THE PATHWAY TO INQUIRY-BASED SCIENCE EDUCATION IN EUROPE AND BEYOND: CHALLENGES AND SOLUTIONS FOR IBSE ADOPTION

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Introduction

High-quality education is one of the principal objectives of all levels of education for EU and the Member States in the context of the learning society (EU, 2011). One of the factors to increase the quality of education is the incorporation of innovative educational approaches and renewal of current pedagogical practices.

Inquiry-Based Science Education (IBSE) has been considered as an important approach for improving Europe's science education (Rocard, 2007; EU, 2010a). It is believed that the adoption of IBSE will support not only authentic knowledge acquisition, but also will help to raise students' general interest in science and will promote scientific studies and carriers. However, a recent analysis of the European Commission shows that IBSE has not yet been adopted significantly in the Members States (EU, 2010b).

IBSE refers to the conscious use of inquiry as a pedagogical strategy where students engage actively with questions and problems associated with their subject or discipline. It is a pedagogical approach that has philosophical and theoretical roots in the constructivist educational paradigm. Five essential features characterise IBSE: 1) Learners are engaged by scientifically oriented questions; 2) Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions; 3) Learners formulate explanations from evidence to address scientifically oriented questions; 4) Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding; and 5) Learners communicate and justify their proposed explanations (NRC, 2000).

While definitions of inquiry might vary, there is agreement that its central feature is the emphasis on the inquiry question as the driver of students' learning experiences (e.g. Crawford 2000; Cuevas et al 2005; Deters 2004; Drayton and Falk 2001). Moreover, there is often an emphasis on students engaging in collaborative inquiry with peers (e.g. Hmeo-Silver, 2006, Bell et al, 2010). Furthermore, 'inquiry-guided learning, promotes the acquisition of new knowledge, abilities and attitudes through the investigation of questions, problems and issues using the ways and standards of inquiry in the disciplines' (Lee, 2011).

The project PATHWAY[1] faces the challenge of facilitating the wide adoption of IBSE in Europe and beyond. It involves 25 partners from 15 countries collaborating to propose a standard-based approach to teaching science by inquiry outlining instructional models that will help teachers to organise effectively their instruction. The project will produce a unique collection of open educational resources and teaching practices linked with the science curricula that have proven their efficiency and efficacy and that are expanding the limitations of classroom instruction. Moreover, PATHWAY will mobilize a community of active teachers, experts on science education, researchers from the field of pedagogy, policy makers and curriculum developers with the objective to promote inquiry based techniques and to motivate large number of teachers to adopt IBSE activities.

From March to July 2011 PATHWAY organised a series of 38 Visionary Workshops in 12 countries (Austria, Belgium, Bulgaria, Finland, Ireland, Italy, Germany, Greece, Romania, Russia, Spain and UK), involving 1024 participants. In these workshops PATHWAY explored current teaching needs and addressed specific curricular objectives in order to later enable the large scale introduction of IBSE methods. Teachers and teacher trainers, students, school administrators, curriculum developers and policy makers (in different combinations according to

[1] PATHWAY: The Pathway to Inquiry Based Science Teaching, www.bayceer.uni-bayreuth.de/pathway/

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each partner conditions) were introduced to PATHWAY and initiated discussion about the important needs, limitations, and barriers for implementing IBSE in the involved countries.

Current state of science education

PATHWAY Visionary Workshops revealed a rather low level of adoption of IBSE in the involved countries. Even though the adoption of IBSE is supported or at least not impeded by the curriculum of several countries, such as Belgium, Germany and Spain, only in some (e.g. Finland and Greece) stakeholders report good overall adoption. Teachers who implement IBSE activities are usually isolated cases. Often they feel alone, not supported neither by the curriculum, nor by the school and rarely collaborating locally with their colleague.

The workshops attendants in many countries (e.g. Bulgaria, Italy, Romania, etc.) report serious limitations and obstacles in the curriculum and the school practices that should be faced for a wide IBSE adoption. For example, in most countries, there is an expectation to use textbooks especially in the later years of schooling, due to an exam-based culture, where it is believed (by many teachers, parents and students) that learning can only ever be measured through exam results. There is considerable pressure to 'cover the content' in terms of subject knowledge which impacts upon teachers willingness and ability to engage in less structured activities, such as IBSE activities. This type of thinking is very closely linked to university entrance and is particularly volatile the closer a student nears the completion of compulsory schools and the last school year before university. There is a perception that IBSE would impede the completion of the curriculum. Furthermore, a change in the teaching approach generally starts fears amongst parents that their children are not taught properly.

Many educational systems (e.g. in Austria, Belgium, Italy, Spain and UK) have adopted student research projects including IBSE activities as a valuable modality within the advanced years of compulsory education. IBSE is sometimes implemented as hand-on science involving students in practical and experimental work, although pupils often just perform pre-scientific hands-on tasks without really formulating and revising scientific explanations. It is widely accepted that IBSE can be applied to many aspects of the major science strands – Biology, Chemistry, Geology and Physics. Apart from all natural sciences, inquiry based learning could be successfully applied to other school subjects as well, such as learning foreign languages and history. Research based learning can also be applied to all stages of the developmental curriculum.

Limitations were reported in terms of school organisation and school practices. Most importantly, teachers spoke about lack of time for preparing IBSE classes, too little teaching hours dedicated in science and too short time frames in the school scheduler for implementing such lessons (e.g. Austria, Belgium, Bulgaria, Germany, Romania, Spain, and UK). Large students groups were also reported as a challenge in the teachers daily activities. Small or poorly equipped labs and lack of material for experiments is an important obstacle that was revealed (e.g. Italy, Romania, Russia, etc.).

Regardless of the limitations and obstacles discussed, participants were optimistic and preferred to look for solutions to overcome the challenges. In all workshops, teachers expressed desire to implement IBSE.

Challenges and solutions for IBSE adoption

In general, it is believed that there is a need of improved quality of science education for all, both for future science graduates as well all students. Adopting IBSE wider might be a way to do so, although the wide adoption would be challenging and many problems should be overcome. Based on profound discussions, several such challenges were identified and PATHWAY Visionary Workshops participants discussed around the ways to overcome these difficulties in their context. Hereby we list (without ranking) some of the challenges identified:

- Incompatibility between current school schedules and time required for inquiry activities
- Large number of students per class
- Lack of teacher experience with IBSE and lack of good IBSE-related materials or knowledge about such
- Lack of time for preparation and implementation of innovative classroom activities
- No dedicated time in teachers' schedule for further professional training
- Heavily content oriented curriculum and strong dependence on textbooks
- Exam-based culture and pressure from university-entry exams in the last school years

- Teacher who currently implement IBSE are lonely fighters that rarely collaborate with other teachers and are not supported by the management

Several distinct strategies were proposed by teachers for solving the problems discussed.

Changes in the educational system and the organisation of educational activities

Changes in the educational organisation have been proposed within many workshops. For example, for overcoming the incompatibility between current school schedules and time required for inquiry activities participants propose changing the time and location of science lessons, thus allowing for longer sessions and blurring the boundaries between theory and practice. Furthermore, changes are needed in order to face the problem of the large number of students per group - a problem reported in several countries. However, some teachers were not confident such changes would happen, mainly because due to the economic crisis governments are planning costs cuts that might result in increase of the number of students per classroom.

In Austria, participants suggested exploring different timetable models that could allow more time for teachers to both be more creative within the curriculum parameters and also to have some professional development time in the school year without impacting on their scheduled classes. Furthermore, there is a need to explore different models for resource allocation and sharing within school regions.

Changes in the educational organisation might solve issues regarding the pressure of the exam at the end of upper-secondary school. More concretely, Spanish participants suggested changing the university entry-level examination contents and methods, which would give more freedom to teachers to cover the curriculum as they think it is more appropriate. Another possibility could be to allow two itineraries in the last two years of upper-secondary school, i.e. depending on whether the student wants to join university or not. Furthermore, IBSE activities could be made optional to students, thus "IBSE would be for the ones who are interested".

Italian participants see a way towards adopting IBSE in the possibility of working with student interest groups, i.e. students who stay longer hours at school or choose to do science as additional lab subjects in their free time or in student-project allocated time slots. In UK after school clubs and awards programs were also seen as opportunities for IBSE.

It should be mentioned that some teachers believe that a more positive and valued experience of science during the pre-16 educational course may impact upon uptake of science courses post 16.

Support from senior management

During some of the workshops it has been underlined that it is critical to get approval and support from senior management teams in schools as this creates a school climate in which there is 'permission' to take risks with classroom practice and explore new approaches to developing science knowledge. Some teachers also felt that they would need more support than what the currently receive from the headmasters in order to be able to successfully apply IBSE strategies. Participants also believe that school principals should be involved, but they also see that for successfully doing so the principles need to see a return. It was stated that schools (not individual teachers) set targets and receive resources, thus the importance of involving the senior management.

Having the support of a management figure such as a head of science was seen as critical to any shift in practice. Support or input from someone above them in the management structure was also seen as likely to enable and contribute to any real change. For shifting the extent to which IBSE is adopted in teachers' practices they see the need of a 'champion' or evangelist who is well versed with the techniques and the materials.

Increase coordination among teachers

One of the challenges in respect to the wide spreading of IBSE identified in the Visionary workshops is the lack of collaboration between teachers. With regards to this, participants suggested improving the communication flow between teachers and between the staff in their school in general. If teachers shared experiences and resources, it would be easier to prepare and carry out IBSE activities, and it could also spread more easily.

Increased collaboration and coordination was identified as a solution to several problems coming from school organization in Spain, such as the too short time for IBSE activities in the classroom. As one teacher put it, "I could steal time from other teachers and have, for instance, a 3 hour-long lesson". Teachers should share more what they are doing and try to reach agreements. IBSE would spread more easily if teachers saw that their colleagues are using it.

German teachers also suggest that working in a strong collaborative environment where staff support each other there are more opportunities to improve teaching and engage more students.

Italian teachers state that working with other teachers seems to be essential for increasing both the quality and quantity of IBSE activities. Teachers suggested working with other colleagues and each preparing different lessons/modules. There was also the suggestion of working with colleagues from different subjects, age and experience. Contact between senior and younger teachers should be encouraged, so that different learning styles could be integrated and shared. IBSE teacher committees could and should be created and encouraged within individual schools. Tight colleague collaboration could also allow an internal rearrangement of subject hours among teachers, ensuring more flexibility in the work schedule. Collective peer to peer programming is useful also when planning for summative and formative testing.

It was suggested that for high school teachers it would be interesting to see how primary school teachers work with their students. In fact they seem to be much more accustomed to having pupils (even those in classes of 30 children) work in small groups and on hands-on experiences.

Communication between teachers and textbook publishers

Regarding the textbooks, teachers suggested that the book editors took their opinions into account when designing books. This might allow inclusion of certain tested inquiry-based activities linked to the curriculum and thus wider adoption/acceptance of IBSE.

Filling the theory-practice gap

Teachers in several countries, such as Spain and UK agreed that the separation between theory and practice should disappear in science education. However, they didn't agree on whether the space to use should be the classroom or the lab. Whereas two teachers in Spain said that they "always bring instruments and physical objects to the classroom to perform experiments", another Spanish participant said that "all science lessons should be given in the lab.", which shows the lack of agreement on which is the best solution to the problem.

Production of ready-made IBSE packages

Most teachers acknowledged that existing resources could be utilised for IBSE. Teachers pointed out that this might be easier for some subjects than for others (for example, experimental materials seemed to be easier to find for physics experiences rather than for biology). However, there was general agreement that specifically designed resource banks and centres could assist teachers to find the appropriate resource to use with the methodology and thereby save time for the teacher in implementing the scenario.

Most participants said that having comprehensive and easy to implement IBSE resources would facilitate the use of this methodology among mainstream teachers. IBSE resources and experiments should adequately meet teachers' needs, such as time and cost of the activity, as well as the availability of resources and facilities. It was pointed out that there is certain perception that IBSE requires quite sophisticated facilities. We should avoid the feeling of many teachers stating that "I can do the same, more easily, with less means".

Providing teachers with case-studies of IBSE in action, detailing the positive impact on students' learning, was also requested as teachers feel more comfortable trying out a new approach if they have the advice and experience of other practitioners that tested it previously. It was suggested that in the development of learning scenarios, there should be a section that shows how the scenario links to the curriculum. Well-chosen and well-produced materials and resources can help enrich and build upon existing science teaching already taking place.

Participants in UK also suggested PATHWAY should create and publicise a resource bank of support materials and examples of IBSE in practice. It was pointed out, however, that the availability of good IBSE ready-made resources increased the risk of them being used in a rigid way, spoiling the very nature of IBS learning.

Furthermore, personal development programs should point to good repositories with relevant resources.

New professional development IBSE support

Teacher training and support in developing IBSE classroom practice has been underlined as essential in the process of IBSE adoption. Good teacher training is crucial, especially such that puts the teacher in the shoes of the student/learner. This is recognised as a very effective way to help change one's teaching style and practice.

Often, teachers believe to be familiar with IBSE, but when they are asked to discussed it, it is revealed that they see it more as problem solving approach or just hands-on education, where students perform step by step experiments, but are not required to formulate and revise scientific explanations. Some teachers are familiar with the concept of the initial challenging question but are probably less familiar with the notion of encouraging the students to develop their own research question. Furthermore, whilst teachers are familiar with the role of facilitator, there is a tendency for more teachers directed learning. Training on IBSE should trigger these issues. Developing a full and informed understanding of IBSE approaches, their benefits and ways to implement them is essential, i.e. a well-informed, trained and supported staff (with materials and other resources) can drive significant change in practice. Good technical support is also required as this can help/facilitate teachers to try new things.

New ways of assessing science knowledge

Regarding assessment, it was agreed that exploring new ways of assessing science knowledge is necessity. Assessment-based constraints often placed on schools and teachers by examination systems that value subject knowledge above other aspects of science education may limit the impact of any attempts to incorporate IBSE practices in science teaching. New approaches are needed that focus not only on facts and content, but also on processes and skills. For reconnect the testing process to the on-going classroom practice, it is important to build in a good self-evaluation process for students and work on other interim evaluation tools and methodologies.

The idea of using computer gaming as assessment was raised, whereby students pass through various levels of a game, with the levels being the assessment of their inquiry skills and science knowledge. Furthermore, other ways to reward inquiry (i.e. not only concentrate on assessment) should be explored.

Increase acceptance and support by the society

Some teachers pointed out the challenge of IBSE not being perceived as the correct way to teach students and that it takes too long. The prevailing in most countries exam-based culture leads to low acceptance of IBSE, including by teachers, parents and students, many of which expect and require textbooks to be used. There is an expectation from parents and students that the role of the teacher is to tell students what they need to know to pass the exam so there may be some initial resistance for adopting IBSE.

IBSE is understood to be best applied in physics or chemistry, not so much in other natural sciences. It would be an important challenge to show the wide possibilities of IBSE and extend the viewpoint about its appropriateness and positive characteristics.

It is very important to always strongly market one's methodology, strategy and real practice with the headmasters, parents and colleagues in order for IBSE to be widely adopted into the school practice. A better communication process about IBSE should be developed to show the advantages and results of such a process.

Next steps

In order to foster the wide adoption of IBSE in Europe and beyond, during 2012 and 2013 PATHWAY will implement a large number of teacher training activities facilitating the effective introduction of inquiry to science classrooms and professional development programmes. During the implementation teachers will have access to a

unique collection of open educational resources (linked with the science curricula) that have proven their efficiency and efficacy in promoting inquiry based education.

Furthermore, PATHWAY is bringing together a network of educational communities, science centres and museums and research centres in Germany, Austria, United Kingdom, Ireland, Spain, Italy, Greece, Finland, France, The Netherlands, Belgium, Israel, Switzerland, Bulgaria, Romania and Russia in order to act as a pilot group for the project activities. At a second level with the support of European Physical Society (EPS[2]) and the European Schoolnet (EUN[3]) a greater number of teachers training centres and schools will join the PATHWAY community in order to create a pan-European network and to validate the proposed approach. These training centres are already offering training and professional development opportunities to science teachers in the different European countries. Through the support of EPS (EPS coordinates the network of the National Physical Societies in all European countries) and in the framework of the implementation of the European Science Education Academy Initiative the PATHWAY methods and activities will be integrated to the training curricula of these training centres. The PATHWAY training practices will populate the Central Information Provider (Scientix Platform[4]) that will be set up to centralise and disseminate best practices in IBSE.

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[2] www.eps.org
[3] www.eun.org
[4] www.scientix.eu