Report

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Dissemination strategy for inquiry-based methods in France

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Note: As the purpose of this document is to provide recommendations specifically geared towards the French educational system, the French version of this text is definitive, and provides an account of current thinking about IBST and its dissemination in France, based particularly on the results of the French S-TEAM National Workshop, Grenoble, October 20-22, 2009. The English version follows the French text but is not a direct translation.

For further information about S-TEAM see: www.ntnu.no/s-team

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Introduction: Inquiry-based methods: a dynamic of European policies

Declining interest in scientific studies and careers is currently affecting European countries. This decline could be problematic for scientific and economic life, as well as for civic society, since understanding of scientific and technological knowledge is necessary to take part in current societal debates. These facts are made clear in the Rocard report, *Science Education Now!*[1] To overcome this difficulty, the authors of this European report rely on the introduction of new teaching methods, and especially on inquiry-based science teaching (IBST). **Can schools take up this challenge** through improved teaching methods and teachers' professional development? The S-TEAM project aims to explore this question.

The extension of a long-standing dynamic in IBST

The renewal of teaching demanded by the Rocard report does not appear from nowhere. It is based on experiments that appeared to be successful in Europe and particularly on the initiative *La main à la pâte* initiated in France by a group of renowned scientists. Nevertheless, as often happens with French educational reforms, many actors believe that similar methods have already appeared in educational history. In his lecture for the French S-TEAM National Workshop (October 20th-22th, 2009, Grenoble), Joel Lebeaume showed how, since the 1960s, IBST methods seem to be prefigured by many prescribed teaching strategies (e.g. scientific experimental works, in 1960). From the same perspective, in 1968, a French minister's circular proposed to develop such inquiry-based methods in order to enhance students' interest in science and to encourage a scientific attitude. As with current initiatives, these texts emphasised both the pupils' active role in the learning process and the need for coordination or integration of science subjects. **Do we, therefore, face a perpetual cycle, constantly introducing initiatives that will eventually be phased out?**

Three factors allow us to think that educational history is not a simple repetition.

Firstly, **societal choices involving science are now very numerous and highly meaningful** for public opinion. They raise many new questions. Can we consume GM foods? Can we personally act on climate change? Do we always have to vaccinate? Therefore, to maintain the

[1] EC (European Commission) (2007) *Science Education Now: A renewed Pedagogy for the Future of Europe: Report of the High-Level Group on Science Education* Brussels, EC Directorate -General for Research: available at: http://ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf

quality of public debate, there is a necessity for pupils to understand the scientific approach because they will all become citizens, regardless of their future career in school and beyond.

Secondly, the **digitisation of many experiments** means that they no longer require as much equipment as was formerly the case (A 1968 Circular suggested the installation of a greenhouse and a breeding room in schools). Though electronic simulation of experimentation raises some problems, it provides a new way of presenting science to students. Through digital methods such as computer-assisted experimentation, new problems can be tackled and new solutions can be found. Thus, through the evolution of technology, IBST methods have additional potential to render obsolete the teaching practices that prevailed just a few years ago.

Thirdly, and in the same vein, the rise of the internet has vastly increased **the availability of pedagogical resources for teachers**. Databases, resource platforms and discussion forums are accelerating the dissemination of new teaching methods and practices. This raises both the question of the understanding of these resources by teachers and of their personal role in sustaining these websites. Thus, initial teacher education, as well as continuing professional development (CPD) programmes, are challenged.

Overview of the report

This report aims to develop some markers for the field and to outline some strategic proposals to effectively develop and promote IBST methods.

The report is in four sections. The first section aims to define inquiry-based science teaching (IBST). The second section reports on the place of IBST methods within the French curriculum. The third section analyses continuing professional development (CPD) programmes for science teachers, drawing upon case studies of the three French regions in which the S-TEAM project is located (Grenoble, Lyon and Rennes). The fourth and final section describes current projects aimed at developing pupil interest in science subjects.

The data collected for this report come from an exploration of the Internet sites of official bodies, associations or professional authorities in science education. The report also draws upon the contributions of participants in the S-TEAM French National Workshop held in Grenoble in October 2009. Finally, it includes data from an open questionnaire given to science education stakeholders (see appendix 1).

Section 1: Teaching strategies and inquiry-based science teaching methods

Six questions should be asked in order to understand IBST:

- What is the **definition** of the term 'IBST methods'?
- What are the overall **purposes** of these methods?
- What **distinction** can be made between IBST methods and traditional approaches to science teaching?
- How can the **change** from traditional methods be justified?
- What specific **benefits** do IBST methods offer to teachers or students?
- What new **constraints** do they imply?

1. The actors' point of view

1.1. Institutional actors

The first question regarding the definition of IBST is **whether a specific teaching strategy can be described as IBST**. The answer is important for teachers who need to have discussions about their experiences of well-defined and accepted practices. It is also important for observers of teachers, particularly student teachers, who need to understand the teachers' specific goals and the projected learning outcomes.

During the S-TEAM French National Workshop in 2009, Florence Robine (National Education General Inspector) suggested moving away from a definition of IBST as a "catalogue" (posing problems, providing hypotheses, proposing experiences, etc.) as suggested by a narrow reading of French school programmes. It might be more relevant to figure out what really happens in the class-room, and to understand activities from the point of view of teaching and learning. What is it that teachers do, what kind of autonomy do they allow pupils in expressing their thoughts, organizing their work, in discussions and what do the pupils actually do? Thus, the underlying goal of IBST is not the narrow application of procedures. The goal is to allow pupils to think by themselves, in order that they become active in science learning. It is therefore important to support **collaboration amongst pupils** and to develop **cross-disciplinary attitudes** such as the abilities of reasoning and **communicating with classmates and teachers**. Thus, IBST aims mainly at mastery of these competences for experimentation and argumentation.

With respect to mathematics, according to Patrick Ferrand (Coordinator of the scientific inspectors in Grenoble Region), the teachers' conception of IBST methods has evolved recently. A few years ago, this approach was only used for the introduction of new concepts, and these methods took up a high proportion of lesson time at the expense of other activities. Today, the new high school curriculum prescribes the setting of problems, allowing pupils to investigate and experiment with the relevant problem-solving tools. The overall aim is to improve **the competence of pupils to overcome problems from real life**, particularly scientific problems.

This point of view is shared by Nicolas Giroud (mathematics teacher), who defines IBST methods as ways of solving problems whose solution is unknown. The aim of the inquirer is to find a full or partial answer for the initial problem, through the retrieval of documentation or by conducting experiments. Thus, IBST methods allow students to "make" science, rather than just "seeing" its results. From the learner's point of view, being scientifically active and **responsible for the research process** is the main difference between IBST and traditional teaching strategies. If we consider that "doing mathematical research" is part of mathematics, then it is normal to allow pupils to 'live' this activity. It is an aspect of scientific activity that is often overlooked in the classroom.

Nevertheless, defining IBST is complex as it depends heavily on the subject area. Thus, according to Dominique Rojat (National Education General Inspector), in biology, there is a long history of methods based on pupil action even if the name of these pedagogies has changed over time (i.e. rediscovery processes, teaching by scientific problem). However, action alone is insufficient to achieve a genuine inquiry: action has to be justified and set within a global plan. Thus, to some extent, IBST is also a **project-based pedagogy**, and yet from the 1968 *Circular regarding biology instruction at the entrance of the secondary school* (age 11-12) two main objectives emerge:

- Awakening of students' interests through real world teaching strategies. This implies that understanding problems from real life is complex because these problems link various scientific fields. **Solutions require both specific knowledge and understanding of the problem's global nature**.
- Enhancement of pupils' **scientific attitude**, or "**scientific concern**". This implies that one should avoid giving them a false sense of security and should make them aware of the difficulties inherent in scientific research.

The word "inquiry", associated with "method" or "approach", appears in the French secondary school curricula in 2006. Nevertheless, it is already present in primary school programmes in

2002, mainly through the *La main à la pâte* approach. According to Jacques Toussaint[2], at the S-TEAM French National Workshop, all these terms lead to an emphasis on pupil action. However, from an epistemological point of view, inquiry is "*the deliberate study of the circumstances that are thought to relate to an existing fact or idea*"[3]. Thus, there is **neither a systematic search for a definitive answer, nor a rigid research design**.

In fact, IBST implementation corresponds to a double need. The first is related to the structure of scientific knowledge since "*for a scientific thinking, all knowledge is a response to a question. If there was no question, no scientific knowledge can appear*"[4] Therefore we must investigate and attempt to provide some answers. The second need is related to the elaboration of individual knowledge since psychological studies show that **knowledge building is supported by hands-on activities and discussion of the results amongst learners**.

The question of the difference between IBST and the traditional approach[5] depends on which approaches are being discussed. There is continuity with active methods, even with traditional ones. With traditional expositive methods, the difference concerns the practice of argumentation based on the analysis of natural or experimental facts by the students themselves. The successful implementation of IBST relies on improving the pupils' **attention**, **memory** of studied concepts, methodological **abilities**, and scientific **reasoning**. Thus, IBST emphasizes the need to improve interactions both with actual material and amongst learners.

IBST creates **a space of freedom for students**: they can ask new questions and try to resolve their own issues. Moreover the means which they can use are not imposed upon them, according to N. Giroud.

A constraint results from the fact that this activity seems **more suited to small groups** than the whole class, at least for new teachers, according to N. Giroud. It is also an activity that **takes time**, and programmes need to be better adapted. Those constraints are seen as less problematic by Hélène Combel[6], who reports that she has observed many teachers conducting very interesting IBST lessons, which are sustained by discussion amongst pupils; such observations occur also within very disadvantaged sectors. She suggests that teachers who are using IBST can easily cover the annual lower secondary school curriculum, which is specifically designed to give time to IBST. Nevertheless, **these IBST methods eventually impose a new teacher posture, a new way to deal with students**.

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[2] Recteur of Lyon counsellor and researcher in the sciences epistemology and didactic laboratory

[3] Ziman, J. M. (1984) An Introduction to Science Studies, Cambridge, Cambridge University Press, p.18

[4] Bachelard, Gaston (19971938) La formation de l'esprit scientifique: contribution à une psychanalyse de la connaissance objective Paris, Vrin, p.16.

[5] In S-TEAM we are beginning to use the term 'direct teaching' as the counterpart to IBST or investigative methods.

[6] Regional Pedagogical Inspector in Physics and Chemistry in Créteil

Evelyne Excoffon[7] insists that one of the aims of IBST methods is to increase student motivation. Thus, IBST methods and traditional expositive methods in science teaching represent two very different approaches: **creativity versus reproduction**. Thus, teachers have to change their posture: but can they accept such a change? In any case, this requires teacher development programmes.

1.2. University actors

According to Patrick Mendelsohn[8], the term 'IBST methods' refers to a structured movement, initiated by the French Academy of Science, which aims to renew teaching methods through experimental science. This movement results from the relative failure of traditional teaching practices, especially in primary schools. It aims to **return to the foundations of “what makes science”**, comprising an open mind for discovery, and an experimental approach in its active and playful dimensions.

If we assume that traditional science teaching approaches tend to emphasize the formal dimension of scientific activity (e.g. the application of a formula to answer a question), **IBST methods support the experimental approach and scientific reasoning based on practical problems in everyday life**. This distinction is justified by the results of the formal approach, which leads pupils to solve problems perfectly using equations, without the slightest idea of what really happens within the studied phenomena. These skills of repetition and application are often the focus of traditional assessment tests in French schools. Thus, IBST implementation should lead to a significant change in assessment methods.

The benefits of IBST methods are directly related to the principles on which they are based: **pupils can make sense of what they learn**, insofar as they are led to think in context and from a problem whose solution seems reachable. Such a motivational starting point allows strong pupil involvement in the process of reasoning and, at the same time, an understanding of how difficult it is to prove the stability of any scientific phenomenon. Finally, **IBST methods allow an integrated teaching approach** since many competences are taught and learned together: written and oral expression, reasoning, knowledge about the world and mathematics. Nevertheless, this integrated approach is very time consuming and requires specific teacher education and CPD in order to ensure that students actually develop transferable skills in new situations.

The above aspects of IBST are clarified by Joel Lebeaume[9]. For him, IBST methods involve **the initiation of pupil activity on the basis of their own questioning**, when the teacher has evaluated this as 'scientific questioning'. This origin of the questioning in the pupils themselves

[7] Regional Pedagogical Inspector in Physics and Chemistry in Grenoble

[8] Head of Teacher Education Institute (IUFM) of Grenoble region.

[9] Professor of Educational Sciences, Paris

creates a distinction between IBST and traditional approaches. Such a change is consistent with the French approach to teaching based on pupil competence development. Another advantage of IBST methods is that they usually imply **more dynamic lessons**, for both pupils and teachers. They also generate assessment practices that **take into account pupil development**. Finally, they are based on situations that emphasize the skills and capacities of those **pupils who are usually too quiet or who encounter difficulties at school**.

However, IBST methods do not work with all scientific concepts. There can be **a degree of artificiality in the starting points of some lessons**, where pupils' questioning is often marginalized. Additionally, IBST is **risky for teachers**: such methods require constant adjustments during the session and the matching of results to the curriculum is not always guaranteed. Furthermore, it requires a strong **adaptation** to students' initial knowledge, an **anticipation** of how they might express the knowledge which is embedded within an IBST session, and a **reformulation** or overview of the whole method at the end of the session.

This question of what is learned represents a key problem for IBST, according to Pascal Bressoux.[10] From his point of view, it is crucial to specify what one means by IBST: is it a pedagogy of discovery? Is it a variant of socioconstructivism? P. Bressoux is afraid that a pedagogy of minimal guidance is concealed behind these labels, whilst much empirical research shows the weakness of that pedagogy in enhancing pupil learning. Thus, we might make a big mistake if we think that IBST can sustain cognitive procedures which automatically organize themselves after a research activity: **very strong clarification is needed after any phase of inquiry and discovery**. The research shows that successful pupils manage to cope with implicit teaching methods but weak pupils are heavily penalized unless there is explicit modeling.

2. Summary: a constellation of teaching strategies

IBST methods appear to be **a constellation of teaching strategies** within which teachers, educators, inspectors and researchers have to position themselves. They can be organized along four dimensions, as follows:

- The first dimension is represented by **the existence of a research problem** whose answer is not obvious, even sometimes for the scientific community. Therefore, learners could elaborate the ability to recognize everything that is not clear, everything that requires further inquiries. It is a **critical attitude** to achieve.
- A second dimension concerns **the origin of questioning**. Allowing learners to live a scientific experience implies that the questioning which sustains the inquiry is congruent with that of the learners. This dimension is very demanding for teachers who must change their

[10] Professor, Head of the *Laboratoire de.Sciences d'.Education*, Université Pierre Mendes-France, Grenoble

posture by taking more account of the learners' initial conceptions and by giving them more autonomy for experimenting with their ideas. Nevertheless, **experiencing the scientific approach** certainly helps to understand its requirements.

- A third dimension, more commonly associated with IBST methods, concerns the **learners' activity**. Any research method involves the use of equipment and documentation, requires creativity, causes attempts and errors and induces interaction and cooperation. This creates an opportunity for some pupils, who are less comfortable with content-centred teaching approaches, to improve their **motivation for scientific activities at school**.

- A fourth dimension is the **level of explanation about what is learned**. Research in school shows that it is insufficient to set learners into activity believing that knowledge results only from action. In any case, this does not work for all pupils, and often those who face difficulties at school are penalized by these kinds of implicit- knowledge based methods. Therefore, teachers need **to take time to make explicit** for the learners what concepts and methods should be acquired through the IBST session. Improving our understanding of these metacognitive or regulatory aspects of IBST is a challenge for further research.

Thus, the degree of guidance of pupils' activities by teachers appears to be one of the most important points about IBST. Where there is minimal guidance, research shows that some students' difficulties increase[11]. Where there is guidance which is too restrictive, as pointed out in the Rocard report, students' motivation decreases. In order to overcome this obstacle, **teachers could diversify the type of classroom session during the whole sequence**: some sessions, with low guidance, give priority to living a scientific experience; other sessions, mainly based on learners' self-regulation, focus on developing abilities required for scientific practices; the last ones, narrowly regulated by teacher's modelling, aim at the acquisition of scientific knowledge. These three types of sessions are linked together within the framework of IBST.

[11] See e.g.Kirschner P.A. et al (2006) Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching *Educational Psychologist*, 41/2, 75–86.

Section 2: Teaching programmes, school courses and assessment

The following questions help us to understand the place of IBST in French curricula.

- What is the **role** of IBST in the curriculum, particularly in secondary schools, including vocational schools?
- Is IBST **integrated** within the curriculum? Does it overload teachers with extra work?
- Does IBST lead to restructured lessons when it receives sufficient time and **resources** for its implementation?
- To what extent are officially established **assessment** practices coherent with IBST?
- In schools, what are the emerging assessment practices that aim to promote **motivation** and pupils' **interest** in scientific disciplines?

1. The actors' point of view

1.1. Institutional actors

IBST is clearly implemented in the French school curriculum for primary and secondary schools, according to D. Rojat. However, F. Robine reports that teachers often claim that IBST methods are extremely time consuming when they are properly implemented, that is, when students have the possibility to express themselves and to advance at their own pace. Thus, IBST needs to be conceived not as an addition to existing programmes but as another way of organizing work. In France, it needs a more profound reorganization of programmes and lessons. Programmes should be less defined as lists of notions or concepts to be learned, and the **objectives of intellectual competence development should be better highlighted**.

This is particularly true in high schools (*Lycée*, age 15-18) where huge improvements still need to be made to **better prepare French students for success in higher education, in terms of autonomy of thinking, cross-disciplinary and scientific competences**. This type of improvement has already been made for the lower secondary school (collége) curriculum, but remains to be improved for the high school curriculum. This idea is shared amongst the general inspection scientific teams (the upper level of the French inspection system). However, programmes and curricula are designed through negotiations amongst inspectors and other experts, and these latter are sometimes opposed to the development of IBST methods.

Assessment processes for IBST are organized in three ways, as reported by D. Rojat:

- **Students assess directly the results** of their own inquiry (or one of its aspects, e.g. hypothesis formulation, material use, concluding explanation, etc.).

- **Teachers assess the reasoning competences** developed by students through IBST methods.
- **Practical tests evaluate experimental competences** in class and at the baccalaureate (final high school examination, equivalent to A level in UK).

However, assessment in IBST is a very difficult issue. Assessment practices in classrooms are mostly based on the testing of immediate knowledge, rather than complex tasks. They emphasize the resolution of exercises that leave little autonomy to students, as noted by F. Robine. This represents a real challenge since **formative assessment is very underdeveloped** in classrooms and does not constitute part of French teachers' normal repertoire of actions. Implementing new methods, which enhance the autonomy and quality of students' thinking, remains very difficult. It requires **further action research**, which can help to improve the education, training and support received by teachers. This point is echoed by P. Ferrand, who suggests that there has been a change in teachers' views about student assessment, where new curricula offer total autonomy for teachers to assess students on their capacity to solve problems. However, the question most often asked by teachers is "how do we assess learners in IBST? »

1.2. University actors

Inquiry-based methods are central within the secondary school curriculum and even constitute the only comprehensive approach prescribed for primary schools, but for J. Lebeaume, these approaches too often become formal procedures. Researchers are unanimous in noting also that IBST methods may result in overload to programmes, if the many constraints and additional requirements that they involve are not taken into account: J. Lebeaume, P. Bressoux and P. Mendelsohn all raise the time-consuming aspect of IBST methods.

Overall, traditional assessment procedures and curricula do not require the competences that could be gained through IBST. Thus, **these activities may not be applied systematically nor do they represent the only possible way of gaining knowledge and scientific competences**.

However, according to P. Mendelsohn, these methods really represent an **opportunity to restructure teaching strategies**. The movement initiated by *La main à la pâte* itself has the potential to partially restructure science teaching, particularly because it is inspired by movements in other areas of education, which emphasize pupil activity and which rely on reference to the school environment for meaning-making from taught knowledge. This movement is also connected with developments in current educational policy, particularly regarding the “common knowledge and competence base, which needs to be acquired by all students”. This could cause a real reorganization of teaching, in line with IBST goals, if competence assessment is seriously taken into account in formal examinations. The university actors' observations are, therefore, similar to those of the institutional representatives.

To go further, P. Bressoux questions the ability of educational systems to really promote success in science subjects. The scientific career represents the path of excellence and, therefore, students do not take scientific classes because they particularly appreciate mathematics or science, but primarily because they are identified as strong students in a set of crucial subjects. Similarly, the scientific baccalaureate is often gained with very average marks in science, but they are offset by better marks in other subjects. Students and parents think that a scientific baccalaureate offers more opportunities to enter desirable careers. We must recognize the **selective and elitist nature of science subjects** and their preferred role in determining students' careers.

Emphasizing the same idea, P. Mendelsohn says that IBST methods need to be evaluated in order to justify their relevance. We should survey career choices of students who benefited from IBST. We also need to evaluate whether competences acquired by IBST methods could **be used in other domains of science** without new learning processes; this is potentially an implicit advantage of IBST but has not been yet proven.

2. The current curriculum

The introduction of secondary school programmes, published in 2008 and implemented in September 2009, is common to all four scientific subjects: mathematics, physic and chemistry, biology, and technology. A section is devoted specifically to IBST, in line with the primary school curriculum. IBST's diverse components are described step by step; such a presentation could support a formal reading of the curriculum, leading to a narrow conception of IBST, or a “catalogue” of unlinked actions. **While IBST methods are explicitly associated with student-centred teaching approaches, they are not presented as the only appropriate method**. Teachers must decide the relevance of IBST according to the subjects being taught. The method of implementation shows both similarities and differences between subjects, specifically for the validation phase, which could occur either through experimentation (natural sciences) or demonstration (mathematics).

Each specific syllabus provides teachers with some guidance on IBST implementation, and specific learner activities are promoted, such as questioning, problem solving, observation, experimentation, looking for explanations or justifications, argumentation and discussion. Syllabi emphasize the outcomes of these activities in terms of structuring and understanding of taught knowledge, competences and mastery of technical expertise. The same message recurs: we must understand IBST not only according to its methodological and pedagogical aspects, but we must consider mastery of the inquiry approach as a learning goal in itself. Students must master both the scientific approach as well as the required concepts, skills and attitudes. The continuity of direction in high school programmes is well established, since the year 2000 syllabus stated that:

> *Science is not based on certainties, it is made up of questions and answers that evolve and change over time. All of this shows that we must focus first and foremost on teaching strategies which sustain the scientific approach including the mastery of observation and experience*

Thus school shows its willingness to teach “science in progress” and not just prior results and “readymade knowledge”, which are sometimes obsolete in comparison with current scientific research.

3. Summary: approaches required by the programmes and questions raised

Inquiry-based methods are heavily featured in the French curriculum. Both primary and secondary schools curricula establish that "the pedagogical logic underlying these new approaches lies in the fact that the development of science is made by going back and forth between observation and experience on one side, conceptualization and modelling on the other, and that the formal presentation of “readymade science” does not match the dynamic of the actual scientific work in progress " (programmes for the first year of upper secondary school). However, in the absence of systematic research, some central issues strongly impede IBST dissemination:

- There is a prevalent view that the list of scientific concepts which pupils should acquire is too long in relation to the time available to conduct actual IBST. For some teachers, this causes **conflicts**, which they cannot overcome without external resources.
- Pupils acquire mainly skills and attitudes through IBST. The assessment of these competences is more difficult than knowledge assessment. It is even more difficult when the assessment process is based on marks, and when these marks govern pupils' advancement and choices within the curriculum. For some actors, this idea demonstrates a lack of **consistency** between learning outcomes resulting from officially advocated approaches, such as IBST, and the formal assessment modes which are still preferred by the institution.
- Scientific evidence of the benefits of IBST methods for all students is still incomplete. The intellectual and conceptual efforts necessary to benefit from these methods are not always accessible to all learners. Thus, there is probably a conflict of **loyalty** for some teachers: as they are uncertain of the benefits of IBST and as these approaches require changes to their teaching practices, they often prefer to continue with old routines and procedures.

Therefore **research programs should be designed** in order to evaluate the benefits and to specify the conditions for effective IBST methods.

Section 3: Teacher education and professional development

The introduction of IBST methods comprehensively challenges expositive, transmissive and normative practices. Thus teachers need specific education and continuing professional development (CPD) programmes. This third section deals with this topic based on three questions:

- What do educational and CPD **policies** say about the dissemination of IBST methods?
- How do CPD providers allow teachers to enhance their **repertoire of actions** for the implementation of IBST?
- What **resources** are available to provide support to teachers or schools teams?

1. The actors' point of view

1.1. Institutional actors

Currently, in France, there are few CPD programmes specifically dedicated to IBST. However D. Rojat states that almost all forthcoming CPD activities will address these methods. Thus, each CPD activity on the implementation of new pedagogical materials will connect this material with IBST. According to Rojat, in biological sciences, **almost all CPD programmes refer to IBST** approach and, similarly, all new materials will incorporate it.

Nevertheless, as education authorities face severe budgetary constraints, **the CPD programmes' goals are specified in the latest national reforms**, as P. Ferrand explains. Thus, today, most actions are focused on implementing the "knowledge and competences common base". Nevertheless, IBST methods underlie all these CPD programs.

Since the last French legislation regarding schools in 2005, trials of new teaching methods can be conducted under contracts between schools and local authorities, as P. Ferrand mentions. These projects are designed by groups of professionals (school administration, teachers, local authorities, etc.) who **jointly** research the best strategies for **overcoming their local problems**. These contracts guarantee specific resources for three years, although actions can vary from year to year, depending on the strategies needed to achieve their goals. The educational system is therefore moving toward a system of governance having contracted goals, which allow some autonomy for each school. After validation from the local educational authority, these trials may involve the teaching methods of science.

This is the case in the Lyon Region, as shown by J. Toussaint. Local authorities are able to allocate resources to teachers and schools for specific studies. A project conducted by 35 high schools aims to transform science teaching in the first year of high school (age 16). Through "integrated science teaching" (P2S), **pupils can learn about scientific themes, which require the pooling of teachers' competences** in physics, chemistry, biology, geology, or mathematics. Teachers need to share their activities and resources. Amongst these shared themes are: water in the environment; air quality and pollutants; food, etc. A survey conducted amongst teachers engaged in this new practice for science teaching shows that 4 out of 5 of them are satisfied by this teaching approach because it allows them to properly implement IBST methods. Some questions about CPD programmes emerge from this survey:

The first set of questions addresses **CPD programmes** about IBST:

- What is the nature of common scientific practices?
- Why is IBST the preferred approach to these practices?
- What are the conceptual tools required for IBST?
- What in particular are the roles of mathematics and ICT?

Further questions focus on the **scientific content** of IBST activities:

- What is the role of pupil questions about scientific issues?
- What is the scientific value of problems from everyday life?
- What is the status of experimentation and its heuristic value with respect to different subjects?
- What is the place of explanatory models, specifically in physics and chemistry?

Didactic research shows that, depending on how a particular concept is tackled, teachers are more or less successful in achieving the intended learning outcomes for their students. J. Toussaint hypothesizes that these experiments with "integrated scientific teaching" will lead to the evaluation of different teaching approaches.

1.2. University actors

For P. Mendelsohn, the dissemination of IBST results primarily from a **volunteer movement** supported by motivated teachers gathered around a 'pioneer' of such methods. Although many executives, especially inspectors, are involved in the development of this policy, institutions still have to organize the implementation of IBST generally. Mendelsohn also emphasizes that schools and teachers' educational **institutions need the necessary scientific equipment** in order to support such teaching strategies; an aspect that requires investments whose "political" dimension is obvious.

The Grenoble IUFM[12] has supported IBST methods for a long time, and more generally the "Hands On" experimental approach in teacher education. Their view is that it is essential for new teachers to experiment by themselves before engaging in such practices with their future students. Thus, during their teacher education, it is crucial **to give new teachers the opportunity to conduct experiments by themselves**. In order to allow new teachers to become familiar with IBST methods, IUFM has always supported the creation of both specific rooms dedicated to experimentation, and lab-assistant jobs.

In the Versailles region, as reported by J. Lebeaume, IBST methods are present in all CPD programmes. In order to promote better understanding, they are organized in non-sequential modules: **teachers discuss, test** specific teaching contents, and **validate** them (or not), then **compare** their implementations. IUFM offers materials, educators, and documentary resources. Local authorities post teaching sequences on their websites, maintain a network of centres for science resources and organize pedagogical counsellors' interventions for primary schools.

2. Teachers' CPD programmes

Most CPD programmes are offered by either local authorities or research institutes.

2.1. CPD for In-service teachers

In order to better understand what is available in respect of CPD programmes about IBST, an investigation has been conducted into training provision by the educational regions of Grenoble, Lyon and Rennes, which are the regions of the laboratories involved in S-TEAM.

2.1.1. Grenoble educational region

Concerning inquiry-based methods, twelve CPD programmes have been offered during the 2009-2010 school year: two in mathematics, three in physics and chemistry, three in technology, one in biology and three for teachers who are competent both in mathematics and science (in vocational high schools). They will involve 755 teachers in CPD programmes lasting an average of six hours.

Three CPD programmes include explicit IBST methods in physics and technology. The other titles address scientific activities (modeling and evidence, classification), the understanding of teaching content [pedagogical content knowledge] and teaching approaches from new programmes and new forms of assessment.

The descriptions of CPD programme contents and goals suggest that IBST methods are a central concern, and are often explicitly mentioned. Furthermore, the use of terms such as

[12] Instituts Universitaires de Formation des Maîtres - the French teacher training providers

'experimental' or 'inductive' teaching approaches or the description of problem-solving situations suggest that CPD programmes rely heavily on IBST methods.

Analysis of course goals highlights the desire to make teachers rethink their own roles, and those of pupils, in this type of educational approach. There is also a desire to rethink work environments (use of ICT, new software, laboratory design). Finally, these courses aim to ensure that teachers use new assessment methods, particularly in relation to pupils' experimental abilities.

Observation, experimentation and reasoning, acquisition and mobilization of knowledge are central for these teaching approaches. **Learning outcomes concerned specific scientific knowledge acquisition** and not problem-solving or generic attitudes such as motivation. Several measures require knowledge from different scientific or industrial fields, without teachers from different disciplines being involved in these cross-disciplinary CPD programmes.

2.1.2. Lyon educational region

It offers 23 CPD programmes including two interdisciplinary ones, for 1 300 teachers of mathematics, physical sciences, technology and biology. The average length of these programmes is ten hours.

Inquiry-based methods or situations are specifically addressed by twelve programmes. Six deal with experimental work and problem-solving situations, and five others with computer-assisted experimentation (CAE) or knowledge contributions for specific scientific content.

Inquiry as a teaching approach or learning situation constitutes a professional development issue regarding disciplinary content, the common base of competences, or the use of digital material. CPD programmes emphasize teaching strategies organized around themes or issues that necessitate the acquisition and mobilization of specific knowledge. They aim to disseminate new teaching strategies, and to identify pupil activities amenable to IBST methods. Pupil activity is mainly addressed with respect to their initial representations of scientific concepts, their learning outcomes, or their possible attitude during inquiry, questioning and research activities. Teachers are invited to **identify the different stages of IBST and its links with problem solving or technical project approaches**. The development of new teaching strategies and new assessment procedures thus represent the core of CPD programmes in the Lyon region.

2.1.3. Rennes educational region

It offers thirteen CPD programmes to 246 teachers, with an average duration of ten hours. Content and objectives in relation to IBST are explicitly present in nine of them. One programme focuses on interdisciplinarity and continuity between the primary and secondary school levels, including the relationship between inquiry-based learning and project or problem solving approaches.

The new science curriculum has given rise to CPD programmes, mainly due to new problems emerging from IBST. These programmes clarify issues of motivation, commitment, autonomy, initial ideas and understanding through the analysis of pupil activities. **The design of teaching material by teacher teams, the analysis of practices, and the sharing of experiences are central to these CPD programmes**.

2.2. Training offered by Research Institutes

The CPD programmes of the Mathematics Teaching Research Institute (IREM) and the Pedagogical Research National Institute (INRP) concern modeling, development of experimental protocols, problem solving approaches during the baccalaureate experimental test, and the integrated curriculum of science and technology (EIST). The main difference from the local authorities' CPD programmes is their duration, ranging from 12 to 18 hours. **CPD include reflection about teachers' experiences and presentation of current scientific knowledge**.

3. Summary: inquiry-based methods and their integration with other training issues

Currently, IBST methods are the target of CPD programmes through the implementation of **new curricular materials, educational procedures and assessment methods**. In addition to an improved understanding of the IBST approach, CPD programmes help teachers **to understand pupil activities** resulting from IBST, in order to better regulate teaching and learning processes.

Most CPD programme descriptions highlight the link between the nature of scientific knowledge, the necessary acquisition of knowledge by students and IBST. **Experience sharing and analysis are the main CPD programme procedures**. Only a few of these programmes bring together teachers from different disciplines, although the emerging need to grasp the complexity of the physical and human world requires **interdisciplinary** IBST strategies.

Finally, within these programmes, IBST methods are either separated from those of problem solving, or considered in connection with them. Furthermore, they distinguish between real **scientific practices** and **pedagogic approaches** promoting curiosity and preparing students to learn. This may help to renovate didactic and pedagogic approaches in science education, allowing pupils to be involved in authentic and accessible scientific practices, through the implementation of IBST.

Section 4: Education and training policies for inquiry-based methods

Along with formal CPD, the transformation of teachers' conceptions and practices often results from social interactions generated through cooperative projects, whether initiated by local authorities, or in partnerships, and supported by communities. The questions regarding policy, therefore, are:

- Which ongoing **projects** aim to promote pupils’ motivation and interest in science?
- What is the **role** of the institutions (Ministry of Education, university, local authorities)?

1. The actors' point of view

1.1. Institutional actors

For the institutional actors of this investigation, the experimental introduction of science and technology integrated curriculum (EIST) in lower secondary school (age 11-14) creates an opportunity to implement IBST methods, as reported by D. Rojat. This integration of different scientific subjects is part of the goal of a **common knowledge and competences base**, to be mastered by all students at the end of compulsory schooling (age 16). During the S-TEAM French National Workshop at Grenoble, Alice Pedregosa, who followed the EIST experimentation for the Academy of Sciences, described this common base. It states that, through experimental science and technology learning, students will be able to:

- Practice a scientific approach, to know how to observe, to question, to formulate an hypothesis and validate it, to argue, and to model in a basic way
- Manipulate and perform experiments with natural phenomena

EIST aims to offer students a **unique science and technology teaching** and learning experience during the first two years of lower secondary school. Implementing this integrated teaching necessitates a team of teachers from three subjects: biology, technology and physics-chemistry. These three teachers act closely in order to elaborate teaching sequences and conduct pupil assessment. They have an hour of cooperation [per week] in their agenda. Three groups of students are formed from two sections. Each teacher supports one group of the same students throughout the year to teach the entire course of "science and technology".

This integration aims **to minimize the division of subjects** which makes difficult to grasp the meaning of taught knowledge. According to A. Pedregosa, however, integration is not without risk because it can affect the students' identification and construction of the various scientific fields, or make some fields entirely disappear. In extreme cases it could lead to the emergence of a new single discipline. Controversial and complex at the same time, this subject still faces numerous obstacles. Integration is positioned as a compromise between the extremes poles of division and fusion.

Some partial evaluations of the EIST experiment have been made. They show, as reported by A. Pedregosa, that the fundamental contribution of this experiment comes from **the collaboration, teamwork, meetings and partnerships** that result from this new approach to teaching. At the local level, these interactions take place within the core group formed by the three volunteer teachers, supported by their head teacher who ensures the project's cohesion and dynamism. At the regional level, support and guidance for teachers is provided by the inspectors of each of the relevant subjects, and specific local authority services for innovation. Finally, the EIST website plays an essential role for information sharing and collaboration amongst teams and with national actors. These first results demonstrate an evolution of teaching practices with benefits for pupils in terms of competences related to inquiry-based learning. These results remain to be validated in order to identify a model for further development of EIST.

According to A. Pedregosa, the originality of EIST relies on the collaboration between three teachers, who are each subject specialists, in order to build an integrated teaching process. This collaboration is the core of the project. It must however be accompanied by **resources for teachers**, such as specific material and guidelines.

Regarding high school, J. Toussaint reinforces the case for P2S (see above, p.23). The service for innovation and experimentation (PASIE) closely supports this programme. In this context, students were interviewed about these activities, which occupy two to three hours per week during the year. Their answers show that they like hands-on activities, teamwork and complex matters, but above all they are interested in the research approach, and in their **autonomy** during inquiry-based sessions. So learners' motivation seems to be improved by IBST. How can we know more about the factors influencing this motivation?

The international ROSE (Relevance of Science Education) project[13] aims to compare the orientations of 15 year-old pupils in different countries towards a wide range of topics relating to science. According to Faouzia Kalali (INRP) this project takes account of their point of view in order to design more relevant science themes and teaching procedures, since pupil motivation plays a central role in scientific learning. This motivation has been evaluated by Florence le Hebel and Pascale Montpied (ICAR CNRS laboratory - ENS Lyon), using a significant French sample. They consider pupils' 'ideal types' profiles about willingness to learn subjects relating to science.

[13] www.ils.uio.no/english/rose/

Coherently with many previous studies, the results suggest that **girls and boys maintain separate motivations to learn science**. Being aware of this duality of views is useful in order to adjust science lessons by respecting and benefiting from this diversity. Overall, however, these results show that **some extra-educational experiences favour the appearance of specific interests in scientific questions**. The results show that students are interested and motivated by questions requiring integration of knowledge from several scientific disciplines. This suggests that teachers' discourse and activities need to consider both the diversity of students' experiences, and the relationships amongst phenomena and elements of science, which result from true-life experiences and representations. Such experiences seem necessary for the generation of pupil motivation. Six positively valued themes were identified and may provide a basis for the improved design of teaching sequences:

- Living organisms, molecules, atoms and molecular biology (from ecosystems to cloning)
- Human life and death: from esoteric, biological or medical views to bodily aesthetic issues
- What made science what it is, the history of science, what remains unknown and how science impacts upon our present
- Space and all types of scientific discoveries around it
- The relationship of science and technology to the planet, from high technology to ecology, and from their advantages and problems to how they function;
- Earth and the universe: how human activity interferes with their dynamics.

1.2. Local authority actors

Local authorities are important actors in school policy since each local level (city, district, region) is in charge of a school level (primary, lower secondary or high school). The case of Grenoble city is very interesting. This was described at the S-TEAM French National Workshop in 2009 by Xavier Normand, who is responsible for the creation of a "**pilot science high school**" in socially disadvantaged sectors of Grenoble.

This project arose from a meeting between Georges Charpak, Nobel laureate in physics and founder of *La main à la pâte*, and Michel Destot, deputy mayor of Grenoble, at the conference "Science Learning in the Europe of Knowledge", in November 2008. This project is modelled on Leon Lederman's *Teachers' Academy for Mathematics and Science* in Chicago. It aims to create a high school, welcoming 600 students from **all socio-cultural backgrounds** with **gender parity**, **promoting teaching strategies radically based on IBST methods**. Through this project, Grenoble city wants to pursue its support for innovative educational approaches, as with e.g. *lycée international de Grenoble* (International High School). It aims to strengthen the scientific field by bridging together universities, research organizations and companies. It wants to encourage scientific vocations amongst the younger generations and to clearly promote science as a factor of social development --particularly within socially and culturally disadvantaged people who are under-represented in the scientific departments of the universities.

The project itself has four parts, each being either the transposition of an existing process or the creation of an innovative and transposable process:

- The creation of a **pilot centre** for *La main à la pâte* which allow the generalization of IBST to primary schools within the city's territory and its suburbs.
- Supporting the dissemination process of **science and technology integrated curriculum** (EIST), based on IBST in a local lower secondary school (ages 11-14) and of the creation of science workshops, as a way to arouse pupils' curiosity and motivation, and prepare them for registration in "Charpak sections" of the new high school.
- The creation of "Charpak sections" in the new high school (ages 15-18), which will offer **specific science courses to students**. Students will be recruited for their interest in science and technology, under an individual learning contract. The three-year curriculum will prepare all students for a scientific baccalaureate and for university studies. Specific actions will give greater visibility to scientific careers in laboratories and innovative companies, while providing students with motivation and self-confidence.
- The construction of a **boarding school of excellence** that will enable the new scientific high school to accept at least one third of its students from the wider region (Rhône-Alpes).

This project is in progress, but shows that it is possible to support synergies between different actors of social, scientific, economic, cultural and political life through IBST dissemination.

This idea is echoed by Genevieve Fioraso, who attended the S-TEAM French National Workshop as a deputy in the National Assembly (Parliament). She identifies several factors hindering the development of a knowledge society which promotes solidarity amongst people:

- In Western countries, entry to science vocations after high school is **decreasing**, especially for girls. Nevertheless, in France, more girls than boys get a scientific degree with high marks.
- A **lack** of basic scientific culture is felt at the highest level of political representation. Debates, e.g. about GMO, are often polarised, or merge scientific data and economic factors with political postures.
- This polarised climate and the resulting decisions amplify a **loss** of confidence in science as a source of social, health, and civic development. Unfortunately, media often prefer sensational approaches to more pedagogical ones, and amplify public distrust of science. This creates misunderstanding between scientists and journalists, and reduces the attractiveness of science.

- The French educational system shares responsibility: scientific disciplines are used as vectors of student **selection**, and not for their intrinsic interest or the discoveries they allow. Moreover, subject divisions are dissuasive, particularly in higher education where many students have multiple interests. Such open-mindedness is, however, required for scientific research.

These facts lead to some recommendations from G. Fioraso:

- Specific actions should be taken to encourage interest in science subjects for girls, through a better understanding of scientific and technological careers or the **intervention of female scientists in science classes**. An improvement in gender parity within research organizations is also needed.
- Teamwork and exchanges of good practice amongst teachers should be encouraged, as a way to improve teaching strategies and to create a dynamic climate of innovation in which students can be involved. Here, **international exchanges**, especially those involving **European cooperation**, are particularly suitable because they allow both the practice of foreign languages by students and the sharing of scientific, didactic and pedagogical knowledge by teachers.
- The removal of barriers between subjects should be encouraged, by **supporting interdisciplinary projects**. To enhance science's attractiveness, we need to develop connections between arts and sciences, and between social sciences and natural sciences. The creation of combined courses (e.g. business and technology, art and science) could be made easier.
- To focus on interactive teaching methods, with **more hands-on activities**, practical work, experimentation. There needs to be trust in curiosity and inquiry.
- To develop **partnerships and networks**: the competences of the Industrial, Technical, Scientific and Cultural Centres (CCSTI) and the interventions of specialized voluntary associations should be used and encouraged in schools or with pupils.

In a more general way, G. Fioraso calls for **societal, social, economic and cultural issues** to be put back into the core of the scientific enterprise. It is important to position science at the centre of sustainable development in its three dimensions: economic development, environmental protection and solidarity, at the global level. According to her, two local initiatives promote these recommendations.

The first of these comprises the project for a scientific high school for young people from disadvantaged sectors, described above by X. Normand. The second is the establishment of a support action in higher education, by the University Joseph Fourier, for socially disadvantaged students who obtained vocational or technological baccalaureate with high marks, which will be presented below.

1.3. University actors

The Grenoble University Joseph Fourier (UJF) is in charge of science teaching in the region, and has historically promoted science courses in higher education. Jacques Gasqui, University vice Dean, aims to enhance pupils' ambition to engage in scientific studies. For this, we need to create contacts between "worlds" that do not know enough about each other, and particularly between secondary schools and higher education. A **network of high schools and universities** was founded in early 2005, through the ASUR operation.

The ASUR operation has allowed the **development of exchanges designed to sustain high school pupils' interest in science**, such as lectures by researchers in classrooms, pupil visits to scientific laboratories and university students giving talks to pupils from their former schools. These university students are ambassadors for their scientific discipline, who help to support pupils in creative projects and experimental work. ASUR also promotes exchanges on educational practices between teachers from secondary schools and those in higher education. Other activities include students tutoring pupils from educationally disadvantaged areas, participation in the national contest "Science Summit[14]" or hosting "Expo-Sciences" every two years on campus. The UJF supports all these programs with specific credits and recognition of the workloads they involve for lecturers and researchers.

On the other hand, UJF aims to strengthen the attractiveness of scientific courses. From first year undergraduate courses (age 19) onwards, UJF introduces 'fast-track' courses of excellence whilst being **open to all students and providing equal opportunities**. J. Gasqui mentions the "courses of excellence" in research laboratories for the best students from the first and second years of undergraduate study, and also specific support for students facing difficulties. Finally, since autumn 2009, the UJF has established the Higher Education Vocational Education National School (ENEPS), which is a track of excellence reserved for **vocational graduates** in the production sector. It provides education opportunities at Masters level in the fields of energy management, renewable energy and communication. In this school, pedagogy is strengthened: on the one hand, tutoring and supervision in small groups is the norm; on the other hand, each student benefits from personal sponsorship by a professional from the local economic sector.

In a similar perspective, P. Mendelsohn describes the case of the Grenoble institute for teacher education (IUFM), which offers **specific scientific programmes for student teachers**. The fact that the IUFM is part of UJF guarantees its quality: the many training platforms and famous UJF

[14] Faites de la Science

laboratories allow students to readily observe research “in progress”. This promotes the education of future teachers who are dedicated to IBST.

2. Summary: numerous actions promoting science teaching

This survey, though far from exhaustive, shows that there are numerous actions in progress for IBST dissemination. They are organized in three areas: CPD programmes, educational structures and networks.

Regarding CPD programmes, the French tradition is to focus on current reforms, which is perhaps not the most efficient way to proceed. On the one hand, this gives actors a sense of perpetual change, which does not lead to the enhancement of teaching strategies in the long term, since future initiatives will focus on other issues. On the other hand, the lack of continuity weakens the cohesion between younger and older teachers from the same school, since they cannot benefit from the same CPD programmes.

Fortunately, beyond the change of CPD programme titles, the same content persists, especially concerning IBST methods. In experimental science, at least, the **IBST dissemination is embedded within CPD** programmes. The creation of integrated science curricula, the central role of the “knowledge and competences common base” or the mastery of digital tools provide many opportunities to implement approaches based on experiments or inquiries, and to give some autonomy to learners. French programmes are based on these IBST methods.

The dissemination of IBST also requires **structural changes**. In secondary schools, we quoted a scientific high school project designed to motivate pupils from socially disadvantaged sectors towards scientific careers. In higher education, we reported the creation of a school for students in vocational and technological careers in order to support these students who do not come from traditional courses. Teacher education also aims to enable future science teachers to master the necessary knowledge and competences to "make" science with their students.

In the long term, IBST dissemination will be facilitated by the establishment or strengthening of exchange **networks amongst teachers or amongst educational institutions**. On one level, these networks are specifically for teachers. They consist of databases maintained by local authorities, professional associations or research institutes such as INRP, and also involve direct interactions, through class sponsorship by scientists and pupil tutoring by students.

At another level, these networks involve **partnerships**, often maintained with the help of communities and based on science-related interventions in schools by actors from the voluntary sector, European exchanges between classes, etc. These partnerships provide opportunities for real-life experiences of science, and these moments seem to play an important role in pupils' motivation to learn about science.

Conclusion: a dynamic in progress

Dissemination strategy of inquiry-based methods in France is still a dynamic in progress. This dynamic is anchored in the traditional “learning by doing” pedagogy, which aims to support learners in making meaning at school. Nevertheless, this dynamic is stimulated by the **current challenges of scientific, social and cultural life**: the **complexity** of issues which require the merging of multiple approaches beyond disciplinary boundaries; the **speed** of societal and economic changes which enhance the development of flexible competences and minimize the transmission of obsolescent knowledge; the need for a minimum of cultural **cohesion** for people to understand, discuss and vote on scientific and socio-technical questions. Since it plays a central role in these challenges, IBST needs to be improved.

These improvements are in three main areas. Firstly, the amount of **autonomy** given to learners in inquiries or investigations needs to be increased. Secondly, what has been learned during the IBST session, in other words, its learning outcomes, must be made **explicit**. Finally, there is a need for **assessment** practices which support learning outcomes, including outcomes from self-regulated learning. With respect to these points, teacher education and continuing professional development **need to be intensified**.

Key factors for IBST improvement

Inquiry-based methods are not, however, suitable for all students. Several studies have shown that **some students are disadvantaged by socioconstructivist approaches** which are based on student actions and problem solving, on open- ended investigations, on social interactions and on knowledge transfer from an experimental mode to a higher level of conceptualization. Thus, should we immediately give up the methods proposed by the Rocard report[15]? The S-TEAM project aims to prove that the answer is 'no'.

This is, firstly, because our German colleagues have validated the development of approaches based on pupil activity. They show that IBST increases performance in standardized evaluations (cf. Appendix 2). But there is a condition for this development: teachers need to regularly question and discuss their conceptions and practices amongst themselves and with educators in order to

[15] EC (European Commission) (2007) *Science Education Now: A renewed Pedagogy for the Future of Europe: Report of the High-Level Group on Science Education* Brussels, EC Directorate -General for Research: available at: http://ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf

avoid isolation in the face of change. **Reinforcing collective work amongst teacher** represents the first key factor for IBST dissemination and improvement.

Secondly, IBST is effective because constructivist approaches can be enhanced by explaining to students what they have to learn and providing effective learning strategies. Again, many studies show that supporting students' metacognitive processes, or explicitly teaching them metacognitive strategies, in addition to posing authentic problems, helps them to master scientific competences. **Enhancing self-regulated learning** represents a second key factor since it increases learners' motivation and promotes greater equity in success.

These two points suggest new fields of research and practical experimentation, for the development and improvement of IBST. Therefore this report concludes that IBST dissemination should continue, on condition that the concept is **refined** and that the related teacher education and continuing professional development programmes are **strengthened**.

And if everything was not depending on educational actors…

Despite the advantages of IBST, as outlined above, it is unlikely that teaching methods alone can change the orientation of pupils towards scientific careers. During the 2009 S-TEAM French National Workshop, P. Bressoux drew attention to the danger of relying on an over-simplified view of the causal links between interest in science at school and entry into scientific careers.

For the director of the Educational Science Laboratory (L.S.E), any plan for promoting motivation and students' interest in science subjects must refer to an explanatory model of disaffection for scientific studies, such as the model of eligibility proposed by Louis Lévy-Garboua.[16] In this model, the expected benefits of a degree will decrease, on average, when there is mass access to university. Thus, students are faced with two crucial options: either they try to maximize their future income and thus sacrifice their current well-being; or, if they feel they are unlikely to achieve social integration, or to maximize their incomes, and then they will, conversely, favour their current well-being. Thus, **individuals face a choice between current life quality and membership of future elite**. The investment required by scientific studies corresponds to the elite market, since scientific studies probably require more work than other subjects. This choice represents a key element for the understanding of disaffection with scientific studies. Indeed, a research study by L.S.E. of student attitudes throughout the Rhône-Alpes region shows very clearly that the degree of effort allocated by students to their studies depends on their expectation of future earnings.

Thus, **disaffection with scientific studies needs to be considered in relation to current and expected socio-professional integration**. On the one hand, through appropriate teaching

[16] see e.g. Garboua, Louis-Lévy (2004),'' An Economist's View of Schooling Systems'' (with N. Damoiselet, G. Lassibille, L. Navarro-Gomez), in C. Sofer (ed.), Human Capital over the Life Cycle, London: Edward Elgar, 53-68.

strategies, we need to improve the chances of success in science subjects of all types of students. On the other hand, however, we need to ensure that the nature and distribution of available career opportunities for science graduates are desirable and fair. These two approaches are likely to operate in parallel.

Prospects for institutions, teacher education, and research

Regarding institutions, some changes are needed. They focus on programmes and assessment procedures.

- Focusing the curriculum on **competence mastery**: i.e. on the acquisition of established knowledge; on development of the capacity to act in different situations; on establishment of appropriate attitudes towards everyday scientific issues. This leads to the creation of spaces in which there is freedom for both the deployment of inquiry-based methods and the integration of different scientific subjects.
- Developing **formative assessment** of pupil scientific competence development, as prescribed by the curriculum, which is open to the use of external resources for problem solving, even during tests, and supported by pupil self-regulation of learning. Normative tests that only require knowledge or know-how replication need to be replaced by more accurate assessment strategies. Regarding teacher education and CPD programmes, the main changes should focus on strengthening teachers' collective work and resource implementation, notably online (see appendix 3):
- Supporting **interactions amongst science teaching professionals** about issues which concern them. These interactions should not only bring together teachers from the same team, but also teachers from different levels (primary and secondary, secondary and higher education), together with field scientists, local authority partners (voluntary sector, resource centres, museums, etc..), and entrepreneurs in the scientific field. Overall, there should be exchanges amongst all stakeholders concerned with the enhancement of science teaching and by its attractiveness to both boys and girls.
- Implementing **resources for science teachers**. These include human resources (classes split into groups of 12-15 pupils; laboratory workers to assist with experiments). They also include structural resources, such as the creation of excellence courses, especially for young people from disadvantaged social groups, or specific courses for students aiming to be teachers. Finally, they include digital resources, for example because web-based meetings, at national, European and global level, are useful for changing ideas and teaching practices.

Finally, two perspectives can be identified regarding research. One is about the activity of actors during inquiry-based methods, the other about the effects of these IBST approaches on school learning.

- **Understanding teachers' activity in inquiry-based learning**. From an ergonomic perspective, related to research which models the activities of aircraft pilots or fire fighters, we need to understand what teachers do when they implement IBST. What are their goals? What are the cues which guide them in IBST sessions? What is the extent of their repertoire of actions? From what reference knowledge do they justify their actions? Most of these practices come from professional culture, thus we need to identify forms of collective work which influence teaching towards the most appropriate strategies, including strategies for coping with learners' diversity.
- **Measuring IBST impact on learning outcomes**. This impact can occur at several levels: the nature of activity displayed by different types of student during inquiry sessions; acquisition of the various elements of competence; motivation for science; competence in self-regulation. We argue that these weaknesses in research cause uncertainty for teachers, and impede IBST dissemination.

Each of these points is based on current knowledge, or actions which are already beginning to take place. Therefore, we need only to support a work in progress!

Appendix 1: Questionnaire about the dissemination strategy of IBST

Within the European S-TEAM project, we wish to specify a dissemination strategy for inquiry-based methods, especially in France. The objective is to identify appropriate strategies for teacher professional development (TPD) programmes at local, national and European level, in order to make them known throughout the different education systems.

We need information on four areas: teaching strategies, programmes and educational courses, evaluation approaches, educational and training policies, all regarding inquiry-based methods. We would like to know your opinion on these issues, or at least on those that concern you most.

Finally, in order to make our results more concrete, we would like you to briefly describe a TPD programme for teachers which seems particularly appropriate to you.

We undertake to provide you with a draft document drawn from your answers so you can make requests for changes or provide comments.

Thank you very much for your cooperation.

1. Teaching strategies regarding inquiry-based methods

a) How would you define the term: inquiry-based science teaching (IBST)?

b) What are the purposes of these teaching strategies?

c) What distinction can be made between IBST and traditional approaches to science education and instruction?

d) How can this distinction be justified?

e) What benefits do IBST offer to teachers or students?

f) What new constraints do they imply?

2. Teaching programmes and school courses

a) What part do IBST play in current teaching programmes and school courses, notably in secondary schools, including professional or vocational schools?

b) Are these IBST strategies integrated into current teaching programmes and school courses?

c) Alternatively, do they constitute an additional workload within these programmes and courses?

d) Do they constitute an opportunity to restructure lessons?

e) Are sufficient time and resources provided for their implementation?

3. Assessment

a) To what extent are officially established assessment practices coherent with IBST strategies?

b) In schools, what are the emerging assessment practices that aim to promote motivation and pupil interest in scientific disciplines?

4. Educational and training policies regarding inquiry-based methods

a) What part do IBST play in education and training policies?

b) How do teacher development providers enable teachers to enhance their repertoire of actions for the implementation of IBST strategies?

c) What professional development resources are available for teachers, including the pedagogic or subject-specialist teams of the educational institution?

d) What ongoing projects seek to promote motivation and students' interest in science disciplines?

e) What is the role of your institution (Ministry of National Education, teacher training provider, university, research, local authorities) in this matter?

5. Brief description of a particularly relevant TPD programme

a) What is your target audience?

b) How are participants selected?

c) What are the main objectives of the TPD?

d) How does the TPD take into account the expectations of participants?

e) How is the training system organized?

f) What are the features of the TPD which give a sense of responsibility to participants?

g) What are the expected and recorded effects of the TPD programme?

h) Can you provide a web link to access the training content or can you send written documents?

Appendix 2: The dissemination of inquiry-based methods in SINUS

The concept of the programme SINUS aims to improve instruction in mathematics and science in secondary schools (grades 5-10) and hence students' attitudes towards, and their achievement in these subjects. It offers teachers the opportunity to develop instructional skills in groups with teacher colleagues from their own and other schools, in conjunction with researchers. The programme was jointly funded by the Federal Ministry of Education and the Ministries of Education of the 16 federal states in Germany and was designed to reach a substantial number of schools within approximately ten years. It started in 1998 with 180 schools from 15 federal states. In two dissemination phases between 2003 and 2007, the number of schools increased to about 1,800 (from 13 federal states). The official funding of the program ended in 2007. From then on, the federal states have been in charge of the further dissemination of the approach.

The designers of the SINUS approach assumed that in order to achieve substantial and sustainable improvements in instruction, teachers have to be given ownership of the process. They have to find ways to deal with challenging situations and to broaden and refine their repertoire of actions by themselves, instead of being told by someone from the outside. This can best be achieved if teachers work on their instruction in groups with their colleagues from the department, and with teachers from other schools, on a regular basis. In these groups they have to identify challenging teaching situations and agree on goals they want to achieve within a certain time frame. In order to be able to develop their teaching skills and their instruction, teachers need support, especially at the beginning of the process.

The SINUS approach offers teachers an organizational framework and a structure to develop and improve their instruction in collaboration with colleagues on a long-term basis. The successful implementation required:

- The identification and description of common problem areas in mathematics and science teaching.
- The translation of these problem areas into workpackages (modules) that offer teachers ways of improving their teaching practice based on evidence-based research. These modules do not refer to a specific content area (for instance forces or chemical equations) or teaching method (for instance group work or use of argumentation). They focus instead on the question of how instruction has to be changed to improve pupils' learning (how should teachers deal with pupils' conceptions? how could assignments offer pupils more opportunities for learning?).

- Teachers have to be supported by material that provides new ideas and examples of teaching approaches, productive assignments for practicing, lesson plans, etc.
- Teachers have to be supported by the heads of their schools.
- Teachers have to be given time and resources to jointly develop new approaches in their groups, try them out in their classes and deeply reflect on the outcomes with their colleagues.
- These processes in schools have to be facilitated by coordinators who initiate and organize the work, offer feedback, arrange for the exchange of ideas and experiences with other schools, and make sure that the teacher groups work in line with the concept.

Although a variety of materials has been produced by the participating teachers over the last 12 years, the distinctiveness and strength of SINUS lies in the actual process. Dissemination of the SINUS approach thus means to disseminate this process. It does not mean the production and distribution of materials to other schools in the form of booklets, CDs or via the Internet.

The dissemination uses many of the same principles as the implementation of the programme but is based on a much broader range of experiences. The more experiences from schools are available, the more the dissemination is facilitated.

For a successful dissemination, the teachers and the school heads have to be committed to the goals and principles of the approach. This can be achieved by letting them decide which of the modules are relevant in their school context. The module structure offers a possibility to focus on specific problems, which minimizes the risks that teachers feel overchallenged and unable to cope with the changes. Moreover, it creates the possibility of seeing and experiencing success. The science department in an individual school has to agree on a binding working programme. The teachers have to identify typical teaching problems and potential ways of improvement with respect to the modules. Important aspects of the modules should be included into the syllabi of the school. The teachers have to document and evaluate the new approaches in order to be able to share and discuss them with teachers from other schools.

The teachers need support from coordinators at different levels. There should be one coordinator in each school who is responsible for the organization of the work and the communication with other levels. There should also be regional coordinators who are responsible for a network of schools. They should know the principles of the approach very well and be able to initiate the work in the schools. Furthermore, they should arrange the exchange with neighbouring schools and provide feedback at regular intervals. Finally, there should be an overall coordination which enables the exchange of ideas and experiences between the school networks, provides new ideas and training for coordinators and schools, and tries to ensure the overall consistency of the programme.

School authorities should support the dissemination by providing time and space for the teachers to work collaboratively on their instruction. Moreover, they could further facilitate the dissemination and the appreciation of the programme by adequate changes in curricula and assessments to show teachers, parents and pupils that this development in instruction is consistent with the overall educational goals. Institutes for teacher training and universities should provide appropriate courses for the schools and strengthen the pedagogical ideas of the approach (modules) in their programmes for initial teacher education.

Appendix 3: Online resources

ACCESS (Continuous Update of Teachers Knowledge in Science)

Web link: http://acces.inrp.fr/

The ACCESS team is an INRP team working on issues of updating teachers' knowledge in Life and Earth sciences. The resources available on the website include collaborative work spaces on modelling practices and simulation in geosciences as well as in neuroscience, many software downloads, several training offers (notably "Formaterre" and "Formavie") and a set of information files (including several theses and publications) and teaching activities in the field of Life and Earth Sciences.

La main à la pâte

Web link: http://www.lamap.fr/

La main à la pâte was launched in 1996, at the initiative of Georges Charpak, Nobel Prize in Physics in 1992, Pierre Léna, Yves Quéré and the Academy of Sciences in order to renovate sciences and technology teaching in primary schools by promoting an instruction based on a scientific inquiry approach. The approach advocated by *La main à la pâte* is based on ten principles and articulates scientific learning, mastery of language and citizenship education. For this, teachers submit objects and world phenomena to their pupils' curiosity, inspiring scientific questioning. This leads to the formulation of hypotheses to be tested by experimentation or verified by information retrieval. Thus, students gradually take ownership of scientific concepts and operative techniques and strengthen their speaking and writing.

Many actors, teachers, trainers, pedagogic advisers, inspectors, engineers, scientists, science students, etc... participate in the various accompanying measures implemented by *La main à la pâte*. The operation is coordinated at the national and international levels by a team of fifteen people based in the premises of the Ecole Normale Superieure in Montrouge.

Available resources on the website include scientific literature on various topics (astronomy and space, plant and animal biology, human biology, ecology, etc) and documentation addressing the use of experiment booklets, the implementation of inquiry-based methods, a clarification of the 10 principles of *La main à la pâte* and on the teacher's role, and finally several studies on the relationship between cognitive science and education.

A special space is reserved for the integrated teaching of science and technology in secondary school.

Pairform@nce

Web link: http://national.pairformance.education.fr/

The program *Pairform@nce* is a national teacher training project for teachers from primary and secondary schools, aiming at the integration of technologies. *Pairform@nce* training is based on a principle of collaborative creation of class sequences. The national platform *Pairform@nce* offers continuous training courses, which are structures and sets of resources for implementation in continuous training academies.

- The project *INRP-Pairform@nce* is a research and development project of continuous training courses in mathematics, physics, geology and geography. Some of these courses, already published or under development, relate directly to inquiry-based methods:
- In mathematics, the course "Design geometry practical works with a dynamic geometry software", and aims at the implementation of inquiry-based methods in geometry in secondary to high school, by exploiting the potential of dynamic geometry software. A course titled "Inquiry-based methods in mathematics at secondary school with software" is being designed;
- In geology, "Virtual Globes" (Four courses, according to the technical expertise of trainees) seeks to integrate in geology (or possible joint work with geography teachers) some of the current tools of geomatics (Geographic Information Systems), by paying particular attention to the relationship between the experimental dimensions they allow, and scientific knowledge;
- In physics the course aims the implementation of an approach allowing teachers to explain the functioning of physics and modelling. The experimental devices are designed in such a way that students can construct ideas from physics' point of view but also, when relevant, from everyday life. In these approaches, the emphasis is put on working in small groups and on allowing students the autonomy to construct knowledge's meaning. This allows the implementation of inquiry-based methods allowing students to ensure a sense of responsibility in the construction of taught knowledge.

PEGASE (for Teachers and Students, a Guide to Learning and Teaching Science)

Web link: http://pegase.inrp.fr/

Resources available in Pegase consist of teaching sequences including a series of activities to help students capture the essential elements of the official program. The activities are organized to allow students to actively participate in taught knowledge construction in the classroom and thus promote its understanding and ownership. Activities are varied and designed to enable students to have "freedom of thought", to facilitate debates both in small groups and class in order to build the entire meaning of the concepts at stake and thus to be grounded in inquiry-based learning.

These resources also include an important component for the professional development of teachers. Some of these resources consist on comments associated with sequences, relating to the purpose of the activity (part of a sequence or a whole sequence), to its preparation, to the knowledge at stake, its correction and finally to pupils' behaviour. This last kind of comment includes, in some cases, videos of pupils currently undertaking activities. Another part of these resources provides the reasons for choices made when designing sequences and activities; in particular it presents the choices made to make pupils autonomous by having the ability to debate, while enabling them to acquire new knowledge.

Pedagogical resources of Academies surveyed:

Grenoble Academy

Web link: http://www.ac-grenoble.fr/accueil_peda/accueil.php

Lyon Academy

Web link: http://www.ac-lyon.fr/ressources-pedagogiques-academie-lyon.html

Rennes Academy

Web link: http://espaceeducatif.ac-rennes.fr/

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(1) To March 2010
(2) From April 2010

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SEVENTH FRAMEWORK PROGRAMME