EU Action in developments in the curricula and teaching methods appropriate for the future global technical challenges

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***Abstract*—In keeping with the IEEE conference theme 'Developments in the curricula and teaching methods appropriate for the future global technical challenges' the purpose of our presentation is to show how we are promoting new development in the curricula and bringing new ideas into action. This paper sets out the context for the EU Seventh Framework 'Pathway to Inquiry Based Science and Maths Education' (IBSE) project (2011-2013). It outlines the current situation with regard to Science at Junior Certificate level (13-15) in Ireland and highlights the recent developments with the establishment of a new Junior Cycle. Key findings from an online survey on the use of Virtual learning Environments (VLEs) to support IBSE will be presented. Finally, we will outline the workshops that took place in Ireland and Greece, as part of the Pathway project, and the incorporation of digital technologies into the Inquiry process especially the use of computational models to support teaching and learning.**

***Keywords*—Curriculum Innovation; Teaching methods; Inquiry based education; Virtual online environments; Computational models**.

I. INTRODUCTION

The International Centre for e-Innovation and Workplace Learning is interested in the innovative design and use of technologies in a range of workplace contexts. It seeks to collaborate with and empower practitioner-researchers in making explicit their implicit knowledge and strives to encourage actions based upon wise and considered practice. The Centre is a partner in the European Seventh Framework project 'Pathway to Inquiry Based Science Education' and the European Competitive and Innovation project 'Inspiring Science Education' (ISE).

The Pathway project was a European Seventh Framework initiative (2010-2013) aimed at improving Inquiry Based Science and Maths Education (IBSE) in schools across Europe. The Pathway Consortium consisted of twenty-five partners. The project involved experts in the field of Science education research and teachers' communities, scientists and researchers in pioneering scientific research, policy makers and curriculum developers to promote the effective widespread use of Inquiry and problem based Science and Maths teaching techniques in primary and secondary schools in Europe and beyond.

The aim of the project was to set the pathway toward a standard based approach to teaching Science by Inquiry, to support the adoption of Inquiry teaching by demonstrating ways to reduce the constraints presented by teachers and school organisation, to demonstrate and disseminate methods and exemplary cases of both effective introduction of Inquiry to Science classrooms and professional development programmes, and finally to deliver a set of guidelines for the educational community to further explore and exploit the unique benefits of the proposed approach in Science teaching. The main activities and outcomes of Pathway project can be accessed on the EU Pathway website at http://www.pathway-project.eu/ The follow-on European project 'Inspiring Science Education' (ISE) (2013-2016) continues the focus on Inquiry with the addition of e-tools to make Science and maths education more challenging, imaginative and inspiring for today's students who will be the citizens of tomorrow.

The 'Science Education Now: A Renewed Pedagogy for the future of Europe', [1] refers to the alarming decline in

young people's interest in key Science studies. This is also highlighted in the Report of the Taskforce on Education of Mathematics and Science at Second Level published by Engineers Ireland (2010) which highlights that 73% of students believe that Junior Certificate Science (13-15 years old) had some impact on their decision not to study physics or chemistry to Leaving Certificate level (17-18 years old). These reports indicate that there are problems in the way in which Science and maths are taught in schools across Europe.

II. EU PATHWAY PROJECT

The core elements of the Pathway project's conceptualisation of Inquiry Based Science and Maths Education are outlined in Table 1. Pathway approach to IBSE. (Adapted from [3])

TABLE I. PATHWAY APPROACH TO IBSE

A. Structured	Strongly teacher-directed. Students follow their teacher's direction in pursuing a scientific investigation to produce some form of prescribed product, e.g. they investigate a question provided by the teacher through procedures that the teacher determines, and receive detailed step-by step instructions for each stage of their investigation.
B. Guided	More loosely scaffolded. Students take some responsibility for establishing the direction and methods of their Inquiry. The teacher helps students to develop investigations, for example offering a pool of possible Inquiry questions from which students select, and proposing guidelines on methods.
C. Open	Strongly student-directed. Students take the lead in establishing the Inquiry question and methods, while benefiting from teacher support. For example, students initiate the Inquiry process by generating scientific questions and take their own decisions about the design and conduct of the Inquiry and the communication of results.
D. Coupled	A combination of two types of Inquiry, for example a guided Inquiry phase followed by an open Inquiry phase.

International and national workshops on IBSE were facilitated by the Pathway teams in Ireland and Greece over the course of 2012 and 2013. The EU Pathway workshops that took place in Ireland can be accessed at http://www.pathway-project.eu/activitiesIE and the activities in Greece can be accessed at http://www.pathway-project.eu/activitiesGR

III. NATIONAL SITUATION IN IRELAND

Students attending post-primary schools in Ireland between the ages of 13 to 15, study Junior Certificate Science. This is a combined course divided into three areas: Physics, Chemistry and Biology. Science is not a compulsory subject at post-primary level but many schools treat Junior Science as a core subject. Statistics from the Report of Task Force on Education of Maths and Science at Second Level [2] indicate that over the past nine years, on average 85.6% of the student cohort sit a Junior Certificate Science Examination. After three years students are assesed by way of the Junior Certificate Examination. The assessment involves a written examination and course work submission.

Students can choose to do a Higher level or Ordinary level examination depending on their ability and the advice of their teacher. Figures from the Task Force Report indicate that approximately 70% of students study for the Higher level examination. Aspects of IBSE are already inherent in the Science curriculum of the post-primary Junior Cycle as planning, investigations, critiquing experiments, searching for information, debating with peers and forming coherent arguments are all part of the Junior Science Syllabus. However, only planning, investigations and forming coherent arguments are assessed.

At Junior Cycle, the practical nature of the curriculum and the method of assesssment allow space for IBSE to be incorporated into the curriculum. Junior Cycle assessment in Science involves a final written examination (65%) along with two Course Reports. Coursework A (10%) is a record of completion of prescribed practical investigations and Coursework B (25%) is a report on two specified investigations undertaken in the third year. Students also are given the option of submitting a report on an investigation of their own choice that meets the criteria.

It is widely recognised that the current assessment system at post-primary level needs to be reviewed. The new assessment approaches will start with the Junior Cycle Science in 2015 and this provides a positive way forward for Inquiry based learning. The current Junior Certificate Examination will be replaced by a new examination called the Junior Cycle Student Award; students will also complete this examination after three years of second level study. The new Junior Cycle will have a school based approach to assessment. This school based assessment will focus on both the process and product of learning through a combination of students' work during the final two years of the cycle and a final examination. The final assessment will be just one element of a broader school based approach to assessment.

IV. NEW JUNIOR CYCLE IN IRELAND

While details of the actual new curriculum have not yet been published a lot of important detail has been published in

the DES document "A Framework for Junior Cycle" [4]. The document outlines eight Principles for Junior Cycle Education and these principles underpin twenty-four Statements of Learning. An examination of these Statements of Learning shows strong support for Inquiry based learning. For example, these following three statements, taken from the list, show some key elements of Inquiry and a move away from a content based curriculum:

The student:

17. Devises and evaluates strategies for investigating and solving problems using mathematical knowledge, reasoning and skills.

18. Observes and evaluates empirical events and processes and draws valid deductions and conclusions.

24. Uses technology and digital media tools to learn, communicate, work and think collaboratively and creatively in a responsible and ethical manner.

Each Junior Cycle subject including Science has six key skills embedded. An analysis of these key skills and some of their elements, as seen in Table II shows strong support for an Inquiry based approach to learning.

TABLE II. SIX KEY SKILLS OF JUNIOR CERTIFICATE

Key Skill	Elements
Managing myself	Being able to reflect on my own learning. Using digital technology to manage my learning and myself.
Staying well	Discussing and debating.
Communicating	Discussing and debating.
Being creative	Stimulating creativity using digital technology.
Working with others	Learning with others. Working with others through digital technology.
Managing information and thinking	Gathering, recording, organising and evaluating information and data.

We will now explore the possibilities that virtual learning environments (VLEs) offer to support IBSE.

V. THE USE OF VIRTUAL LEARNING ENVIRONMENTS TO SUPPORT IBSE

Science teachers in second level schools around Ireland with VLEs were self-selected to participate in an online survey on the use of VLEs and how these online environments can support an Inquiry based approach to Science teaching and learning [5]. A total of sixty Science teachers from different schools responded. The purpose of the questionnaire was to gain more in-depth information on the use of IBSE, and how VLEs were being used to support IBSE.

A focus group of eight Science teachers, three female and five male were brought together in order to discuss the feedback from the questionnaire. The group was composed of experienced or very experienced teachers, with many years' experience in both classroom and in an advisory capacity with one teacher teaching for only two years. The group was all positive towards an Inquiry based approach and was aware of the current situation with regard to classroom teaching of Science.

The focus group agreed that Science education was moving in the direction of an Inquiry based approach and that there was a growing awareness among teachers that Inquiry was the method that should be used. It was also noted that it was now the expectation of the Department of Education and Skills (DES) Inspectorate in Ireland that Science teachers incorporate some element of Inquiry into their classroom practice. Many teachers reported that some proportion of the current Junior Certificate Coursework 'A' was being delivered through Inquiry. However Inquiry is still seen by many as an add-on and 'teaching to the test' is still the main classroom focus.

A total of 50% of the teachers who took the questionnaire agreed that VLEs could support Inquiry. Teachers see VLEs supporting Inquiry chiefly in the areas of providing a supporting context for the subject area (almost 90%), promoting student centred active learning (81%), scaffolding learning activities (82%), supporting interactive simulations to enhance conceptual understanding (77%). Most of the teachers surveyed were only using VLEs for a relatively short time, i.e. two years or so, and this is reflected in the findings on how the survey teachers are using the VLEs with their students. Almost 90% indicated that the VLEs were used for the presentation of content while 66% were using their VLEs to design and set student quizzes.

Teacher responses include mention of the significant barriers at present. While over 60% of the respondents feel that the curriculum supports Inquiry, less than 50% feel assessment supports Inquiry. Time is another factor with less than 20% feeling that there is sufficient time to adopt an Inquiry approach. Grade pressure is another factor, which is experienced by 80% of the respondents. The VLE is also an issue for some teachers with one respondent mentioning the practical nature of Science and the fear of this being replaced by models and simulations. Another fear expressed was about Inquiry resulting in a drop in standards. The lack of Continuing Professional Development (IBSE) in Inquiry was also highlighted as a barrier by some of the teachers.

VI. INQUIRY: OVERCOMING BARRIERS

The teachers who completed the online survey on the use of VLEs have highlighted the current barriers to an Inquiry approach. The nature of the current examination system and assessment was highlighted and indeed discussed at length by the focus group. The proposed new Junior Cycle and the ways in which students will be assessed will be much more favorable and indeed should facilitate an approach which is Inquiry based.

The current upgrading of the Schools Broadband infrastructure by the Technology unit of the Professional Development Service for Teachers (PDST) will provide improved and robust connectivity for Irish second level schools. By September/October 2014, all second level schools will have high-speed 100Mbit/sec broadband. This should provide an opportunity for teachers to use technology and allow classroom usage of online models. High quality Broadband is a critical element of the ICT Infrastructure to facilitate the use of online tools and is specifically relevant when using VLEs and online resources for learning, teaching and assessment.

A. Capabilities and affordances of VLEs to support IBSE

The areas of highest usage are: providing a supporting context for the subject area, promoting student-centred active learning, guiding learning activities, and supporting interactive simulations to enhance conceptual understanding. Areas of highest use are: presentation of content and document links, providing/assessing student assignments, and quizzes. In contrast use of VLEs for peer assessment and collaboration between students are the areas of lowest usage. Lowest levels of use were found in blogging, live chat, peer assessment and wikis.

In relation to personal learning over 95% of teachers believe that VLEs can support personal learning regarding student-centred active learning and higher-order thinking skills, guided (or scaffolded) learning activities, can support students reflecting on their own learning and provide differentiated learning opportunities. Percentages of teachers using these capabilities lie between 54% (for student reflection) and 87% (for scaffolding learning activities), which are significant given the barriers that exist to using a VLE.

Additional findings show a range of diverse VLE uses, including self-directed learning, differentiation, flexibility, support for different learning styles, and extending the classroom:

'Supports self-directed learning'

'can help quiet pupils, everyone has a voice rather than the loudest person in the class'

'Students with a keen interest and ability to manage their own learning are given the chance to do some independent thinking'

'Reflected the different learning styles, and they knew their own learning styles, and knew how it could help them – differentiated'

'place to extend the classroom conversation and space'.

Over 94% of teachers believed that VLEs can support teacher to student communications and collaboration between students. Percentages of teachers using these capabilities lie between 35% for collaboration between students to 57% for teacher to student communications, and are 22% for live chat, 28% for discussion forums and 30.6% for wiki use, which again are significant given the range of barriers that exist.

Other findings reflect the importance of interactivity, engagement and collaboration, as highlighted by the following comments:

'make it clear that what we're doing is interactive, that they're creating stuff and responding to stuff, it's not a textbook anymore, if we can do that then I think we're turning a key'.

The findings in relation to simulation and virtual laboratories show that 100% of teachers believe that VLEs can support doing Science with virtual labs and interactive simulations. Percentages of teachers using these capabilities lie between 62.1% for doing Science with virtual labs' to 77.8% for interactive simulations, which are significant.

The findings in relation to assessment show that between 91 and 100% of teachers believe strongly or very strongly that VLEs can support assessment 'of' learning, scaffold assessment 'for' learning as well as 'peer to peer' assessment. Percentages of teachers using the VLE capabilities for these areas lie between 67% for quizzes, 65% for assessment 'of' learning, 54% for assessment 'for' learning and 24% for peer assessment.

One teacher's comment highlights the effective use of Moodle for assignments and quizzes, and how it contributes to building up an ongoing assessment profile of students:

'there's no content or not much, there's assignments they have to do, quizzes they have to do, and that's how they are graded and assessed, builds up a detailed ongoing assessment picture covering all student work as summarised in Moodle gradebook, this can easily be moderated & shared' (online 12)

'The biggest win for me is the on-going assessment'.

The difficulty of doing peer-to-peer assessment is highlighted in the following comment:

'It can be difficult to have students engage with meaningful peer to peer activities …will only come after careful teaching and coaching in face to face classroom for quite a while first'

Summary Findings regarding VLEs support for Inquiry are:

- Almost all teachers believe or strongly believe that using VLEs can support Inquiry in Science

- As students predominantly don't have access to computers in Science class, this greatly limits opportunities to use the VLE to support Inquiry based approaches.
- VLEs facilitated Inquiry in Science by extending the classroom outside of school hours
- There is a strong belief that VLEs can support Inquiry in four key areas of:

    1) Personal learning.

    2) Communication and collaboration.

    3) Simulation and virtual laboratories.

    4) Assessment.

There is evidence of a range of different levels of use of VLEs to support Inquiry. Despite the fact that until recently the assessment system does not support Inquiry in Science, and that there was huge pressure on teachers to 'teach to the test' and 'cover the course', teachers are still willing to do Inquiry in Science because they believe that it is fundamental to students' understanding of Science.

In summary, the study findings were overwhelmingly positive towards the use of VLEs in Inquiry. If significant other barriers (such as those in assessment, an access to ICT for students) were removed, the use of VLEs would most likely increase.

VII. PATHWAY WORKSHOPS

International and national workshops in IBSE were facilitated by the Pathway team in Ireland and Greece over the course of 2012 and 2013.

The Pathway team in Ireland organised twenty-one IBSE workshops, including an online workshop, for Science Teachers - Pre-Service, In-Service and Teacher-educators. Pathway workshops were also offered at the Annual Conference of The Irish Science Teachers Association (ISTA) and the Annual Conference of the Computers in Education Society of Ireland (CESI). Links were established with the Professional Development Service for Teachers (PDST) and Local Education Support Centres, whose primary role is the facilitation of Professional Development for teachers.

The first international Pathway workshop on a computational approach to IBSE took place in DCU, Dublin in February 2012 and was attended by 20 post-primary teachers from across Ireland and by five K12 teachers from the USA. Further international workshops on a computational approach to IBSE took place in March 2013 targeted at Pre-Service teachers, In-Service teachers and Teacher-educators. These workshops were attended by up to 50 Pre-Service teachers and 15 participants, consisting of a mix of Teacher-educators based in Dublin, post-primary Science teachers from across Ireland and five Teacher-educators from the USA. Policy makers and support staff in national education centres also attended both workshops. Some of the participants had used Inquiry in their teaching previously but were not familiar with Inquiry enhanced by computational thinking.

The workshop sessions were facilitated by Dr. Robert Panoff of the Shodor Institute of Computational Science Education and involved looking at the tools, models and simulations produced by the Shodor Institute and the National Science Digital Library, USA along with other online resources. The workshops examined the different types of Inquiry and how online models and simulations can be used to facilitate Inquiry in Science Education. A number of examples of simulations and models from the Shodor website were used to demonstrate examples of open, seeded and guided Inquiry (http://shodor.org/talks/ct-ibse/model2.html) The workshop also explored the creation of models and simulations as well as showing the existing models and simulations on the Shodor website. Full details of the specific models and simulations explored during the workshop can be accessed at http://doras.dcu.ie/17639/ [6].

In general teachers consider that the use of computational models is a good approach in terms of allowing students think and debate topics so that their learning can be more authentic than otherwise. Planning is more difficult and time consuming, and learners must be prepared to commit to more activity based learning. More input is required from the learner in this approach. Time is the biggest factor - students and parents want to see the course covered in terms of the number of chapters they have covered.

Sixty-one training workshops were organised in Greece in the framework of the Pathway project. These workshops were integrated in the official professional development programme of Greek Science Teachers that took place in national laboratory training centres distributed in different areas in Greece. These centres were operating under the guidance and support of the local educational authorities. The official training programme included 10 three-hour seminars and laboratory-based work for the participants. Most of the sessions took place during school hours and the teachers had to have specific permission from school Principals to attend the training programme.

In the framework of Pathway a modular curriculum was designed to be integrated into the official training framework while training materials in Greek were developed and delivered to the participants. The sessions consisted of three main parts: introduction to Inquiry, presentation of best practice examples (from the Pathway repository) and design of user generated lesson plans, with the active participation of the teachers. A continuous interaction scheme between the trainers and the participants was established to offer opportunities for support and practice reflection.

Overall 1182 Science teachers were trained using the Pathway approach in Greece. In the next paragraphs we will present the main findings from the feedback that was received after the training, immediately following the workshop and in the long term i.e. after three months of implementation of the proposed approach in the school settings of the participants. The teachers applied to participate in the Greek Pathway events for specific reasons and with various expectations. A question in the post-event questionnaire asked them to indicate

to which degree their expectations had been fulfilled. The question asked was:

Please explain why the above expectations have or have not been fulfilled.

The list of options shown in Fig. 1 was offered. Several options could be ticked.

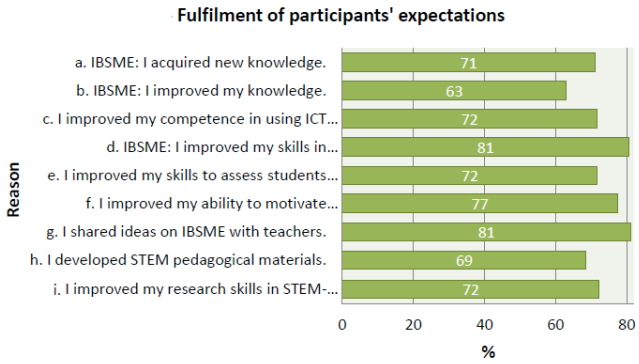

Fig. 1. Fulfilment of participants' expectations

(Data from 61 training events, 1182 responders)

The teachers had to rate each option on a four-point Likert scale. The analysis is based on the redefined scale A (Low/High). The teachers' "High" responses are shown in Fig. 1. We see that the improvement of skills in developing classroom material based on IBSE as well as the sharing of ideas on IBSE with other teachers are highly valued at 81%.

Participating teachers were asked what they were confident doing after having participated in the event. The question asked was:

After this event you feel confident to ...

Many options were offered in response as we show in Fig. 2 and any number of them could be ticked. A four-point Likert scale was used, as well as the corresponding redefined scale A (High/Low). In Fig. 2 we show the results for "High" rating. Teachers value all the options highly, above 70%. The highest percentages (90%) go to the items that would encourage scientific methodology in students (e, g & h). The relatively lowest percentage, but still above 70%, is for extra-school cooperation as a support for STEM (Science, technology, engineering, mathematics) learning.

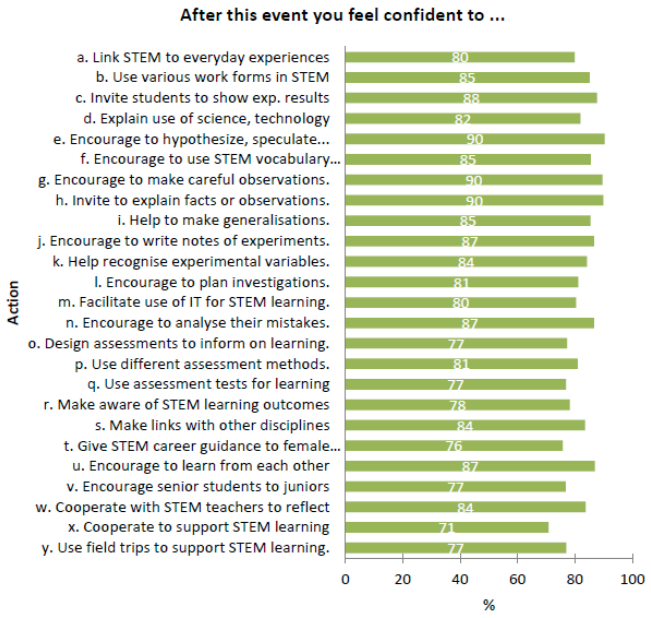

Fig. 2. Confidence level in implementing the proposed approach after the training

(Data from 61 training events, 1182 responders)

Following the event teachers were also asked to give their impressions on the possible impact on their Science teacher training methodology and on their students' learning. One of the questions asked was:

Evaluate the possible impact of this good practice on your work and your way of teaching Science.

The following responses were offered (see Fig. 3), and more than one option could be ticked. The results displayed in Fig. 3 for "High" evaluations show that all three impacts are rated similarly highly (84-87%). In conclusion, teachers had high expectations on the effects of the training on their teaching.

Impact of science teaching

Impact
a. The practice will stimulate my interest and motivation for teaching STEM.
b. The practice will increase my interest, confidence and motivation for teaching STEM using ICT based tools and techniques.
c. The practice will facilitate the teaching of sciences by using ICT for differentiated groups of learners within the same class.

Fig. 3. Impact of the training to the teaching practice

(Data from 61 training events, 1182 responders)

Finally from the results in Fig. 4 for the "High" ratings we see that teachers rate highly all options that concern the impact on students i.e. at 80% or above. Actions related with the development of scientific abilities rate close to 90%, as well as understanding and learning STEM and understanding lab

experiments better. The acquisition of EU competencies for lifelong learning is valued high at 81%.

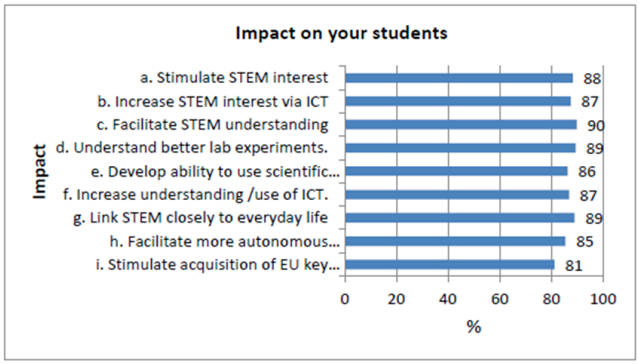

Fig. 4. Impact on the students

(Data from 61 training events, 1182 responders)

VIII. CONCLUSION

This paper outlined the aim and scope of the European Seventh Framework Pathway to Inquiry Based Science Education (IBSE) project and its role in developing Inquiry based approaches to support maths and Science teaching across Europe. The key elements of Pathway's conceptualisation of IBSE was presented.

The positive developments in the Junior Cycle Science curriculum in Ireland with the focus on new teaching methods appropriate for the future global technical challenges was discussed. The proposed new assessment approaches for the Junior Cycle Science provides a positive way forward for Inquiry based learning.

The results of an online survey on the use of Virtual Learning Environments (VLEs) to support Science teaching and learning in second level schools around Ireland showed that the Science teachers in the study believe that using VLEs can effectively support Inquiry in Science and despite significant barriers are using VLEs to support Inquiry approaches.

The form and nature of the Pathway workshops that took place in Ireland and Greece was described and the feedback from the workshops presented.

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