contemporary) in which the author (historian, philosopher, sociologist) give a discourse with distance and the science is not an actor. Principaly, the form of the secondary sources is printed texts.

1. *<u>Original texts :</u>*

If we can access to a primary historical source, we must circle it :

- Who is the author (or the institution), do we know the date of writing and publishing?
- In which language is it written? In original language or a translation ? What is the edition : the first one or an augmented edition ? In the case of the re-edition, is it a contemporary edition ?
- What is the main subject of this source : physics, chemistry, mathematics, geology, biology, technology, or history of sciences education?

2. *Secondary sources*

  - Firstly, who is the author (or the institution), do we know the date of writing and publishing?
  - Do we access directly or with link ? Is it an extract or entire source ?
  - If it's furnshised, what kind of relationships they have with original texts ? Does it serve to understand original documents or to offer more perspectives ?

3. *Elements to understand the document : historical and epistemological aspects*

Before using the document, it is important and necessary to understand it as well as possible. We must have some elements to help the reader to have a precise idea of their historical and epistemological aspects. Thus, we need to have a contextualization of the document, to identify the nature of scientific problem and the epistemology behind this problem.

a. Historical, philosophical and sociological context of the scientific problem

It is essential to study it :

- For instance, have we got biographical element of the author ?
- Can we find an introduction of the social context, time-line in which one can see the studying object in more or less history?
- Can we find an explanation of the reason of this study is important in the micro-history and/or in the macro-history ?
- Can we find a social connexion ?

b. Nature of the historical scientific problem

In the document, it could be possible to see the kind of the scientific or technological topic:

- Is the topic devoted in a specific domain (mathematics, physics, chemistry, biology, geology, …) or in the interaction between some fields ?
- Does it refer to a specific technology (like instruments, chimical manipulations...), or does it evacuate this sort of consideration ?
- What is the relationship with data, i.e. does the author collect data ? What kind of treatment does he use, … ?
- Does it explain and propose a model?
- What is the relationship with the theory ? Does it propose one ? Does it refer explicitly to a specific theory, is it devoted to fight it ?
- Is this document included in a scientific or social controversy ? If yes, what kind of arguments is used ?
- Can one consider the scientific or technological object in the perspective of the case of interaction between science and society?

c. Nature of Science/Epistemology

A better understanding of the social and epistemological dimension constitute a way for educators to improve IBST:

- Does the document help us to well understand the science ? Does it help us to answer at the question : what is the science ?
- Is there any consideration about any scientific methods?
- Does it give a specific view about the scientific implication in the society ?
- Does it give a social statue of science?

Conclusion : If we do consider IBST as authentic Open Problem Based Science Teaching, historical resources in sciences published on website will constitute well-adapted references for educators of authentic (because historical) problems in science in every field. But those historical resources for IBST has then to be used with respect of the guidelines that are described in the deliverable 5.2 “Guidelines for ICT design” : we invite the reader to refer to this deliverable.

4. Conclusions

The first conclusion that we would propose is that the paper reviews 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 last Conference of the European Society of History of Science in Vienna (2008)[44]. Following this research work about HST and IBST, we do organize another symposium inside the next ESHS Conference in Barcelona (november 2010) where the field of the IBST will be also examined[45]. As result of the “Mind the Gap”project, we worked on the creation of an European research[46] network with the ambition to prepare answers to the next European calls about “Science & Society” and the role of philosophy and history of science in Education. We do consider IBST as a Open Problem Based Science Teaching. We shown on Part I that HST could contribute to produce authentic pedagogical problems well-adapted to IBST. The aim of the European network will be :

- to publish on-line resources in history of science in diferent euroepan language and well-adapted to education
- to produce research results about “HST & Education”

The second conclusion concerns the research field about resources in HST with ICT tools for IBST. 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[47], 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 2006[48]). The design and engineering of learning systems about IBST with resources in HST must be considered as an 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 and Al. 2004[49]).

We think that a major point for the future is to work on adaptive technology-enhanced learning systems using a problem-based learning approach and represented by IBST scenarios [50]. The goal of

[44] Third ESHS Conference, Vienna (2008) : Abstract book on line, pp. 45-48, http://conf.ifit.uni-klu.ac.at/eshs/images/M_images/PDFs/suss.%20liste.%206.%20sept.pdf

[45] Fourth ESHS Conference, Barcelona, http://conf.ifit.uni-klu.ac.at/eshs/images/M_images/PDFs/suss.%20liste.%206.%20sept.pdf

[46] University of Barcelona, Spain : M.R. Massa, P. Grapi; University of Flensburg, Germany : P. Heering, University of Athens, Greece : P. Kokkotas, University of Brest, France : O. Bruneau, G. Chambon, S. Laubé, ; Université de Lens, France : T. de Vitorri ; Universite de Guadeloupe, France : H. Ferrière

[47] http://www.intermedia.uio.no/display/Im2/Kaleidoscope

[48] 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)

[49] 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)

[50] Laubé Sylvain, Garlatti Serge, Tetchueng Jean-Louis (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

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 (Quintin, Depover et al. 2005). 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[51]. These ontologies can be used to formalize at knowledge level the different required models of learning systems: learner and teacher models, domain model (i.e. the gender of of digital documents in HST, 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[52] 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[53] 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 technology and computer science researchers to work together about ICT and innovation[54]

To conclude this report, we would focus on the fact that the topic "HST, ICT and IBST" means now a new topic in order to be developped in the future. The "Mind the Gap" project has created an initial network about these issues. Several actions for future years are already taken : the ESHS symposium "HST & Education" in Barcelona in november 2010, a collective book as result of our the European workshop in Brest[55], collaboration project between European universities and labs in order to propose collective answers to the next calls about "Science and Education", but also "Technology-Enhanced Learning"[56].

---

[51] About ontologies for computer science, see: http://semanticweb.org/wiki/Main_Page
[52] http://pahst.bretagne.iufm.fr/?p=84
[53] http://ec.europa.eu/information_society/eeurope/i2010/invest_innov/index_en.htm
[54] http://ec.europa.eu/information_society/tl/research/documents/ict-rdi-strategy.pdf
[55] Editors : P. Grapi (University of Barcelona, Spain), P. Heering (University of Flensburg, Germany), M.R. Massa (University of Barcelona), S. Laubé (University of Brest, France), T. de Vittori (Université de Lens, France)
[56] See, for example, http://www.noe-kaleidoscope.org/telearc/news/default-0-read317-display