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Local culture and IBSE strengths and challenges & bibliography mapping complete

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Abstract (for dissemination)	We present here a survey on IBSE state of the art, where we try to evidence strengths and weaknesses of the method. We also report a mapping of the bibliography on IBSE where we have explored in detail current local barriers to IBSE across European countries.

1. INTRODUCTION

The aim of TEMI is to help transform science and mathematics teaching practice in Europe, by giving teachers new skills to engage with their students, and exciting new resources together with the extended support needed to effectively introduce inquiry based learning into their classrooms. For this purpose, TEMI will work with teacher training institutions and teacher networks across Europe, to implement innovative training programmes called 'enquiry labs'. These will be based around the core scientific concepts and emotionally engaging activity of solving mysteries, i.e. exploring the unknown [TEMI Annex 1].

Even if an Eurobarometer survey on the causes of European young people's disaffection from scientific studies, relates a lack of appeal to the perceived difficulty of these subjects and the poor salary prospects for those working in the world of research [Carpineti et al 2011], there is by now a great amount of research that has given evidence that the way science is traditionally taught is a central cause of students' declining interest in the subject with age [13 Science Education NOW] . The reported decline in student motivation in science occurs mainly between the ages 11 and 16, this is why TEMI is focusing the actions on secondary school [TEMI Annex 1]. The PISA assessment [PISA products] shows some improvement in the scientific literacy of most European countries in the last years, but these improvements are patchily distributed and do not generally affect the general perception of science that is mostly retained to be tedious and lacking of creativity.

From the pioneering studies of Rosalind Driver of '70-'80 [Driver 1985] there has been a growing interest in Inquiry Based Science Education (IBSE) that is now probably considered by researchers the most effective teaching strategy.

Research also suggests that although many teachers believe that enquiry methods are more effective, in practice they do not actually use IBSE at school [Yerrick 2000].

We present here some strengths of IBSE together with most impelling challenges to overcome most important barriers to IBSE implementation in schools.

2. STRENGHT AND WEAKNESS OF IBSE

Traditional teaching, which is mostly teaching by telling, is in general faster and easier than teaching by inquiry. Actually, it considers separately subjects and methods, stimulates little motivation in studying and allows a very poor understanding of the nature of science. It emphasizes knowledge of facts and laws, while the work in labs is used as a verification of previously stated laws. It is focused on answers given to questions posed by the teacher. In traditional teaching science is presented more as a body of knowledge than a way of discovering and building [see for example [MC Dermott et al 2000].

In fact, there is by now clear evidence that teaching by telling is inadequate, as can be inferred by the failure of standard courses. Moreover, even traditional assessment methods are inadequate: teachers should give much more importance to the act of listening instead of that of talking in accessing the intellectual state of students. Besides, in traditional questions, skills in math and science can often mask underling problems in understanding and in appreciation of the science as a culture; therefore, the role of qualitative questions in eliciting students' thinking must be highlighted and improved.

In fact, a survey on the perception of physics carried out with a sample of approximately one thousand high school students in Milan and its province, showed that most of them consider physics as a useful resource, believe that physics is important to society and, besides, that young people should learn its fundamentals [Carpineti et al. 2011]. However, they perceive physics as a subject mainly related to technological development in strict terms, and what's more, they do not see it as closely related to culture, and therefore as capable to affect the ways society thinks and perceives. This is generally considered as a task belonging to humanistic subjects. Moreover, most of the interviewed students believed that physics is too difficult a subject to be understood by most people.

Importantly, according to the data collected, schooling has a negative effect: the appreciation for physics tend to fade over time, generally decreasing as the grade attended increases. Whereas 49% of the students of the 9th and 10th grade deem physics is fascinating, and only 11% think it is a boring subject; in the 13th grade these percentages respectively decrease to 28% and 21%.

This situation may also have important social repercussions. In fact, to be able to really live in a democracy today, people must be scientifically literate because only informed people are able to show real critical attitude. In the book *Scienza e media ai tempi della globalizzazione* (Science and media in the globalization era]) [Greco et al. 2009], the authors Pietro Greco and Nico Pitrelli say that “without a public communication of science there cannot be a real democratic knowledge-based society”. The difficulty is that being scientifically literate (which is a lot more than possessing information about science) is very complicated. Possessing information alone is not enough to make founded choices: in order to do it, a benchmark is needed to interpret data, to distinguish truth from falsity, and therefore a personal knowledge of how science works is compulsory.

Just as an up to date example of the increasing interest in the question above, we report that in July 2013, the European Physical Society (EPS) organized a workshop in Panormo (Greece) which brought together experts in science education to define the framework for the development of a European Science Education Academy [ESEA].

The discussions among workshop participants recognized the need to work together on issues such as ensuring high-level pedagogic content and to increase teachers’ effectiveness in schools. For this purpose they underlined the promotion of a standard-based approach to IBSE and the need of a powerful outlook for the long-term of its implementation.

IBSE STATE OF THE ART

As opposed to traditional teaching, inquiry teaching considers methods and subjects together and brings students to follow step by step the scientific process by observing, stating problems, controlling variables, making hypotheses and predictions, and drawing conclusions. It emphasizes the nature of science and is focused on questions posed by the students themselves. Therefore, it integrates labs into course discussion and it is centered on students learning rather than on teachers teaching [Rocard report].

IBSE methodology is based on the some well-established results of research in science education; mainly that:

- Understanding in science is much more than just knowing the facts;
- Everybody, in particular students, understand and structure their new knowledge by modifying and refining their current concepts and by adding new concepts onto what they already know and believe;

- The social environment in which learners interact is fundamental in mediating learning;
- Effective learning requires that students are aware and take control of their own learning.

For the reasons previously stated, teaching by inquiry encourages personal thinking, questioning, peer discussion and debates. During inquiry lessons, the teacher should avoid appeals to authority while maintaining an environment favorable to inquiry, and should behave as a fellow investigator. Students, in an IBSE approach, work in group with own posed questions, make observations, create and conduct experiments, collect and try to interpret data, formulate hypotheses, draw and defend conclusions on the basis of data.

In fact the National Research Council (NRC) has defined inquiry as ‘‘a set of interrelated processes by which scientists and students pose questions about the natural world and investigate phenomena; in doing so, students acquire knowledge and develop a rich understanding of concepts, principles, models, and theories’’ [National Science Education Standards (1996)]

Unfortunately there are two features in making science that are crucial for having successful inquiry but are problematic with regard to creating scientific experiences at school.

The first feature is the problem that context matters. Scientists operate in an existing framework that guides most of the aspects of their work, for example in judging what can be considered as evidence or what is, or is not, orthodox. Moreover, they feel the necessity/opportunity of a work that is coherent with previous practice and works done by other scientists. On the contrary, students have personal ideas that need not be coherent: *ad hoc* interpretations of natural phenomena appear to work quite well in practice. In general there is a large research evidence that often students use fast thinking to invent plausible understanding of a phenomenon that, quite obviously, need not be coherent with explanations of other phenomena [Driver et al. (1985) and Meyer et al. (2013); Guisasola (2013)]

The second feature refers to the fact that differing interpretations and conclusions can be, also coherently, inferred from the same set of empirical data; especially at the cutting edge of scientific work. This is just the situation in which students are in an inquiry lab, for they are working on what it is new for them. However, this is not the typical situation in which a teacher is, because generally she/he knows the “correct” interpretation.

These two features claim for the importance of a proper educational management of inquiry lessons and, therefore, of a proper effective teachers’ inquiry training labs [Hoffstein et al. (2013)].

CHALLANGES IN TEACHERS’ TRAINING TOWARDS IBSE

Prospective teachers, but often also well experienced teachers, enter teacher training programs and courses with a traditional transmission-oriented view of teaching and learning (in fact you teach mostly the way you are taught…). “Implementation of inquiry can be difficult as the vast majority of teachers have been taught themselves through more traditional direct transmission approaches and hence, may find it difficult to convert to a teaching approach they would never have used nor experienced before” [Barron et al (2012)].

Exactly as their students, teachers are not blank blackboards, but they attend their courses with ideas, that will affect their learning to teach ideas that are going to persist even when they are contradicted by very poor teaching results. In fact, the width of modifications of our viewpoint depends a lot on the ideas we start with, so that teachers attending the same course will not retain, in general, the same points at the end.

In fact, well-established beliefs are strong and resistant to change. It is well-known the fact that even after lessons, students do not modify their ideas, in spite of the teacher’s attempts to challenge them with counter evidence. The same happens in teachers’ training. Teachers often use information from their training courses to confirm their pre-existing beliefs, and are mostly not affected by the findings of educational research [Driver (1985) and Cassidy (2013)].

In particular, for what concerns IBSE, teachers have several pre-training ideas about inquiry teaching, as for example that the scientific method does not include inquiry, that questions have only right or wrong answers, that inquiry teaching is chaotic and, above all, that inquiry requires more time and more efforts than traditional teaching. [Cassidy (2013)].

Many research results report about the challenges to the use of IBSE [see for example Brown (2006); Chinn (2002); Hye Gyoung (2012); Meyer (2013); Wenning

(2005); (2006); (2008) and (2011); Windschitl (2003)]. The most common perceived problems with inquiry teaching, that make teachers not feel at ease with inquiry teaching, can be summarized in the following list:

- The time required is too much (probably the most common barrier);
- The lack of resources;
- The large amount of energy to spend;
- The perception that topics are covered too slowly;
- Lecturing can be very difficult;
- The risk not to fulfill national curriculum requirements (including the risk of not getting students enough prepared for examinations);
- Assessment: Many difficulties in tracking the progresses and the work done by students;
- Student constraints (students do not have the cognitive skills or reasoning skills that are required for inquiry based learning-; maturity levels; habits to rote learning).
- Teaching habits;
- Textbooks are, in general, not adequate;
- Lack of teachers' motivation.

In general, we can classify the most common barrier to what is inquiry, and on how to implement it in classroom, as extrinsic, pedagogical and intrinsic barriers [Hye Gyoung et al. (2012), and Meyer (2013)].

Extrinsic

Time is perhaps the most common of extrinsic barriers and is a great source of pressure for teachers. The issue of time constraints could be broken down to a number of factors related to time. Some teachers reveal that the time of day is a factor which influences the teaching of scientific inquiry. The time constraints associated with having to complete the program are also noted. Finally, the time taken to plan and source resources for inquiry activities is also an impeding factor to the action of inquiry. The (sometimes only believed) rigidity of the curriculum is another extrinsic barrier. In addition, difficulties with colleagues can be seen as another extrinsic barrier.

Finally, we cannot forget the problem of the lack of resources: the lack of equipment and breakage of equipment is identified as a challenge. The facilities, the sharing of limited lab space and the timetabling of classes outside the lab are recognized as being disabling factors towards the implementation of inquiry. The expensive equipments needed, can also be a barrier to inquiry and the issue of larger class groups could be also important.

Pedagogical

The Pedagogical category is not specific to inquiry-based teaching and reflects inherent difficulties any teacher or curriculum designer would be expected to face, regardless of subject matter. For instance: how am I able to engage students? Will students be able to understand what I am proposing them? Are the activities effective for students? I.e. is working in groups effective or is it time wasting? Will the lab work be done by every student, or will there be some students boring? [Meyer (2013)]

Intrinsic

Task was the most common of the intrinsic hurdles. Is the task reasonable for students? Will they be able to gain knowledge form the work done? Will they lose time? Is the inquiry lab authentic or will students follow other (internet or book based) out of control suggestions?
Has the task proposed the right balance of complexity and accessibility, while being also reflective of the real world? [Hye Gyoung et al. (2012)]

There is another great barrier emerging from research [Windschitl (2003)]: teachers who did not have a significant experience of research, have great difficulties in implementing IBSE.

In fact, inquiry is a crucial part of science. Unfortunately the great majority of pre-service teachers often enter their preparation training activities without having conducted a single inquiry experience in their lives; that is without having ever posed a scientific question and planned and designed an investigation to answer that question [Windschitl, 2000 **23**]. Therefore these teachers will not be probably able to develop the idea of using inquiry with their students even because they will not feel able of managing such a complex teaching methodology.

Moreover, teachers who have a poor metacognitive knowledge of their discipline are less able to bring inside their teaching aspect relating on learning how to learn and in making interdisciplinary connections. Sometimes teachers show also a lack of syntactic knowledge of their discipline, fact that may also limit these teachers to learn new information in their fields because they may be unable to determine the validity of claimed discovery within a field.

LOCAL BARRIERS ON IBSE

There are few research results reporting about local barriers against IBSE, and, to the best of our knowledge, they do not explicitly consider differences among European countries. Actually, a detailed comparison between local barriers against IBSE is reported in a study [Abd-el-Khalick (2004)] concerning a number of non European countries (Lebanon, USA, Israel, Venezuela, Australia and Taiwan).

We think it interesting to evaluate the different attitudes towards IBSE of teachers coming from the various TEMI countries. For this purpose we have prepared a questionnaire to be submitted to teachers (See Appendix 1). The idea underlying the questionnaire is to characterize typical teachers' profiles; to identify which skills teachers think to be most important to teach effectively; to understand to what extent they think that teaching methodology can affect teaching results; and finally to monitor their knowledge, and appreciation of IBSE.

Until now we have submitted the questionnaire to 58 Italian pre-service teachers, to 286 Austrian teachers (various seniorities), to 14 Israeli teachers and to 31 Irish teachers. We have compared these results to those obtained in Ireland in a PhD thesis.

The data collected until now are globally in agreement with the results reported in literature although some differences can be noticed between the four countries. We plan to increment this research, collecting data coming from other countries, but in the meantime it can be useful to compare the principal difficulties perceived by the teachers in the various countries.

In Italy the most important obstacles to IBSE were recognized as

1. Time 37%
2. Difficulties in managing the class 20%
3. IBSE perceived as not effective 17%
4. Rigidity of the curriculum 14%
5. Not enough prepared for IBSE 6%
6. Hostility and/or difficulties with colleagues 6%

In Austria, the categories are almost the same and the results can be summarised as:

1 Time 34 %

2 Difficulties in managing the class 20%

3 IBSE perceived as not effective 2%

4 Rigidity of the curriculum 8 %

5 Not enough prepared for IBSE 11 %

6 Hostility and/or difficulties with colleagues 1 %

7 Lack of resources and room facilities 16 %

8 Others (organization, personal habits, school system) 8 %

The Irish results are reported in the following. The percentages are calculated on the number of teachers who answered the questionnaire (31), although, some of them have indicated more than one obstacle against IBSE, for a total of 40 answers in spite of 31.

1 Time 55 %

2 Difficulties in managing the class 1 %

3 IBSE perceived as not effective 0 %

4 Rigidity of the curriculum 9.7%

5 Not enough prepared for IBSE 6.5 %

6 Hostility and/or difficulties with colleagues 3.2 %

7 Lack of resources and room facilities 26 %

8 Others (organization, personal habits, school system) 26 %

The Israel results are resumed in the following. As in the case of Ireland some teachers have given more than one answer (total number=17), but the percentages are calculated on the number of teachers (14).

1 Time 7%

2 Difficulties in managing the class 57%

3 IBSE perceived as not effective 29 %

4 Rigidity of the curriculum 0%

5 Not enough prepared for IBSE 14,3 %

6 Hostility and/or difficulties with colleagues 0 %

7 Lack of resources and room facilities 7 %

8 Others (organization, personal habits, school system) 7 %

As it can be noticed (see Fig. 1), time is the basic problem recognized in Austria, in Italy and in Ireland. By contrast in Israel only 7% of the teachers mention time lack as a challenge. The difference in this case is particularly impressive as in the literature time is almost unanimously reported as the most important challenge against IBSE perceived by teachers. Actually the statistical sample for Israel is quite small, and this can affect somehow the results.
Difficulty in managing the classes is perceived as a problem by a large number of teachers in Austria and in Italy (both 20%), and in Israel (57%) although only 1% of the Irish teachers cite it as a possible challenge. Another important difference between the countries is that IBSE is perceived as not effective by 17 % of the Italian teachers who answered the questionnaire, by 29 % of Israeli ones but only by 2% Austrian and none Irish ones. A final difference is that the lack of resources and room facilities is perceived as an important challenge against IBSE by Irish, Austrian, and Israeli teachers (by 26%, 16%, and 7% of them, respectively), while it is not even mentioned by Italian teachers.

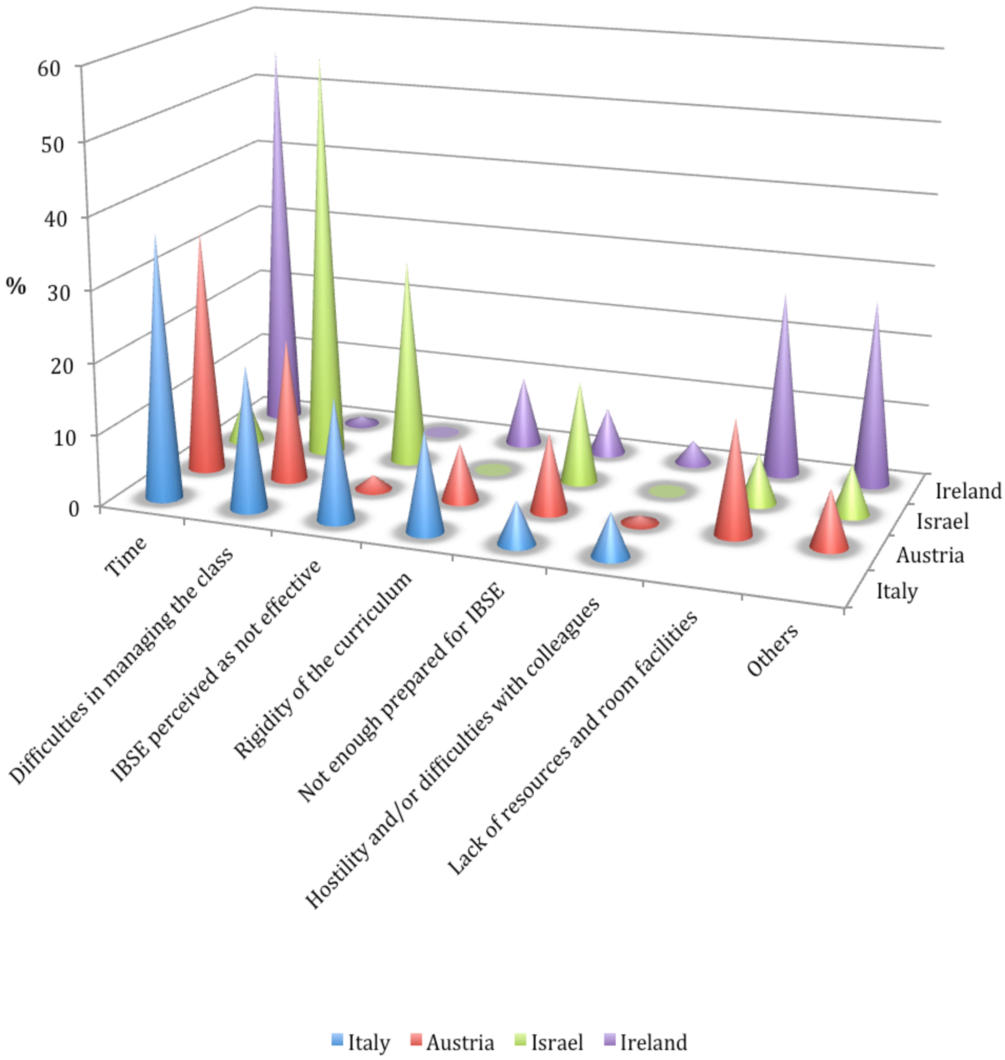

Figure 1

Another interesting result is that a large percentage of teachers do not know the existence of IBSE (approximately 40 % in Austria and Italy, and 23 % in Ireland). This is extremely surprising, as IBSE is widely cited in most of the programmatic teaching documents. Moreover, for what concerns Italy, the questionnaire was answered by 58 perspective teachers in math and physics at the TFA (Formative Active Training) course of the University of Milan, where they have all been introduced to IBSE.

The preliminary results of our research indicate that some local differences in the barriers against IBSE perceived by teachers probably exist. Actually, it emerges quite clearly that, as it is reported in literature, the action of inquiry is still very much the exception rather than the norm. A large majority of teachers report to give students step by step instructions, or to carry out the procedure themselves. This result reflects the teachers' approach to science that has become all too familiar in the classrooms. We plan to detect some of the constraints which teachers identify as preventative factors towards implementing inquiry.

OTHER EUROPEAN PROJECTS ON IBSE

Another issue we need to address is the interplay of TEMI with other enquiry based FP7 projects in each country. This factor must be taken into account in thinking about the local culture and IBSE strengths. In fact, as it is well explained in the interesting report of the project INSTEM [26], many good practices and recommendations can be derived by the comparison with other projects.
In the following we briefly describe some of the IBSE EU funded projects:

CHREACT – (Chain Reaction: A Sustainable Approach to Inquiry-Based Science Education) The Chain Reaction project aims to capitalize on a previously successful approach to delivering IBSE in the UK in an attempt to embed IBSE practice within European schools. The key aim is to equip teacher educators to train teachers across twelve countries in the use of IBSE materials and techniques. The Project is coordinated by Sheffield Hallam University and the consortium includes the University of Limerick. The project will take 3 years to complete and it officially began on 1st June 2013. Website: To be confirmed.

ESTABLISH – (European Science and Technology in Action: Building Links with Industry, Schools and Home) is a four year (01-01-10 – 31-12-13) project funded by the European Commission's Framework 7 Programme for Science in Society. The overall objective of this project is to facilitate and implement an inquiry-based approach to science education for second level students (age 12-18 years) on a widespread scale across Europe by bringing together, within a collaborative environment, the specific key stakeholders in science education.
ESTABLISH is coordinated by Dublin City University Website: http://www.establish-fp7.eu/

EU UNIVERSE AWARENESS- INSPIRING EVERY CHILD WITH OUR WONDERFUL COSMOS - EU Universe Awareness uses the beauty and grandeur of the Universe to inspire young children and encourage them to develop an interest in science and technology. The programme also aims to introduce children to the idea of global citizenship and tolerance at a crucial stage of their development – to show them that they are part of an international community. Until the advent of EU Universe Awareness, there were no large scale attempts to use astronomy as a tool for inspiring and educating young children. Therefore, while our resources are open to all, the programme is aimed at children aged 4 to 10 years, especially those from underprivileged communities.
Project is coordinated by Leiden University, the Netherlands and funded by European Community's Seventh Framework Programme ([FP7/2007-2013]) under grant agreement n° 263325

FIBONACCI – The aim of this programme was to design, implement, test and formalise a process of dissemination in Europe of inquiry-based teaching and learning methods in science and mathematics in primary and secondary schools. This project began in January 2010 and ended in February 2013. Fibonacci was coordinated by École normale supérieure (Paris) and included St. Patricks College, Dublin as one of its twin centres.Website: http://www.fibonacci-project.eu/

PATHWAY- The objective of this three year (01-01-11 – 31-12-13) project is to set the pathway toward a standard-based approach to teaching science by inquiry. The project aims to support the adoption of inquiry teaching by demonstrating ways to reduce the constraints presented by teachers and school organisations, to demonstrate and disseminate methods and exemplary cases of both effective introduction of inquiry to science classrooms and professional development programmes, and to deliver a set of guidelines for the educational community to further explore and exploit the unique benefits of the proposed approach in science teaching.
This project is coordinated by University of Bayreuth and includes Dublin City University as a partner.
Website: http://www.pathway-project.eu/

PROFILES – (Professional Reflection-Oriented Focus on Inquiry-based Learning and Education through Science) is a four year (01-12-10 - 30-11-14) project funded by the FP7 programme of the European Commission. This project aims to disseminate Inquiry-Based Science Education by conducting and using innovative learning

environments and programmes for the enhancement of teachers' continuous professional development.
The Freie University in Berlin is the coordinator of this project of which there is a consortium of 21 partner institutions, including University College Cork.
Website: http://www.profiles-project.eu/

SAILS – (Strategies for Assessment of Inquiry Learning in Science)is a four year (01-01-12 to 31-12-15) project which aims to prepare second level science teachers across Europe, not only to be able to teach science through inquiry, but also to be confident and competent in the assessment of their students' learning through inquiry. This ongoing project is coordinated by Dublin City University, which also has a second Irish partner involved, INTEL Performance Learning Solutions Limited (private company).
Website: http://www.sails-project.eu/portal/

Although no formal coordination has taken place between these projects, some contacts have been established, in particular with PROFILES, PATHWAY, CHREAT and ESTABLISH.

Finally, we point out the existence of INSTEM, which, although not a FP7 project is extremely relevant for our report. INSTEM (website: http://instem.tibs.at/) is a Comenius network (2012 – 2015), which brings together the experience and learning of a wide range of projects in European Science and Mathematics education. INSTEM links research, practice and policy in a unique way. Its main goal is to promote inquiry based teaching, to gather innovative teaching methods and to raise students' interest in science as well as offering them careers information in STEM subjects, in order to respond to global challenges in teaching and gender imbalances in STEM education. In particular, in the report [27] many interesting ideas can be found, but in particular a long list of other IBSE related EU projects.

3. IMPROVING TEACHERS' TRAINING TOWARDS IBSE

Direct experience is important in itself. In order to understand what is entailed in creating an inquiry-oriented learning situation, prospective teachers need opportunities to learn about the inquiry approach both implicitly and explicitly. In fact, subject-matter knowledge does not necessarily provide the expertise to conduct inquiry-based teaching labs; but, being able to improve your own knowledge in a field is not enough for being able to teach others how to learn; and finally, not even the pedagogical knowledge of how one learns is enough. A pedagogical content knowledge is required [Schulman's (1988)].

Inquiry training labs should also improve teachers' awareness of what they are doing together with their mastership in conducting classrooms inquiry labs.

In this situation, we have the need to turn the (perceived and/or real) lack of disciplinary preparation of teachers into an opportunity.

A great possibility is that *inquiry training labs* be prepared with activities in which teachers are strongly and actively engaged, but in which they are not confident. In fact, the more the inquiry lab with students at school is "real", the more it is effective. Teachers should be motivated to undertake also inquiry paths giving rise to questions and answers not already known to them before.

And here a fundamental problem comes: constructing new knowledge requires some sort of knowledge base to work from; but, for a task not to appear trivial there must be opportunities for lacking knowledge and also honest disagreement in given answers. These two requirements strongly design the landmarks for good tasks.

Also, the affective side of learning must be promoted, because it is one of the strongest motivational forces. For this reason, TEMI inquiry labs are so strongly grounded on the sense of mystery, because it is a strong boost towards exploration and discovery. Before any inquiry activity, there must be a mystery perceived. If some piece of scientific knowledge is not perceived as an answer to a mystery to be solved, then it will be easily seen as a mechanical, non-culturally embedded, activity.

The experience of some of us (especially the Milan University group) indicates that the scientific theatre shows can be very effective as a first step in generating motivation in students and in facing them with mysteries in science [Carpineti et al (2011)]. Therefore, they can be a way to overcome initial and important barrier towards IBSE implementation in school. The widely use of mysteries in inquiry labs should also be very effective in engaging a large part of the students.

To get over the barriers given by national standards curricula and by final examinations, it could be very important for the inquiry labs to create groups of teachers coming from the same school and, moreover, having a strong headmaster support. More in general, stakeholders are fundamental even because the image of IBSE as a fundamental didactic strategy should be strongly advertised to foster the required changes in the teachers' role. Probably a critical mass of teachers practising IBSE would be required before a widespread use of it is fostered.

Curricula developers, publishing houses and also evaluators have to be strongly coupled in inquiry teachers' formation in long-term activities.

To improve IBSE effectively, adequate locations are also important. For instance, the designing of the lab-room is important not only to perform own-thought experiments, but also to be able to facilitate peer discussion. For this purpose a classroom with all the desks oriented towards the teaching post is certainly not suited. Much better is when students can work around a table [Elkis et al. 2013].

A crucial role should be given in integrating research findings into practice. In fact, part of the ineffectiveness of research results in school practice can be addressed to the attempt to transfer general findings, instead of integrate them into practice. For this purpose we have to construct formation modules with teachers that have to expand their competencies together with content and pedagogical knowledge, in an integrated and more general pedagogical content knowledge [Sperandeo RM (2013)].

In order to overcome the lack of experience in research that teachers often show, there is the great opportunity to improve some classroom action research in which lessons become also a devise to make research on students' thinking and a way of approaching scientific themes, looking thus at teachers as researchers [Mamlok-Naaman & Eilks (2012)]. Therefore teachers need less educational paths coming from research and more structured activities built together by teachers and trainers. The effectiveness of this activities coming from inquiry labs could be monitored and evaluated keeping in mind three phases of work in the inquiry labs:

1) The work done together by instructors and teachers
2) The work done by instructors - teachers - and students
3) The students "final" learning results.

Moreover, in order to have cascade effect interventions should be reproducible.

In IBSE teachers' training, traditional strategies that presents first a general framework and then tries to apply it to real problems should be inverted.

The study should begin with open-ended investigation in the laboratory where students can become familiar with the phenomena of interest. Instead of starting with new concepts or principles by definitions, the teacher should build up situations that suggest the need for new concepts and/or new principles. [Mc Dermott (2000)].

For instance instead of speaking first of the general item of waves, and then study the problem of noise pollution, one can start from the problem of noise pollution and, only when needed, deal with mechanical waves and energetic questions. Obviously, this approach should not be concretized in *a priori* specific path, otherwise inquiry would be prevented. Therefore only some scientific and educational landmark must be pre assigned or prepared and the knowledge cycle, engage - explore – explain – extend – evaluate fostered.

The teacher should pose questions designed to help students think critically about and task questions on their own. Very often the good response to most questions is another question that can help guide the students to arrive at their own answers.

It is also important to recognize that concept formation requires students to become mentally engaged. Therefore remarks and hints should be given with great accuracy and generally they should be consciously resisted (even if with some difficulty).

Findings from research indicate that the quality of student response to questions increases significantly with an increase in “wait time”, the time the instructor waits without comment after asking a question [Mc Dermott (2000)].

In the labs, teachers should improve their competences in designing an experiment, in collecting data, in analysing the data collected, in the use of multiple representations in describing phenomena and explanations with words, diagrams or formula. Moreover teachers must be prepared not to teach … because instructions must not interfere (at least in first steps) with students thoughts and connections.

The implementation of IBSE in school is an important challenge for the future of our schools, and it is a long-term goal. In order to continuously follow the teachers in their work, strongly interconnected problem-based network must be used. TEMI project will create local and European support communities, both face to face and online, where teachers and other stakeholders can exchange experiences and best practices around the IBSE activities, providing continuous support to facilitate transformational change in classroom practice [TEMI].

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APPENDIX 1

TEMI questionnaire to be submitted to teachers (2013/2014)

Personal information

1. **Gender**

○ M

○ F

2. In which kind of school do you teach?

○ Public school

○ Private school

○ Presently I am not teaching

Age of your students

○ 14-16

○ 16-19

3. Which subjects do you teach?

4 How many years have you been teaching to date?

5. Which skills do you think to be important for a good teacher?

(from 0=not important at all to 10=extremely important)

	0	1	2	3	4	5	6	7	8	9	10
Knowledge of the topics	○	○	○	○	○	○	○	○	○	○	○
Communication skills	○	○	○	○	○	○	○	○	○	○	○
Competency in the use of technical tools (microscopy, computer, etc.)	○	○	○	○	○	○	○	○	○	○	○
Accurately plan the lesson as a function of the class characteristics	○	○	○	○	○	○	○	○	○	○	○

Modify the approach when unexpected difficulties emerge during the lesson	○	○	○	○	○	○	○	○	○	○	○
Operate in different areas and environments (in the classroom, in the laboratory, in a museum etc.)	○	○	○	○	○	○	○	○	○	○	○
Proactively engage students in the activities	○	○	○	○	○	○	○	○	○	○	○
Transfer to students curiosity and passion for the subject	○	○	○	○	○	○	○	○	○	○	○
Be available to answer the questions of students	○	○	○	○	○	○	○	○	○	○	○
Regularly propose group activities besides individual activity	○	○	○	○	○	○	○	○	○	○	○
Evaluate from time to time the effectiveness of the lessons	○	○	○	○	○	○	○	○	○	○	○

Relate with other teachers about the respective works	○	○	○	○	○	○	○	○	○	○	○
Keep competencies up to date	○	○	○	○	○	○	○	○	○	○	○

Others (+ rating 0-10)

…………………..

………………….

…………………..

……………	○	○	○	○	○	○	○	○	○	○	○

6. In a rating scale from 0 to 10, in your experience, how much important are teaching methods, to obtain

	0	1	2	3	4	5	6	7	8	9	10
Motivation	○	○	○	○	○	○	○	○	○	○	○
Development of scientific knowledge	○	○	○	○	○	○	○	○	○	○	○
Opportunity to pursue an active learning	○	○	○	○	○	○	○	○	○	○	○

	0	1	2	3	4	5	6	7	8	9	10
Understanding of scientific concepts	○	○	○	○	○	○	○	○	○	○	○
Reasons for teamwork	○	○	○	○	○	○	○	○	○	○	○
Developing skills (to observe, to argue etc.).	○	○	○	○	○	○	○	○	○	○	○

7. In a rating scale from 0 to 10, which aspects should be strengthened to promote scientific learning of a subject matter?

	0	1	2	3	4	5	6	7	8	9	10
Disciplinary preparation of the teacher	○	○	○	○	○	○	○	○	○	○	○
Adopted methodology	○	○	○	○	○	○	○	○	○	○	○
Extracurricular activities proposed by the teacher (non-formal and / or informal)	○	○	○	○	○	○	○	○	○	○	○
Lab activities	○	○	○	○	○	○	○	○	○	○	○
Active role of	○	○	○	○	○	○	○	○	○	○	○

	0	1	2	3	4	5	6	7	8	9	10
the students											
Interdisciplinary activities	○	○	○	○	○	○	○	○	○	○	○
Connection with reality ...	○	○	○	○	○	○	○	○	○	○	○
Students' motivation	○	○	○	○	○	○	○	○	○	○	○

8.Do you know I.B.S.E. (Inquiry Based Science Education) method?

9. If yes, have you applied it at least on one occasion? Briefly describe your experience (context, content, outcomes ...)

○ Yes

○ No

If yes

10. What are or could be possible obstacles to the use dell'IBSE?

Thank-you for your cooperation.