ADAPTING IBSE MATERIAL ACROSS EUROPE: EXPERIENCES FROM THE PRI-SCI-NET FP7 PROJECT

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Abstract: This paper combines 4 presentations making up a symposium. Inquiry-based learning in science has been advocated by the European Commission at both primary and secondary level of education (Rocard *et al*, *2007)* However, changes in science pedagogy across Europe has proved to be a challenge. In addition cultural and linguistic contexts of learning and education systems across Europe vary and make the transfer of educational resources and pedagogical approaches difficult. The Pri-Sci-Net project is an FP7 Coordination and Supporting Action funded by the European Commission which works to promote the Inquiry-Based approach in Science Education (IBSE) with young primary level children across Europe. One approach through which the project is trying to promote inquiry science is through producing educational material (in the form of 45 IBSE activities) which are to be translated in different European languages. Recognising European diversity, some of these activities were then tested for cultural and language adaptation in the partner countries. This paper provides the research results of an evaluation exercise carried out by some of the partners. The results provide insights into the barriers which students and teachers face in implementing the new inquiry-based approach. The evaluation exercise showed that while there were few cultural and linguistice differences, the main difficulties encountered related more to general education issues such as: teachers' inexperience and lack of confidence in implementing the inquiry-based learning approach; the children's expectations of how learning in science should be; the structured aspect of some curricula which allowed little space for inquiry activities; and teachers' and students' uneasiness in getting used to a new mode of learning. All these aspects highlight the need for time to allow systems, teachers and students to adapt to the inquiry-based learning approach. Curricular and pedagogical changes thus need to be introduced slowly such that adjustment takes place gradually. In addition, during this process, schools and teachers need to have continuous professional support.

Keywords: Inquiry-based learning, Primary, Challenge to implementation

INTRODUCTION

There is a worldwide call to increase the number of young people pursuing science later in their schooling and at University (Osborne and Dillon, 2008). This reflects the different governments' needs to remain competitive in a global market through a constant supply of scientists and researchers who innovate and introduce new products in the market. Such need is reflected across Europe and is targeted specifically in the EU2020 Strategy (European Commission, 2010).

The experiences in science at primary level that young children have can sow the seeds of interest and understanding in science. However, the way in which science, including primary science is often taught leaves little room for inquiry based learning and the development of scientific literacy (Osborne and Dillon, 2008). This situation may thus decrease students' appetite for continuing with science and may be responsible for the decline in the numbers of students following a science or technology career (Rocard et al., 2007). In addition, during the past two decades, many studies have indicated a decline in young people's interest for science and mathematics (Osborne 2003). International monitoring studies like PISA have also revealed that the level of scientific literacy in a number of countries, among them European countries, is disappointing. Reports on the state of Science Education in Europe (Rocard et al 2007; Osborne & Dillon 2008) have consequently provided recommendations to improve scientific literacy at European level.

The International Bureau of Education for Teaching Science and Technology at primary and secondary level (Poisson, 2000), argues that Science Education should involve: (1) scientific content; (2) scientific approach to inquiry; and (3) science as a social enterprise. These recommendations have recently converged into a novel approach, already advocated in the US, towards Science Education, the so called Inquiry Based Science Education (IBSE) (e.g., Bell, *et al*., 2010). Thus, gaining an appreciation of how science works in conjunction to understanding science concepts and developing investigative skills is best achieved through inquiry, which is to start from an early age, and is regarded as an important factor in retaining students' interest in the subject in later years. Inquiry based science education has been shown to be efficacious in stimulating children's curiosity and interest about the world. Furthermore it is an inclusive pedagogical approach that enables children regardless of differences in attainment levels or gender to engage in science activities and enjoy doing science.

This paper presents some insights gained on the barriers that: education systems, schools, teachers and students experience and have to overcome when implementing Inquiry-based learning at primary level.

THEORETICAL BACKGROUND:INQUIRY SCIENCE AT PRIMARY LEVEL

There are various problems with pedagogy at primary level. Research in the United Kingdom shows how conceptual level of understanding has decreased since the 1970's (Tymmes *et al.*, 2008). One of the major obstacles identified is the number of primary school teachers who find themselves having to teach a subject which they are not that confident in. Primary teachers tend to be class teachers, teaching a range of subjects. In addition to the basic language and numeracy skills, they are also required to teach, along other areas also science, a subject in which they lack sufficient self-confidence and knowledge. Faced with limited knowledge and understanding, primary teachers often choose the traditional ‘chalk and talk’ approach with which they feel more comfortable and consequently avoid inquiry-based methods that require them to have deeper integrated science understanding. The pedagogy adopted is that of memorizing scientific knowledge rather than promoting understanding; furthermore, teachers are also faced with heavy workloads which leave little time for meaningful experiments. In addition, research shows that children reflect on their own everyday direct experiences of the world around them when using scientific knowledge (Gatt et al, 2007; 2008). They rarely fall back on knowledge that they have gained in traditional ways at school. This highlights the great need for young children to experience and live science rather than reading about it. It is thus of great importance to help primary teachers to develop the skills in using Inquiry based learning and approaches which promote the engagement of children in science. Fortunately gender differences in science have not appeared at primary (Haworth *et al.*, 2008). This does not mean that the gender dimension does not need to be taken into consideration as gender differences appear instead in terms of attitudes with boys holding more positive attitudes (Weinbourgh, 1995).

At primary level, inquiry based learning is perfectly adapted to young children and appropriate for introducing science education as it makes the best use of children’s innate tendency to want to learn and know more – to feed them when they are still in their ‘curiosity golden age’ (Rocard, 2007). Having said this, it is to be acknowledged that there are already many dynamic teachers who have developed multiple innovative practices. They are an untapped resource.

Inquiry-based science education (IBSE) has also proven its efficacy at both primary and secondary levels in increasing children’s and students’ interest and attainment levels and at the same time stimulate teacher motivation (European Commission, 2007). IBSE is also found to be effective with all kinds of students from the weakest to the most able and is fully compatible with the ambition of excellence. This is mainly the case as it allows children to engage with science phenomena at different levels. Moreover IBSE is beneficial in promoting science with girls as they enjoy participating in science activities and can pursue aspects of science more to their interest. It thus works in favour of promoting better attitudes towards science, particularly with girls who tend to be less enthusiastic.

THE PRI-SCI-NET PROJECT

PRI-SCI-NET is an EU funded FP7 Supporting and coordinating action (Call SiS-2010-2.2.1.1) on innovative methods in science education: teacher training on inquiry based teaching methods on a large scale in Europe. The project is coordinated by the Malta Council for Science and Technology (MCST) and has 17 partners from 14 countries. The project started in September 2011 and is three years long.

The project promotes the use of the Inquiry-based learning approach among primary teachers teaching science to young children in the age range of 3-11 years. In doing so it has brought together a group of science educators from all over Europe specialising in primary science education to develop together 45 inquiry-based activities for children between the ages of 3 and 11 years (Keys & Bryan, 2001). The project also intends to set up a Europe-wide network for professionals and academics in the area of Primary Science Education. Furthermore, as PRI-SCI-NET acknowledges the need to train and network primary teachers, teacher-trainers and educators as part of their professional development there is a significant investment in national and international teacher-trainings and conferences across Europe. The training and professional support to teachers aims to help them use Inquiry based learning in Science in schools. A virtual platform at European level will also be developed to network professionals as well as support the organisation of training courses. The project also recognizes teachers' and researchers' achievements through a Certificate of Excellence.

The Vision for Inquiry-based learning in Science

The Pri-Sci-Net team of about 30 primary science educators from a number of EU Member States have worked together to develop the vision for inquiry-based learning in science which they want to promote when doing science with young children. It is believed that a strong vision was needed, not only so that all the different partners share the same understanding of the type of inquiry which they would like to promote across Europe, but also because a clear vision would make the message put forward stronger. Current thinking in education circles on the nature and techniques used in inquiry-based learning were considered, and together with their personal experience and views, the partners have developed a vision which defines what characteristics inquiry-based activities are to have.

This Vision for doing inquiry with young children within the project Pri-Sci-Net is that: Inquiry-based science at primary level is a teaching and learning framework with implications about learning science, learning to do science, and learning about science. In this framework: children

- engage actively in the learning process with emphasis on observations and experiences as sources of evidence;
- tackle authentic and problem based learning activities where the correctness of an answer is evaluated only with respect to the available evidence and getting to a correct answer may not be the main priority;
- practice and develop the skills of systematic observation, questioning, planning and recording to obtain evidence;
- participate in collaborative group work, interact in a social context, construct discursive argumentation and communicate with others as the main process of learning;
- develop autonomy and self-regulation through experience;

The teacher scaffolds and guides learning by providing a role model of an inquiring learner. The teacher does not function, in the eyes of the children, as the sole bearer of expert knowledge. Instead, the main role of the teacher is to facilitate negotiation of ideas and to highlight criteria for formulating classroom knowledge. This builds on Constructivist views of learning that provide theoretical support for teachers as facilitators in the students' process of reconstructing their knowledge by interacting with objects in the environment and engaging in higher-level thinking and inquiry based problem solving (Crawford, 2000). The assessment framework within such a vision is mainly formative, providing feedback to the teaching and learning process for all classroom participants. Written examinations leave little space for inquiry and promote too much rote learning. Thus formative assessment is considered to be more appropriate.

AIMS OF RESEARCH

This study involved the evaluation of a number of the inquiry activities developed by the project partnership. The inquiry activities were initially chosen from a larger selection of activities proposed by the partners. These were evaluated against the criteria reflected in the project vision of inquiry. The 45 activities eventually chosen were then translated and a number of them were to be trialled in the different countries for linguistic and cultural adaptation.

The specific research questions targeted in the evaluation exercise were the following:

1) What linguistic difficulties have been identified in translating and implementing the activities? What linguistic aspects need to be taken into consideration?

2) What cultural problems/difficulties have been identified in implementing the activities in the different countries across Europe? What cultural aspects need to be taken into consideration when translating in the different languages for use in different countries?

3) To what degree do the activities evaluated fit within Pri-Sci-Net's vision for IBSE in primary science? What aspects need to be given extra attention in the development of the education material?

METHODOLOGY

The main evaluation tools used for the research exercise involved: non-participant observation; interview with the teachers after implementing the activities, and with a number of children after the activity. All the research tools focused on observing and identifying how well the inquiry-based activities were well received by both teachers and students, as well as whether they also encountered any difficulties with respect to the activities involved and any language used during the activities. These tools provided rich data on the implementation of inquiry across Europe.

In this paper, the results obtained by the partners involved in trialling the activities in England, France, Greece and Germany are reported.

Greece

In Greece, the learning of natural science at primary level is integrated with the social sciences under the subject of 'studies of the environment' and which is taught between the ages of 7 and 10 years. This fulfils one of the stated goals of the primary curriculum in Greece which includes the *familiarisation with scientific thinking and scientific methodology (including observing, collecting, utilising data, forming hypothesis, experimenting, analysing and interpreting data, drawing conclusions, making generalisations and constructing models) and information and communication technology, so that they (students) are fully prepared as future scientists to carry out research and technology planning* (CTPSCFNS, 2003, P171). In Greece, three activities, namely 'shadows' which was developed by the University of Southampton, United Kingdom, and two other activities 'Air as Matter' and 'Magnetic Power' developed by the University of Tvarna, Slovakia, were translated into Greek. Following authorisation from the Cretan Regional Educational Authority the activity on magnets was tested with the 3rd Grade (9 year olds), while the activities 'Air as Matter' and 'Shadows' were trialled in the 2nd Grade (8 year olds). The activities were tested in four primary schools, two of which were held in urban areas and the other two in rural areas.

Before the pilot, a 3 hour training seminar was held with each of the school teachers who were going to use the materials. The aims of the session were to familiarise the teachers with the Pri-Sci-Net goals, vision of inquiry as well as the activities that were to be tested. As part of the evaluation process, four students from each class was interviewed as well as the teacher at the end of each session. Parents' consent was obtained for interviews following the project's ethical protocol. The activities were carried out in the normal classroom in all cases except one which was carried out in a science laboratory. The size of the calss in the urban schools was double (22) that in the rural schools (10).

France

Primary school in France includes both kindergarten and elementary school, and it is organized in three cycles. During the first cycle (kindergarten) science learning is meant as a discovery of the natural world, by sensibilizing pupils to human duties towards animal, plants and health. The second cycle (last year of kindergarten, Preparatory Course and First Elementary Course) is dedicated to acquisition of skills like orientation in space and time and classification of objects and materials. Finally, in the third cycle (Second Elementary Course, First Intermediary Course, and Second Intermediary Course) pupils are introduced to perform guided experiments, as well as to educative technologies.

Teachers of an urban Parisian public elementary school and researchers of University of Paris 8 were involved in the testing of three IBSE activities. The activity *Seed Spinners* - developed by the University of Southampton, England - was tested in two classes (54 children) of 6-7 years old pupils. The activities *Air as matter* and *Magnetic power* developed by the University of Tvarna, Slovakia - were tested in five classes (respectively 107 and 28 children) of 7-8 year old pupils.

In a preliminary phase, several meetings were arranged with pedagogical staff in order to present the project, discuss its relevance with relation to cultural and contextual factors, its pertinence to the school curricula, and its applicability in terms of logistics, timing, ethics and safety issues. Further meetings have taken place during the implementation of the activities, to progressively adjust the scenario of the pedagogical sheets according to the class needs.

The activities were carried out during the lessons in class. Interviews, questionnaires and observation schedules were employed by the researchers to mainly estimate: enjoyment of the activities, novelty of the approach, its appropriateness with relation to age, curriculum, linguistic as well as cultural context, and its effectiveness in terms of progressive IBSE skills acquisition (observing, collecting evidence, using evidence, making critical discourse etc.). These estimations were made both by pupils and by teachers.

England

In England there generally exists a positive climate with regard to Inquiry Based Science Education at primary level, and at Early Years level, the general philosophy of learning (in which effective teaching and learning is considered to be characterised by playing and exploring, active learning, creating, and thinking critically) fits very well with the IBSE principles. IBSE has for decades had a strong focus in the primary curriculum, but in September 2014, a new national curriculum will be implemented which will focus more strongly on learning facts and concepts. In primary education, science as a subject has less status than maths and English,as a consequence there is less time available to teach it, and thus makes it more difficult to deliver

IBSE lessons, which often require longer time. Also, despite the fact that teachers are trained in the IBSE approach during their teacher education, science is one of many subjects they receive training in and the total duration of the full training is relatively short. Many teachers therefore still lack confidence in teaching science, especially inquiry based aspects. Furthermore, there are not many opportunities for IBSE professional development in England, and it is generally very difficult for teachers to be allowed time away from school in order to receive further training.

The project partners from the University of Southampton (UOS) and the Institute of Education, University of London (IOE), were involved in the trialling of the activities in England. The activities trialled included ‘Exploring the world around us: shadows, day and night’, developed by UOS; and ‘Exercise for Health’ and ‘Magnetic Power’ which were both developed by the University of Tvarna, Slovakia. These activities were developed for children aged 6-8 years; however in England they were trialled with children aged between 5 and 8 years old, as this are the early primary age ranges in England. Each of these three activities was trialled four times (and the Magnetic Power activity an additional fifth time), in different age groups at different schools across the South of England.

In addition, the partner from the IOE trialled three activities with younger children aged 3 to 5 years old. The activities trialled with this age group included ‘Magnets’ developed by the University of Cyprus; and ‘The Swing Game’ and ‘Strong Walls’, both developed by KATHO, the partners from Belgium. Each of these activities was trialled once, in two different Early Years education settings in London.

The activities were observed using an observation rating scheme which was designed by the KATHO partners in Belgium, and used by all partners for the trial observations. After the activities were finished, individual or small groups of children were interviewed for up to 20 minutes about their views and feelings about the IBSE activity; whether this was a novel way of working for them; what they enjoyed; and what they found challenging or less enjoyable. The teacher was then interviewed for up to 20 minutes with regard to any linguistic or cultural issues encountered upon implementing the activity; any adaptations they made or would make if using the activity again in the future, and why; and to rate the activity against the PriSciNet criteria of inquiry based science education.

Germany

Inquiry-based approaches are mentioned in major German policy papers for preschool and primary school, and it is emphasized that children should be able to ask relevant, scientific questions and to investigate them. However, during initial teacher training, science is only an optional subject of minor importance. In preschool, teachers often feel overburdened by teaching sciences due to their lack of science knowledge. In primary school, natural science are taught together with social sciences and history, and teachers feel unsure with their own expertise on the subject matter as well as on inquiry approaches.

The evaluation exercise in Germany was done with 6-8 years old pupils (n=73) from three different classes in two different urban schools. The activities’ themes covered “Seed spinners” by the University of Southampton, “Exercises for Health” and “Air as Matter” developed by the University of Tvarna, Slovakia. The relevant school authorities were contacted for permission to carry out the research in schools. Following obtaining these permissions, support was provided to teachers (primarily background information about the scientific content) to be able to implement the inquiry activities in the class.

RESULTS

The trials that took place have shown that the children in the four countries included in this study were overall very excited to do science through inquiry. They were very eager to handle objects and try things out themselves. This aspect was also acknowledged by all the teachers involved. These results are not new and resonate with other studies as well as arguments put forward in favour of the inquiry-based approach in science as one of the main pedagogies to be used to teach science (cf. Rocard, *et al*, 2007).

The research, however, helped identify some insights into the impact of implementing inquiry-based activities at national level across Europe. These insights were categorized at student, teacher, school, and system levels. These insights are not identified for the purpose of carrying out a comparative study, but rather to try and understand why it has been so difficult for inquiry-based learning in science to take off within national education systems in Europe.

Insights at student level

Children in each of the four different countries found the activities interesting and were observed by their teachers as well as the researchers to be very engaged. In *Germany*, the children were highly involved in observations, developing predictions, gathering evidence and communicating with others in collaborative group work. This was probably the case because primary level children in Germany are used to pedagogical approaches that foster discovery and exploration. They communicated with others and participated in collaborative group work. However, systematic planning and recording to obtain evidence was less important in these lessons, and the teachers adapted the worksheets (mainly simplifying and shortening) to be able to spend more time with the children on exploration and active hands-on engagement. Reflection and discussion about evidence and explanations was done orally, generally with the whole class, sitting in a circle. In *England*, the children also responded well to the inquiry-based activities; they were excited and highly engaged. Children demonstrated scientific learning. Similarly, in *France*, the children's enthusiasm towards the practical aspect as well as participating in group work was noted. In *Greece,* children participating had sparkling eyes and were eager to try out the experiments with their own hands. This shows both that the activities used reflected the project's vision of inquiry as well as the efficacy of inquiry science teaching. This does not mean, however, that no difficulties were encountered while children were learning through inquiry. Various aspects of inquiry emerged to be both innovative and engaging but at the same time challenging. These challenges create barriers which so far have kept inquiry from establishing its presence in the primary curriculum.

Difficulties with collaborative group work

It was highlighted in a number of countries that while children were enthusiastic to work together, they experienced difficulties in working collaboratively. In *England*, for example, whereas the children spoke favourably about working in groups, they also highlighted that it could be challenging, particularly if group members did not collaborate well or did not contribute in helpful ways. Circumstances mentioned included having group members who are dominating, do not listen or do not give helpful suggestions, or do not respond to suggestions made by the group leader. In *Greece*, children were not very much used to working in groups and during the trials there was a need to have one supporting adult with each group in order to facilitate collaborative learning. In *France,* children were not acquainted to groupwork, so teachers proposed to form groups by gathering children with different learning profiles in each group.

Difficulties with Process Skills

Children in the different countries demonstrated some difficulties in carrying out the activities and in employing process skills which form part of inquiry science. In *Germany*, for example, while children were proficient in carrying out the activities and making their observations, they had more difficulties in systematic planning and recording. They also needed the teachers' support in drawing conclusions. These aspects of systematic inquiry were relatively new to the children. In *England*, it was noted that there was a variety in skill levels, and even children at equal age group levels sometimes appeared to be at different stages of skills acquisition. This affected the level at which children could carry out inquiry activities, thus showing a clear impact on progression of inquiry activities within and between age groups. Teachers of children in younger age groups often felt that specific scientific process skills were too challenging for children at that age, for example making predictions, working in groups, presenting findings or plans to the whole class. Teachers of all age groups 5-11 considered it challenging for pupils to link their findings with scientific knowledge, and to write down a conclusion. In *France*, pupils' initial enthusiasm was often followed by moments in which they struggled in expressing their naïve conceptions; formulating and remembering hypothesis; considering disproving hypothesis as personal failure rather than part of the inquiry process; talking about personal anecdotes that were correlated, but not directly pertinent to the on-going activity; and sharing ideas with others. Moreover, while the children were engaged in empirical reasoning, they could not autonomously construct knowledge upon repeated experiences but needed to be guided to select relevant aspects. However, with respect to the effectiveness of the approach, such struggle led to valuable outcomes: both teachers and researchers noted the pupils' deeper and durable understanding of the science topics, besides an improvement in social cooperative against competitive attitude towards learning. In *Greece*, the children were more concerned with 'getting the right answer' than the process of inquiry. In fact, they were observed to erase their original hypothesis to correct it when they had observations which were different from their predictions. The process of hypothesising appears to have been one of the major challenges encountered by the children as they either were unfamiliar with formulating their own predictions, and even more so, to write them down. This demonstrates an underlying assumption that often children do not consider their ideas to have much value within the school setting, and that teachers or textbooks will usually provide those correct ideas and concepts which they will eventually understand and accept. The children need practice over a period of time in order to learn to hypothesise within a scientific perspective.

Difficulty with written texts

Children also encountered difficulties in using the worksheets during the activities. This shows challenges both in being able to prepare worksheets which are within the children's levels of literacy, as well as training children in the process of articulating in writing down their ideas, observations and conclusions from a young age. This literacy issue was encountered particularly in *Greece* and in *Germany*, where in the former, children lacked conviction in their ability to write down their hypothesis. Similarly, in *France* 6 and 7 year old children encountered some difficulties with written instructions and two-entry tables. Hence, teachers proposed to replace tables by chronological diaries of the activities filled with images and short comments. It was noted that the worksheets used could be made easier and less demanding in terms of the text used. However, it also highlights that teachers need to cater for literacy learning during science. Writing in science does not only require proficient literacy levels, it also demands that children know how to write about phenomena in a scientific way. Thus teachers need to teach literacy for science alongside teaching science through inquiry. In *England* worksheets were often adapted by teachers to the age and ability levels of their pupils, which was as expected. Teachers tended to focus on the practical aspects of the lesson, rather than writing, though in age group 7-9 classes, groups were often asked to write down their questions and ideas for investigations on big sheets of paper to later present to the class. Often this process was led by an able pupil in the group, but other pupils struggled more. Some teachers made a point of spending time on the scientific vocabulary involved in the activity, so that the pupils understood the concepts and could be encouraged to use them. As described under process skills, less time was spent on pupils writing down a conclusion about their findings, and teachers considered this a challenging for pupils. One teacher of a younger age group (5-6 years old) specifically said: « I don't want my science lessons to turn into literacy lessons».

Difficulties in presentation skills

While children in all four countries involved liked the idea of presenting their work to the rest of the class, some also acknowledged that this presented a challenge to them. Children in *England* stated that they were excited to share their work with the rest of the class, but they had difficulty identifying what content they had to share and how to put it into words. They were sometimes annoyed that other children did not seem to be very interested to find out about other groups' work and thus did not listen to the presentations attentively. This was frustrating to the children who were presenting. Some difficulties similar to those identified in England were also encountered by children in *France*, where younger children were not acquainted to presentations. For this reason, tteachers had to <u>encourage discussion</u>, by asking the children of a group to "persuade" the children of another group. This interpretation of discussion in terms of persuasion actually pushed children to find and unfold pertinent arguments providing reasons and examples.

Teachers' Perspective

Teachers also provided insights into the challenges of implementing inquiry-based learning in science at primary level. The teachers involved tended to acknowledge the value and effectiveness of inquiry. This was often a key reason for accepting to participate in the trials. Teachers in *England* highlighted how they liked to provide children with the opportunity to discover things about the world around them through hands-on investigations. Providing multisensory learning experiences through inquiry was also considered important by some teachers. However, although teachers' demonstrated levels of enthusiasm varied, a number of common concerns were highlighted.

Many of the teachers expressed a degree of lack of confidence in doing science through inquiry. This barrier was both the result of a fear of engaging with particular science concepts as well as doing the practical activities included as part of inquiry. In *Germany*, for example, background scientific knowledge had to be provided to the teachers. German primary school teachers often lack sufficient scientific knowledge and confidence in teaching the subject, background information. Professional development opportunities focusing on IBSE approaches would be very beneficial to overcome insecurity and to promote primary science education. In *France*, the researchers collaborated with teachers to divide the main phases of the activity (engagement, inquiry, evaluation) in sub-phases or sequences of steps. This allowed setting a work rate for the whole class as well making the work of each group comparable, and to define what children should have acquired in terms of competence and knowledge at the end of each step. Teachers generally agreed about the fact that implementation of IBSE approach need the re-definition of many aspects of didactics, from logistics and timetable, to pedagogical objectives and tutoring, and that an effective implementing of this educational approach should be measured on the autonomy of both teachers (initiative taking, flexibility in pedagogiy, etc.) and children (relying on evidence, exploiting uncertainity as a stimulus to seek deeper understanding, etc.).

Teachers were also observed to be afraid to move away from a teacher-centred approach and provide children with more opportunities to express their ideas. In the case of *England*, despite their strong motivation to teach IBSE, teachers often seemed reluctant to fully hand over control to the children during their investigative work. It was observed that teachers teaching Early Years groups (3-5 years old) were often more open-ended in their approach than the teachers of the 5-7 age groups. This could be related to the more informal and less structured approach to learning within the Early Years. In *Greece,* teachers were inexperienced in inquiry and were afraid to encourage children to ask questions. Some were not well prepared and expected the research team to facilitate the activity instead. This meant that they were not able to guide students through the investigation.

Difficulties at school and system level

A number of logistical aspects were also noted to impinge on the implementation of inquiry at national level. The curriculum in *France*, for example, tends to be rigid and content laden, which makes it very difficult to implement inquiry in French primary schools. In fact, in *France*, timetabling inquiry proved to be one of the major challenges which needed to be overcome in order to be able to trial the activities in this study. This aspect was encountered despite inquiry not being entirely new to education in *France,* following the impact of the 'Lamain a La Pâte' project over the past ten years. In *Greece* as well as in *Germany*, logistical problems were of a different nature. The many extra-curricular activities such as Christmas festivities, outdoor school activities and others, eat into the normal school learning time. Unfortunately, since doing inquiry is considered to be time consuming, it tends to be left out of the limited remaining school time-table and thus science inquiry suffers.

Methods of established assessment at national level can also create barriers to inquiry. Summative assessment tends to capture mainly the content learnt while inquiry tends to focus on the process of science. The assessment modes do not reflect learning that is best acquired through inquiry. This reality was highlighted in *England* where a strong focus on meeting learning targets for individual pupils seemed to result in hesitance on the part of teachers to have children do inquiry science on a regular basis, or do it in the child-led way it is intended to be. This is because teachers considered assessment of IBSE to be challenging, and were unsure about alternative ways of incorporating assessment into IBSE without hindering its process. In addition, science curricula tend to reflect such assessment practices too, and give more value to content than to process. In terms of inquiry, some teachers in *England* in fact described the existing science curricula as 'dull'.

CONCLUSION

This transnational study has shown how barriers to implementing inquiry-based learning in science at European level present both national and European wide challenges. It is to be noted that whereas the European Commission has for long been advocating the inquiry-based learning approach in science, few were those governments who followed suite and ensured that an effort at national system level be made to find space within the current curriculum. Inquiry-based learning presents an innovative way of learning which not only demands new pedagogical skills, but also requires more time to implement, as well as new forms of assessment. The result is that it is not easy to implement inquiry-based learning within the current existing education systems, many of which are still based on a teacher-centred approach and where the acquisition of knowledge is considered to be more important than skills development. The challenge at system level tends to exist in the different countries involved in this study, even if the challenges are different according to the different national contexts. However, if no effort is made at radically changing the way that school systems operate, it would remain quite difficult for inquiry-based learning in science to become the established mode of learning science across Europe.

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