INSTEM CASE STUDY: IRELAND

Introduction

The Irish INSTEM team are core members of a University STEM education research Centre at Dublin City University and their research interests include: activity-based learning, including inquiry and problem based learning; teacher education strategies and structures; assessment in science and mathematics and technology and e-learning in science. They have been involved in STEM projects and initiatives since 2000 and have successfully received funding from the EU FP7 Science and Society programme to coordinate two large scale EU projects on the use and dissemination of inquiry-based approach to science education for second level students (age 1218 years), ESTABLISH (2010-2014) and SAILS (2012-2015). There is significant national focus and innovation in STEM education, with a new mathematics syllabus (Project Maths) introduced in all secondary schools in 2010 and new science syllabi being developed for implementation at lower secondary level in 2015 to be followed by upper secondary thereafter. In light of these changes, much national debate has taken place and the Irish team has facilitated and strongly contributed leadership and insight to these discussions, through their involvement in the three European projects, ESTABLISH, SAILS and INSTEM.

CONTEXT DESCRIPTION

Dublin City University, one of Ireland's youngest universities, founded in 1981, is a place of learning, with a unique focus of setting out to develop high quality, high value learning within the wider setting of Ireland's economic and social needs. Dublin City University aims to transform lives and societies through education, research and innovation. It ensures that its 16,000 students gain direct experience of industry and other workplaces, and it offers the very latest technology and facilities to ensure that all are equipped to become leaders in their chosen fields. The University has been ranked among the world's best in the world's young universities (QS World Top 50 under 50 University Ranking, ranked 44 in 2013).

The Irish INSTEM partners are core members of CASTeL – the Centre for the Advancement of Science and Mathematics Teaching & Learning, which was established as a University research centre in 2000. The expertise of CASTeL members encompasses the science disciplines and mathematics, in addition to education and its main aim is to improve the learning of science and mathematics at all levels of the educational system. This Irish INSTEM team has successfully received funding from the FP7 Science and Society programme to coordinate two large scale projects on the use and dissemination of inquiry-based approach to science education for second level students (age 12-18 years), ESTABLISH (2010-2014) and SAILS (2012-2015). Dr. Eilish McLoughlin is Director of CASTeL and was coordinator of the ESTABLISH project which had 15 partners across 11 countries. Dr. Odilla Finlayson coordinates the SAILS projects which has 14 partners across 12 countries. Dr. Deirdre McCabe is the European project manager of the SAILS project, deputy project manager ESTABLISH project and also manages the national INSTEM project.

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The overall objective of ESTABLISH was to facilitate and implement an inquiry-based approach to science education for second level students (age 12-18 years) on a widespread scale across Europe by bringing together, within a collaborative environment, the specific key stakeholders in science education; including science teachers and educators, the scientific and industrial communities, the young people and their parents, the policy makers responsible for science curriculum and assessment and the science education research community. This collaboration has informed the development of the project's teaching and learning materials (ESTABLISH Units) as well as educational supports for both in-service and pre-service teachers (ESTABLISH Teacher Education Programmes) designed to promote the use of Inquiry-Based Science Education (IBSE) in classrooms across Europe through specific and targeted dissemination events. The ESTABLISH project partners included AG Education Services, University of Amsterdam, University of Cyprus, University of Umea, Jagiellonian University, Charles University, AcrossLimits, Safarik University in Košice, University of Oldenburg, Tartu University, Palermo University, CMA, Martin Luther Universitaet Halle-Wittenberg, IPN Institute and Malmo University.

The SAILS - Strategies for Assessment of Inquiry-based Learning in Science - project is focused on improving science classroom practice with students aged 12-18 years, by providing teachers with inquiry-based teaching and learning and assessment materials supplemented with teacher education programmes. Many IBSE resources and models for teacher education in IBSE have been developed through projects arising from national and international programmes, including EC FP7 programme for Science in Society, for both pre-service and in-service teachers. These resources will be further developed and enhanced by the SAILS project, specifically through the addition of further elements and implementation of teacher education programmes. In particular, the SAILS project will develop appropriate strategies and frameworks for the assessment of IBSE skills and competences and prepare teachers not only to be able to teach through IBSE, but also to be confident and competent in the assessment of their students' learning. An integrated model addressing teacher education, curriculum and assessment around an inquiry pedagogy has been developed by the consortium for the implementation of IBSE across Europe. The SAILS consortium partners are Intel PLS Limited, Univerzita Pavla Jozefa Safárika, Jagiellonian University, Malmö Universityin, University of South Denmark, Instituto de Educação da Universidade de Lisboa, King's College London, University of Szeged, ATiT, University of Piraeus, Hacettepe University Turkey and Universität Hannover Germany.

ANALYSIS

To achieve their goals, ESTABLISH and SAILS adopted the definition of inquiry as the "*intentional process of diagnosing problems, critiquing experiments, and distinguishing alternative, planning investigations, research conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments*". This was a very necessary first step for the successful development of teacher education programmes and the supporting pedagogical materials for IBSE.

ESTABLISH adopted an agreed framework to guide the development of ESTABLISH teaching and learning units encompassing this definition of inquiry as well as key aspects such as pedagogical content knowledge (PCK) and industrial content knowledge (ICK). Specific project actions involved the identification, development, trialling and evaluation of these units and, where applicable, the localization of these activities and materials to ensure their relevance to current industry and research in science, as well as gender and cultural considerations. The ESTABLISH consortium members collaborated with local actors during the development and piloting of these resources and have prepared 18 substantial IBSE teaching and learning units that are suitable for using in inquiry teaching and learning. In addition an agreed framework for ESTABLISH Teacher Education Programmes (TEPs), which was informed by existing good practice in in-service and pre-service teacher education, was by defined by the project. This framework outlines the purpose and scope of such TEPs and outlines core and additional teaching elements identified as supportive for the implementation of IBSE together with inquiry activity suggestions from the units to enable these elements to be realized. This framework provided a flexible and comparable description of ESTABLISH TEPs which cater for in-service and pre-service teacher education delivered by both face-to-face and online strategies across a variety of cultural, educational and disciplinary contexts. The resulting experiences and examples which have emerged from the implementation of ESTABLISH TEPs across Europe have empowered all participating educators and teachers to improve national TEP models.

The Irish team have disseminated the knowledge gained from ESTABLISH at relevant national events and have prepared and printed a four volume set of the teacher's guides for all 18 IBSE units and distributed these freely to the teachers of Ireland. In this way, teachers that did not participate directly in ESTABLISH TEPs can utilize the resources developed and adapt them for their own classrooms.

However, one of the main issues for innovation in STEM education is around appropriate assessment. In Ireland, at the end of the Junior Cycle Programme (lower secondary) three year programme, students sit a final exam which is set by the State Examination Committee and corrected by external examiners. Students choose between ordinary and higher level. At each level the examination paper will consist of three sections. These will assess students' knowledge and skills in relation to syllabus material and learning outcomes in the areas of biology, chemistry and physics. 65% of the marks go toward the final written exam, while 10% of marks are awarded for completion of the 30 mandatory experiments and 25% for completion of specified investigations, set by the examining authority, in the third year. This Coursework B assessment (25%) is perhaps

the most relevant to inquiry. Each student is required to undertake two specified investigations in the third year and to submit a pro forma report on these for assessment. These additional investigations, based on the topics and learning outcomes in the syllabus, are set by the examining body and vary from year to year. Instead of the set assignments, students may substitute an investigation of their own choice that meets required criteria. The number of candidates who presented an investigation of their own choice was very small, at 0.6%. In practice, the time allocated to the development of inquiry skills and the degree of freedom given to students varies widely from school to school. It is possible to have students write up mandatory experiments without ever having done them; it is not uncommon for teachers to demonstrate the mandatory experiments and for students to write reports on the demonstration. In some schools the inquiry skills are left to year 3, and teachers more or less determine how students carry out the investigation. On the other end of the spectrum, in some schools the spirit of the curriculum is adhered to much more closely and students are given much more freedom to explore and devise their own experimental methods. Assessment in science for upper secondary school takes the form of a written exam only. Inquiry skills are not assessed at present, but this is anticipated to change if the proposed new curriculum is adopted.

The lack of appropriate assessment strategies and instruments was identified as a significant barrier to the successfully adoption of IBSE in Ireland and across Europe and this became a key focus in the development of the SAILS proposal. A key aim of the SAILS project is to present a framework for the assessment of inquiry learning in science. The purpose of this framework is to provide a detailed description of the content of assessment and to describe what and how to assess in the context of IBSE. SAILS Inquiry and Assessment materials will be used as exemplars for using with teachers during teacher education workshops. They will be used by teacher educators with both in-service teachers and pre-service teachers in order to help classroom teachers broaden assessment opportunities. To cater for a broad range of teachers/contexts/cultures materials suitable for a variety of subjects and educational levels will be developed.

The SAILS materials show how assessment practices are linked with the inquiry lesson. The aim of these resources is to show teachers the benefits of inquiry in classroom practice and also illustrate the variety of assessment opportunities/processes available to them. In particular, the outputs from SAILS will have clear examples for teachers of how inquiry skills can be assessed, alongside content knowledge, scientific literacy and scientific reasoning and illustrate the benefits of varied types of assessments. More specifically, they will show how evidence of student learning can be collected and evaluated using a variety of methods, e.g. student discussion, written evidence, diagnostic questions etc. These materials will be informative to the teachers, relate to classroom practice as well as diagnostic assessment and will include examples of assessment items used with students, assessment criteria and a narrative to justify the assessment criteria. The assessment items produced will illustrate for teachers a variety of examples of assessment practices that they can use within their own context of curriculum implementation.

A key objective for the SAILS project is to engage teachers in both teaching and assessing through inquiry practices, with the resultant aim that teachers will be confident and competent, not only to teach science through inquiry methodologies but also to assess skills developed though inquiry in

their classrooms. To this end, a series of TEPs have been developed and implemented within the SAILS project. The roll out of the SAILS TEP in inquiry and assessment is planned over three stages, with three successive cohorts of teachers.

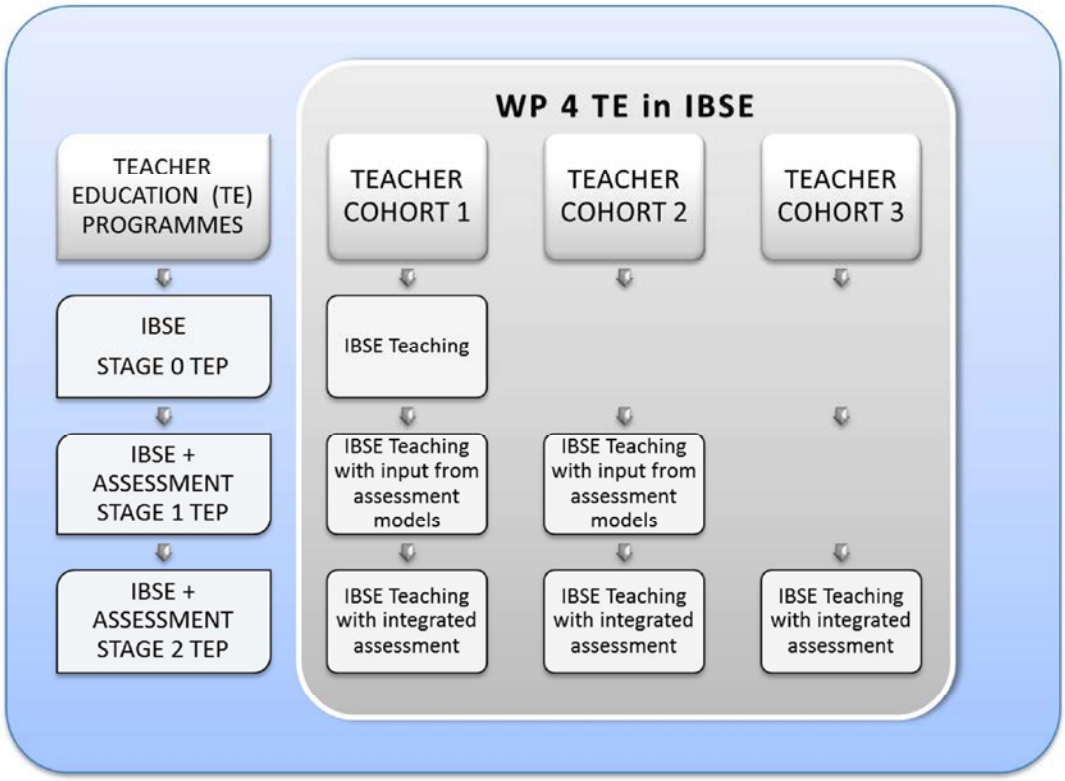

Figure 1. Structure of SAILS TEP over the course of the project

The focus for the first round of TEP (STAGE 0 TEPs) was on introducing teachers to IBSE, helping teachers implement inquiry-based activities in the classroom and addressing key issues such as classroom management strategies, problem-solving, handling investigations, etc. Participants had varying experiences in IBSE and this stage of TEPs were primarily based on existing IBSE materials and teacher education programmes selected from those already developed from IBSE projects funded under the Sixth and Seventh Framework Programmes such as ESTABLISH (2010) and from other national resources.

The second round of TEPs (STAGE 1 TEPs) was aimed at incorporating assessment into the inquiry programme. The programmes included some of these assessment frameworks/instruments within the IBSE teaching and learning materials. Additionally, teachers from the first stage were also invited back to the STAGE 1 TEPs to address how assessment can be carried out in an inquiry classroom. The implementation of this second stage of TEPs has informed the development of the final model (STAGE 2) of SAILS TEP which will have a focus on integrated inquiry and assessment strategies.

The main constraints identified by the teachers and educators in implementing IBSE assessment across different partnering countries were:

1. Lack of time to develop and implement IBSE assessment,
2. High content requirements in national curriculum,
3. External tests are not focused on assessing inquiry skills,
4. Lack of familiarity with formative assessment tools for IBSE.

Therefore to address these barriers and the national needs of teachers the three core elements of the final SAILS TEPS have been identified as (shown in Figure 2):

1. Experiencing inquiry and assessment
2. Trialling IBSE and assessment in the classroom
3. Developing IBSE and assessment resources

In the implementation of national TEPS additional elements may be added, as appropriate to the length of the programme and the experience level of the teachers. In particular, SAILS TEPs may provide participants with additional support for:

- Facilitating and assessing group work
- Developing assessment criteria and/or learning progression
- Facilitating and assessing student argumentation
- Providing students with productive feedback
- Using ICT in assessment.

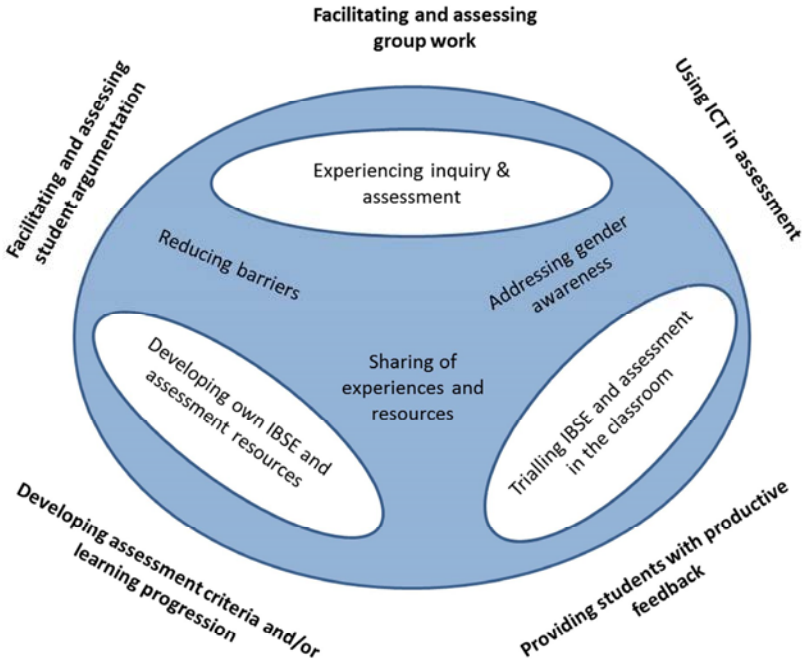

Figure 2 Core Elements in SAILS Teacher Education Programmes in inquiry with integrated assessment

KEY DISSEMINATION ACTIVITIES

The knowledge gained from both of these projects has been extended and disseminated through the organization of two mid-project teacher education conferences. The unique aspects of these two events is that they provided an opportunity for teacher-teacher exchange as well as teachereducator interactions to discuss innovation from the perspectives of both practice and research. The impact of these events has been on increased motivation for teachers to increase the use of inquiry and assessment in their own classroom practice and to engage in further national or European networking projects.

The 5th biennial Science and Mathematics Education Conference (SMEC 2012) took place on 79th June 2012 and was hosted by CASTeL at Dublin City University, Dublin, Ireland. With the chosen theme of "Teaching at the heart of learning" this was a joint conference of the Science and Mathematics Education Conference (SMEC) series and the FP7-funded project ESTABLISH. This conference provided the 240 delegates with a variety of opportunities to address issues pertaining to the teaching and learning of science and mathematics at and across all educational levels, in particular: Classroom Practice, Evaluation & Assessment, Teacher Education and Reflective practitioners. As part of the ESTABLISH project ten partnering countries brought up to 20 secondary level science teachers to share, discuss and exchange ideas about how to teach and assess using inquiry in the science classroom. The conference offered teachers and educators alike the opportunity to learn about innovations in the classroom with plenary presentations from renowned educators such as Prof. William McComas, University of Arkansas[1]; Prof. Paul Black, King's College London[2]; Prof. Janet Ainley University of Leicester[3] and Prof. Ton Ellermeijer[4], Centre for Microcomputer Applications in the Netherlands together with a broad range of contributions from leading Irish, European and international experts and such as Fibonacci[5], Scientix[6] and Inquire[7]. The conference programme included a range of activities including plenary, oral and poster presentations, over 15 workshop sessions, while also facilitating round table discussion sessions for teachers to share and compare their experiences with using inquiry based science education in the classroom. Participants were also offered the opportunity to visit local scientific industries and research centres and meet scientists in their workplace to hear about their needs of future science graduates and emphasized the role of industry in educational innovation.

The 6th biennial Science and Mathematics Education Conference (SMEC 2012) took place on 24th-25th June 2014 and was again hosted by CASTeL at Dublin City University, Dublin, Ireland.

[1] http://coehp.uark.edu/4493.php
[2] http://www.kcl.ac.uk/sspp/departments/education/people/academic/blackp.aspx
[3] http://www2.le.ac.uk/departments/education/people/professor-janet-ainley/professor-janet-ainley
[4] http://cma-science.nl/cmainfo.html
[5] http://www.fibonacci-project.ie/
[6] http://www.scientix.eu/
[7] http://www.inquirebotany.org/

This conference brought together second level teachers and practitioners with teacher educators and researchers to discuss and share their experiences and provided the 174 delegates with a variety of opportunities to address key issues pertaining to the teaching and learning of science and mathematics at and across all educational levels. SAILS project partners selected 68 secondary level science teachers and practitioners from across the 12 participating countries. Each teacher presented a poster and/or gave a short oral presentation on their experiences with implementing inquiry and associated assessment within their teaching practice. This conference offered teachers the unique opportunity to learn about assessment in the classroom with plenary presentations from renowned educators. The plenary speakers were Wynne Harlen (University of Bristol, UK), Paul Black with Christine Harrison (King's College London), Beno Csapo (University of Szeged), Cecília Galvão (Instituto de Educação da Universidade de Lisboa), Malcolm Swan (University of Nottingham) and Michael O'Leary with Zita Lysaght (St. Patrick's College, Drumcondra).

WIDER DISSEMINATION AND VALORIZATION

The involvement in these two projects has led to increased interactions with other such projects, e.g. ESTABLISH invite to S-TEAM to present at its first general assembly and led to the establishment of the ProCoNet (project Coordinators Network). The aim of this network was to enable enhanced exploitation of project findings between STEM education projects and was formalized as an objective in the INSTEM project. The INSTEM model is to establish national working groups in each country to develop strategies for sustainable exploitation of synthesized project results. These reference groups are composed of teachers and representatives of stakeholder organizations including teacher educators, science education researchers, curriculum developers, quality assurance, industry and educational governance communities. In Ireland, these key stakeholders have been identified and are ongoing informed of the project findings and representatives of this group have attended the INSTEM conference in Halle in 25-27 March 2014.

The SAILS project has developed relationships with other projects focused on assessment in STEM education, e.g. ASSIST-Me and FaSMEd project, and have presented joint presentations at events/conferences (FaSMEd, SAILS and ASSIST-me symposium at NARST 2015; FaSMEd, SAILS and ASSIST-Me at Scientix 2014). In addition, the next INSTEM National Working group meeting will be held in Spring 2015 and will focus on the assessment of inquiry in mathematics and science at second-level and will include contributions from FaSMEd and ASSIST-Me projects to inform national STEM education policy development.

CONCLUSIONS

In Ireland, teachers are not required to complete any continued professional development programmes as part of their continued teacher registration. This limits the participation in TEPs to an audience of teachers who are (probably) already very interested in innovations in science teaching. There have been signs from Irish Teaching Council, the body responsible for teacher registration in Ireland that some form of continuous professional development (CPD) will be a

requirement in the future. This would significantly improve the participation rates in STEM TEPs. The lack of funding to release teachers from schools to engage with TEPs is a barrier to when and how often such programmes can run. Personal circumstances may also prevent teachers attending TEPs even if they have a strong desire to do so. Therefore in Ireland, TEP programmes need to offered outside of normal working hours (i.e. outside term time, weekends or evenings) or be included as part of the whole school CPD strategy.

As a direct and sustained impact of these projects, CASTeL has successfully hosted 2-3 day summer schools for science teachers since 2011 and >100 teachers have participated in these to date and this programme is now firmly established in the national science teachers calendar. CASTeL members have enhanced existing modules in pre-service teaching of physics and chemistry modules for undergraduate students to promote and demonstrate IBSE practices and assessment. There has also been increased engagement by CASTeL members with a wider network of industrial and education stakeholders as a result of these projects.

The collective impact of the ESTABLISH and SAILS projects in Ireland have been:

- greater implementation of IBSE methodologies by teachers;
- greater understanding, attitude and ability to use IBSE in their teaching;
- exposure to a wider range of assessment strategies that can be used in the classroom;
- increased student's motivation and communication during science lessons;
- greater student attitude towards science and taking up careers in science or technology;
- increased interaction between those teaching and learning about science and those using science.

The participation in the INSTEM consortium has offered additional opportunities for enhanced exchange between projects and participants and led to increased dissemination and exploitation of resources developed in other STEM education projects.

The main learning gained from participation in these European projects has been the need to adopt effective communication strategies for inter- and intra-stakeholder engagement to support innovation in STEM education at national level. In particular, the Irish National Working Group meeting recommendations were to:

- Adopt multiple communication strategies to engage all stakeholders
- Appropriate use of social media
- Engage relevant professional bodies
- Organise student competitions
- Facilitate teacher exchange
- Involve parents/parent networks

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