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STEM Teacher Education – Initial and Continuing professional development

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WELCOME ADDRESS

SMEC 2016 took place in Dublin City University, St. Patrick's Campus on the 16th and 17th June 2016. With a title of *STEM Teacher Education - Initial and Continuing professional development*, this conference focussed on teacher education in STEM with papers presented in the areas of:

- Initial teacher education; including professional knowledge of teachers; teaching and learning in initial teacher education; relating theory to practice; and issues related to teacher education programs, policy and reform;
- In-service education; including in-service education and training; curricular reform and new programmes
- Continuous professional development for all teachers; including teachers as lifelong learners; methods and innovation in professional development; evaluation of professional development practices; and reflective practice, teachers as researchers, and action research.

SMEC 2016 was the seventh in a series of biennial international Science and Mathematics Education Conferences to be hosted by CASTeL – the Centre for the Advancement of STEM Teaching and Learning. The purpose of this conference series is to provide an international platform for teachers and educators to discuss practices and share their experiences in the teaching and learning of mathematics and science. Previous conferences have focused on themes such as Inquiry-based learning: Assessment in Science and Mathematics; Facilitating authentic learning experiences in science and mathematics; Sciences serving science; and Exploring the interconnections between teaching and learning of mathematics and science.

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Keynote Abstracts

Intervention-based research in (mathematics) teacher education

Andreas J. Stylianides

University of Cambridge, UK

Teacher education research in mathematics and other subject areas has focused more on documenting important and persistent problems of prospective teachers' subject knowledge (including subject-related beliefs) and less on designing interventions to generate promising solutions to some of these problems. In addition, virtually all available interventions have long duration, thus appearing to imply that these problems can only be addressed by lengthy instructional treatment. While any promising solutions to important and persistent problems of prospective teachers' subject knowledge are welcome, I ask whether "quicker solutions" might also be possible. Indeed, if effective instructional interventions of short duration were possible, it would be easier for researchers to tease out their theoretically essentially components and more practicable for teacher educators to use them in their courses. In this talk (1) I will argue the need for more research on the design of interventions of short duration that can help alleviate important and persistent problems of prospective teachers' subject knowledge and (2) I will draw on findings from a 4-year design experiment in a mathematics course for prospective elementary teachers to present suggestive evidence for the possibility of designing such interventions.

Advancing the professional development of science teachers through engagement with research

Shirley Simon

Institute of Education, University College London, United Kingdom

In this talk I will argue that teachers' professional learning can be advanced by engagement with research and research outcomes in different ways. Based on evidence from my collaboration with teachers through funded research projects, higher degree work and professional development I will discuss how different forms of engagement, as suited to individuals and circumstances, can enable teachers to be critically reflective of practice and their own learning. I will draw on examples from research and development projects on teaching argumentation to demonstrate the value of being involved or using outcomes from these projects. I will also use a few examples from reflective accounts written by my masters and doctoral students to show how their research for these degrees has advanced their professional knowledge. A key feature of my current work is on the development of action research with teachers in schools, who are investigating aspects of their own practice. I believe these kinds of inquiry can fruitfully enhance the engagement of teachers with research in the current climate, as evidenced by recent activity within the ASE Research Specialist Group.

School-based professional development for interactive teaching with technology: lessons learned from initiatives in UK and Africa

Sara Hennessy

Faculty of Education at the University of Cambridge, United Kingdom

This talk will focus on school-based teacher professional development (TPD) in the area of interactive pedagogy in technology-supported learning contexts. It is illustrated with examples based on contemporary TPD models that encourage peer learning, experiential tasks and classroom trialling, using lesson video exemplars of practice to stimulate discussion, critical reflection and lesson planning. The presentation explores how we can assist teachers in understanding and exploiting the potential of using digital technology to support subject learning, critical thinking and inquiry – especially through classroom dialogue. At Cambridge we have developed a theoretically informed workshop programme plus multimedia resource bank (http//tinyurl/OUPIWB) for sustained, school-based TPD. My team investigated its impact on the quality of classroom dialogue in contexts using digital technology – especially the ubiquitous interactive whiteboard/display screen. Outcomes of the research include multimedia professional development resources to support effective digital technology use and dialogue.

Colleagues and I have also created and trialled multimedia professional learning resources for interactive primary teaching of mathematics and science – with and without technology – in sub-Saharan Africa (www.oer4schools.org). The OER4Schools project introduced interactive teaching methods, Open Educational Resources and mobile devices into Zambian primary schools through school-based TPD. The presentation will consider what lessons can be learned from this very different context and how resources can be adapted to be culturally appropriate.

Designing and Evaluating Effective Professional Learning

Thomas Guskey

University of Kentucky, United States

Professional learning leaders today are expected to show that what they do makes a difference. Stakeholders at all levels want to know if investments in professional learning truly result in improvement in the practices of educators and, ultimately, in the performance of students. This presentation explores factors that contribute to the effectiveness of professional learning and outlines the various levels professional learning evaluation. The appropriate application of these levels is described, along with procedures for establishing reliable indicators of success during professional learning planning. Participants will learn how to design and implement more effective professional learning activities, how to gather quantitative and qualitative evidence on effects, and how to present that evidence in meaningful ways.

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Preparing the ground: considerations on cultivating scientific inquiry through curriculum

John O'Reilly

University of Limerick, Limerick, Ireland

Science education in secondary schools may be considered to have several purposes to include increasing the number of STEM undergraduate enrolments (economic), developing a scientifically literate citizenry (social) and appreciating the epistemology of the domain (intellectual culture).

Inquiry Based Science Education (IBSE) aims to provide students with learning experiences authentic to scientific work and thinking, ideally drawing on student natural curiosity to address contemporary contexts in a flexible, problem-based approach. Science Technology and Society (STS) advocates an interdisciplinary approach integrating multiple disciplines with science, implied from real world problems, to improve student motivation towards science.

These inductive, student-centred approaches are largely at odds with teacher-centred, didactic approaches that remove students from decision-making. Research has shown that Initial Teacher Education (ITE) and Continuing Professional Development (CPD) have limited effects on changing practice.

This paper proposes that the fundamental change in mind-set required to realise IBSE must focus on increasing student engagement, not solely motivation with science, and considers the role of teacher agency with respect to the new junior science specification in the Junior Cycle Framework (JCF). Empirical work on how power dynamics in classrooms effects IBSE will lead to evidence of the impact of a curriculum structure (Negotiated Integrated Curriculum) on student agentic engagement in STS themes. Considerations will be offered regarding the cultivation of an inquiry habitus in the context of the JCF, ITE and CPD.

Role of technology in promoting formative assessment practices in science and mathematics classes

Niamh Burke, Majella Dempsey, Ann O'Shea

Department of Education, Maynooth University

This paper will report on a professional development (PD) course designed and implemented by researchers in Maynooth University Ireland as part of the FaSMEd project (Formative assessment in Science and Mathematics Education[1]). This project researched the use of technology in formative assessment (FA) classroom practices. In this paper, we describe the design of the professional development process, present the research methods and results, and in discussing the results, pose a hypothesis connecting changes in teachers' knowledge to the changes in their FA practices. We conclude the paper by situating the importance of this work more broadly.

[1]This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration/ ERC under grant agreement no: 612337.

INTRODUCTION

Formative assessment (FA) has gained prominence throughout education policy and practice internationally as a method of gauging and improving student learning (Black & Harrison, 2004; Leahy, Lyon, Thompson, & Wiliam, 2005; Wiliam, 2013). FA refers to the process used by teachers and students to recognise and respond to student learning *in order to enhance that learning, during the learning* (Cowie & Bell, 1999, p. 32). It requires teachers to process information gathered from students in real time, adjust teaching accordingly, and provide effective feedback for pupils to move forward in their learning. Recent changes to lower secondary education in Ireland have highlighted the central role of FA and technology in developing students' skills and capacity for lifelong learning. Mathematics education in Ireland has undergone major change since the introduction of a new mathematics syllabus in 2008. The main aim of these changes has been to focus on student sense making, problem solving and conceptual understanding, in tandem with a call for more real world applications and the use of technology (Jeffes, Jones, Wilson, Lamont, Straw, Wheater, and Dawson, 2013). Science education is now undergoing similar change as part of the development of the Junior Cycle initiative in lower secondary education in Ireland with emphasis being placed on FA (Department of Education and Skills, 2015). One of the aims of the new science curriculum is to focus on the quality of the learning taking place using a collaborative approach to increase students' motivation and to develop their key skills. This research project set out to provide conditions for teachers to develop as a professional learning community. Developing a learning community is not easy and each is unique and formed in different ways to varying degrees of success.

LITERATURE REVIEW

Formative Assessment and the role of technology

Black and William define formative assessment (FA) practice as the extent that;

> evidence about student achievement is elicited, interpreted, and used by teachers, learners, or their peers, to make decisions about the next steps in instruction that are likely to be better, or better founded, than the decisions they would have taken in the absence of the evidence that was elicited (2009, p.9)

Different research studies have highlighted the fundamental strategies of effective FA practices such as:

S1. Learning intentions and criteria for success should be clarified and shared with students and be focused on students' process of learning and progress toward goals;

S2. Use a range of divergent assessment techniques, together with realistic, challenging problems and tasks that elicit evidence of student learning and understanding (Swan, 2005);

S3. Timely feedback, focused on the task at hand instead of marks, should be provided in order to monitor learners' progressive development, helping them become more aware of where they are going, where their learning currently is and what they can do to move forward (Looney, 2010);

S4. Teachers should engineer effective classroom discussions, fostering a classroom culture that encourages active involvement of students in the learning process (Looney, 2010);

S5. Self-assessment and peer-assessment should be encouraged to activate students as both instructional resources for one another and owners of their own learning (Swan, 2005).

Technology can enable sending and displaying of information, processing and analysing of information and act as an interactive environment for learning. These three aspects of the functionality of technology were explored in this research in connection with FA strategies outlined above.

Teacher professional development

There is a considerable amount of literature on professional development, teacher learning and teacher change. Timperley and colleagues, highlight the importance of creating dissonance or cognitive conflict in teachers' thinking in order to bring about changes in their practice. They need to confront what they are doing at present and see better alternatives, rather than layering new thinking onto old practice (Timperley, Wilson, Barrar and Fung, 2007). This is especially important in the development of FA, as many pedagogical practices used may appear familiar to teachers. It is evident from the literature that changing practice is a very complex process, Day contends that professional development consists of *all natural learning experiences and those conscious and planned activities which are intended to be of direct or indirect benefit to the individual, group or school,* and which contribute to the quality of education in the classroom (1999, p.4). It is the process by which, teachers review, renew and extend their commitment as change agents to the moral purpose of teaching (Day and Gu, 2007). Day and Leitch (2001) advise that professional development must give a central role to the emotional dimension of teachers' selves, as teaching requires motivation, commitment and emotional attachment, and this *requires a deep knowledge of self as well as student* (p. 414). At the heart of all professional development endeavours with schools and teachers must be an enhanced experience for learners.

Building on what literature described as effective professional learning, work with teachers in this project had the following key characteristics:

- Workshops were interactive and activity-based, encouraging participants to develop their own thinking on FA to encourage individual and collective professional development of skills in real situations (Conneely, Girvan and Tangey, 2012).
- Workshops focused on pedagogical practices to enhance student learning.
- Key readings were provided for participants to engage with research underpinning the pedagogical practices advocated in order to promote reflective professional enquiry.
- Participants were encouraged to share practice in both a formal and non-formal way during professional development events, to encourage collaboration focused on learning and teaching.
- Participants were encouraged to think and plan how they could develop formative assessment, to build on existing practices, and to explore new practices using a do, review and redo cycle, promoting reflective enquiry.
- Participants were encouraged to discuss FaSMEd classes with their students and to be explicit on FA skills they were developing so that students were focused on their own role in learning and in the research (Cochra-Smith, 2001).
- Participants were encouraged to view each other's practice and to give feedback so as to promote mutual respect, trust and support.

This paper will focus on how collaboration within a group of teachers can foster professional learning of the individual and how this impacted on their practice in teaching, learning and assessment. Wenger (1998) described a 'community of practice' as a group of people informally bound together by mutual engagement, shared experience and passion for a joint enterprise. The joint enterprise here was the implementation of FA practices and technology was one of the tools used to encourage collaboration and professional learning.

METHODOLOGY

Professional Development (PD)

Thirteen teachers from three schools participated in four PD sessions with the researchers throughout the 2014/2015 academic year. The sessions were between three and five hours long and were followed up by school visits and informal conversations following classroom observations. Between sessions, teachers shared their reflections and student work on Schoology[1]. This sharing of practice between sessions encouraged peer support and professional sharing and learning.

Typically, sessions began with the participants sharing their experience of teaching the classes using the FaSMEd toolkit (see www.fasmed.eu). It was important to interrogate these inputs and to explore the complex nature of FA development, so as to avoid the surface or layering-over treatment of the toolkit. Teachers got to experience toolkit lessons in PD sessions, and, to get familiar with the technology with their peers and teachers from the other participating schools. They then planned for how they would teach the lessons with their students and made suggestions for changes and for timing of the lessons in their local context.

Data Collection and Analysis

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[1] Schoology is an online learning environment that allows teachers to create and manage academic courses for their students. It provides teachers with a method of managing lessons, engaging students, sharing content, and connecting with other educators. For more information see the Beginners Guide to Using Schoology.

Formative assessment is a complex concept to examine. To facilitate a true explication of the process including the role of the assessor and the functionality of the technology with the five FA strategies (Wiliam & Thompson, 2007), this research used a mixed methods approach. The research work within the project led to the elaboration of a three-dimensional model taking into account the FA strategies, the properties of technologies and the role of actors (reported elsewhere). Qualitative interviews were analysed using MAXQDA software. Q-Sort data were analysed using PQMethod software, video data using a whole-to-part inductive approach and the questionnaire data analysed using SPSS. Figure 1 provides an overview of the project and data collected.

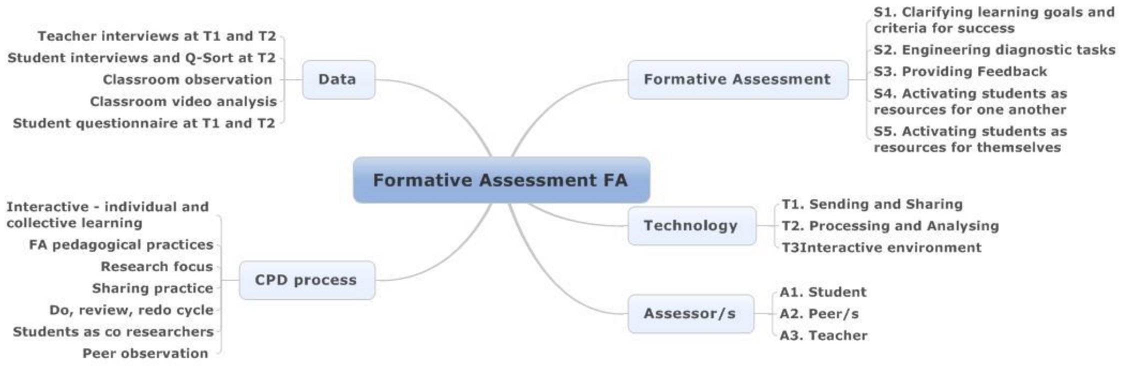

Figure 1: Overview of the research project and data collected.

FINDINGS

Interviews with the case study teachers and others indicate that engagement with the project and carrying out activities did have an impact on the development of teacher professional competences and this in turn led to enhanced formative assessment practice in the classes. Three key characteristics of the professional development were cited as being significant for the teachers:

- Development of professional skills in a collaborative environment
- Observation and feedback on teaching
- Supporting materials and tools

Development of professional skills in a collaborative environment

There were different levels of collaboration throughout the project. At school level there were two science and two mathematics teachers involved which encouraged professional sharing. At project level there were thirteen teachers involved and two university facilitators representing another professional group. The on-line supportive platform also encouraged professional sharing. While it may be beyond the scope of our data to suggest that each of these constituted a community of practice; they did go some way toward doing so. Teachers talked about how having time to discuss materials with colleagues was useful, and about how they helped each other to navigate the complexity of integrating technology into their teaching. There was also evidence for teachers crossing boundaries between different communities, where mathematics teachers and science teachers used common lessons to teach topics such as graphing. In many ways the university researchers where playing the role of brokers in this process, providing feedback after lesson observations and on-line on the Schoology platform (Wenger, 1998).

> I found it (PD) very helpful, particularly the day we were here (in her school) we met up with the other teachers, saw how they were getting on, it was very helpful. It made you reflect I suppose on your own practices. (Maths Case Study Teacher)

There was evidence from analysis of pre and post teacher interviews of the teachers having developed an enhanced understanding of FA. They moved from describing FA as a tool or an addition to learning, for example, *I use traffic lighting with my students,* to describing how students responded to feedback, how they participated in discussions in groups while solving a problem, how they struggled with giving and receiving peer feedback and so on. This shift in professional language at post project interviews was evident with all participants.

Observation and feedback on teaching

Teachers felt they had benefited from participation in the PD sessions and illustrated how the structure of the FaSMEd professional development was better than the conventional PD that they were used to where the focus is often on covering content rather than focusing on pedagogy and learning.

> I would say other professional development I have done would be focused more on the syllabus and different ways of setting up an experiment ...rather than looking at how students are learning, how can we help them learn, what techniques you can use in the classroom to help them learn. (Science Case Study Teacher)

In particular teachers responded very positively to the professional development event that required them to observe and video each other's class, after which they were to have a discussion on their questioning skills with their peer. Classroom observation supported this perceived impact of the professional development process with lesson observations noting increased wait time, use of discussion and use of higher order questioning in subsequent lessons. This is notable as teachers' use of questions is highly resistant to change as it is what Oliveria terms a highly routine practice (2010).

Supporting materials and tools

Teachers reported liking that supporting materials were provided and that these could be adapted to suit the culture and context of their classrooms. They were provided with examples of applications to use with their technology and could adapt or adopt these to suit their needs. The sharing of expertise here was very notable with participants of differing levels of expertise enhancing the transfer of new knowledge across boundaries. In addition, the use of the online platform meant that teachers had to share their experiences and examples of their students' work. This acted both as a motivator and an accountability measure. Teachers felt they had to try out the materials and share their experiences and it also provided a platform for them to compare and contrast their experiences with similar tools. Technology helped teachers to enrol in a complete FA process instead of considering some moments, enhancing their understanding of the process.

CONCLUSION

The model used in this research highlights not only the role of the teacher in FA but also the role of peers and the learner. Several of the class activities resulted in shifting ownership and agency towards students thereby activating them as the owners of their own learning. While this change in culture of learning merits further investigation, it does provide evidence for change in participating teacher's professional practice. It must be noted that while the technology provided useful data and an efficient means of communication, the success of the FA strategies was largely dependent on the skills of the teacher in anticipating misconceptions, selecting appropriate topics for discussion and generating purposeful discussion through effective questioning. The use of feedback from peers and from researchers enhanced this professional learning. The teacher's professional knowledge of FA and how technology could be used to enhance its use in science and mathematics was increased through the project. The role of developing professional learning communities both in schools and between schools, and between schools and the university was central to the success of this project and merits further exploration.

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Assessment and Development of Scientific Literacy Through Socio-Scientific Inquiry in Pre-Service Teacher Education

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Scientific literacy is described as the "ability to engage with science-related issues, and with the ideas of science, as a reflective citizen" (OECD 2013 p7). The scientifically literate individual can explain phenomena scientifically, evaluate and design scientific enquiry, and interpret data and evidence scientifically (OECD 2013). Student-led socio-scientific inquiry has been used to develop and assess many skills associated with scientific literacy. The new Irish Junior Cycle science specification includes the Science in Society Investigation (SSI) which aims to assess students' ability to research a socio-scientific issue, analyse information and secondary data, evaluate claims and opinions and draw evidence-based conclusions (NCCA 2016 p10). The SSI will be carried out by students with the support and guidance of the teacher and student performance will be assessed by the teacher (NCCA 2016 p10). The SSI will be carried out in Irish schools from December 2018 and therefore current pre-service teachers need to be prepared to facilitate and assess the student learning. This study aims to investigate the assessment and development of scientific literacy through student-led socio-scientific inquiry. It was modelled on the Junior Cycle Science in Society Investigation (SSI) and carried out by pre-service teachers (PSTs) as part of a series of lessons on inquiry based teaching. The study was conducted over two years with PSTs in the second year of a concurrent BSc in science education in mathematics, chemistry or physics teaching at secondary level. Thematic analysis was used to analyse data collected from PSTs on their experience of and the competencies developed in the SSI. The competencies that the SSI developed and assessed will be discussed in the context of the PISA framework for scientific literacy. The findings of this study will inform future classroom practices in the facilitation and assessment of socio-scientific research.

INTRODUCTION

Scientific literacy in a broad sense is the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen (OECD 2013). According to the PISA 2015 Draft Science Framework (OECD 2013), a scientifically literate person is willing to engage in reasoned discourse about science and technology, which requires the ability to:

1. Explain phenomena scientifically
2. Evaluate and design scientific enquiry
3. Interpret data and evidence scientifically

Each of the above competencies is divided into five sub-competencies as shown in table 1 (OECD 2013).

The three competencies are underpinned by three types of scientific knowledge: content knowledge, procedural knowledge and epistemic knowledge. These knowledge types are required in order to perform the competencies of scientific literacy.

Many of the competencies of scientific literacy described above can be developed and assessed in the classroom through socio-scientific inquiry. Student-led research tasks that focus on scientific issues of societal importance can provide real life contexts, be personalised by the student to suit their own interests and tend to focus on contemporary, cutting edge science, thus increasing student interest (Zeidler & Nichols 2009).

Table 1: PISA competencies and sub-competencies of scientific literacy (OECD 2013 p15)

Competency 1: Explain phenomena scientifically	**Competency 2: Evaluate and design scientific enquiry**	**Competency 3: Interpret data and evidence scientifically**
A. Recall and apply appropriate scientific knowledge; B. Identify, use and generate explanatory models and representations; C. Make and justify appropriate predictions; D. Offer explanatory hypotheses; E. Explain the potential implications of scientific knowledge for society.	A. Identify the question explored in a given scientific study; B. Distinguish questions that are possible to investigate scientifically; C. Propose a way of exploring a given question scientifically; D. Evaluate ways of exploring a given question scientifically; E. Describe and evaluate a range of ways that scientists use to ensure the reliability of data and the objectivity and generalisability of explanations.	A. Transform data from one representation to another; B. Analyse and interpret data and draw appropriate conclusions; C. Identify the assumptions, evidence and reasoning in science-related texts; D. Distinguish between arguments which are based on scientific evidence and theory and those based on other considerations; E. Evaluate scientific arguments and evidence from different sources (e.g. newspaper, internet, journals).

The Irish Junior Cycle Science Specification, a second level course, contains a classroom based assessment of socio-scientific inquiry, called the Science in Society Investigation (SSI). It will be carried out in 3rd year of secondary school, for the first time in 2018/19. In this assessment, the student will: research a socio-scientific issue; analyse information/secondary data; evaluate claims and opinions; and draw evidence based conclusions. Students will collaborate to research and prepare scientific communications and will make informed decisions about their own health and wellbeing and about issues of social and global importance (NCCA 2015). Teachers facilitating the assessment may give "reasonable support", which includes: clarifying the requirements of the task; using annotated examples; providing instructions at timely intervals; and providing supports for students with special educational needs (SEN). Teachers should not edit draft reports or provide model answers (NCCA 2016 p9).

Research aims

This study aims to investigate the development and assessment of scientific literacy through student-led socio-scientific inquiry. It was modelled on the Junior Cycle Science in Society Investigation (SSI), which was carried out by pre-service teachers (PSTs) as part of a series of lessons on inquiry based teaching. The findings of this study will inform future classroom practice in the facilitation and assessment of socio-scientific inquiry. The research aims to: examine the experiences of the PSTs when carrying out the SSI; and examine these experiences in the context of the PISA framework for scientific literacy to determine which competencies are being developed and assessed through the SSI.

METHODOLOGY

The study was conducted over two years with two cohorts of PSTs, 43 students in total. The PSTs were in the second year of a concurrent BSc in science education in mathematics, chemistry or physics teaching at secondary level. The study was carried out in three phases over a two week period. PSTs acted as learners throughout the study and the researcher was the facilitator, providing "reasonable support"[2].

Phase 1 Student research: PSTs carried out research over 3 hours, in class, with access to the internet. The PSTs researched a topic of their choice based around the Junior Cycle Science learning outcome: "Research and discuss a technological application of physics in terms of scientific, societal and environmental impact." (NCCA 2015 p19 Strand 4: Physical World). During this stage, PSTs chose their topic, decided their specific research question and gathered and recorded their research information. Collaboration was permitted during this phase. The PSTs were then given one week to produce an electronic document containing their research information and sources.

Phase 2 Communicating Findings: The PSTs were given one hour to communicate their findings in response to their chosen research question, using only the information gathered during the research phase the preceding week. PSTs were permitted to communicate their findings in a format of their choice, although the majority of PSTs chose either a written report or a PowerPoint.

Phase 3 Evaluation of the task: In phase three, the PSTs completed a questionnaire reflecting on their experience of the SSI. The first part of the questionnaire consisted of 5 open questions:

1. What do you think are the learning intentions and success criteria of the National 5 Assignment in Science?

2. From your experience of carrying out the National 5 Assignment, list the top 3 things you learnt? This may be knowledge or skills or something else. Give an example for each.

3. What about the National 5 Assignment went particularly well for you? Give examples.

4. What about the National 5 Assignment was particularly challenging for you? Give examples.

5. If you had the chance to complete the Assignment again, what changes, if any, would you make to how you carried out your assignment?

In the second part of the questionnaire the PSTs were asked directly which PISA competencies of scientific literacy they had used while carrying out the SSI and to give an explanation of when or how this competency was used.

Thematic analysis of part 1 of the student questionnaire

Thematic analysis was carried out on the PSTs' answers to the five open questions. The method used was based on Braun & Clarke (2006): familiarising yourself with your data; generating initial codes; searching for themes; reviewing themes; defining and naming themes; and producing the report (Braun & Clarke 2006 p87). An inductive, bottom-up approach was used. No attempt was made to fit the responses into the PISA scientific literacy

[2] For details of reasonable support, see NCCA 2016 p8-9.

framework, meaning the themes were dictated fully by the PST responses. A consistent approach was reached by ensuring that each reference to certain topics or key words was consistently coded into the same working theme. Extracts could be coded into as many themes as were appropriate.

Quantitative analysis of part two of the questionnaire

For each of the 15 sub-competencies a percentage of PSTs who felt they had used it in the assignment was calculated. The PST explanations of when or how a skill was used provide an insight into the PSTs' choice and understanding of the competencies.

RESULTS AND DISCUSSION

Themes emerging from student experience of the SSI

Thematic analysis of PST experience of the SSI revealed two themes: skills and scientific knowledge. Table 2 shows the themes and their sub-themes with relevant extracts.

Table 2: Themes and relevant extracts related to PST experience of the SSI

Themes	Sub-themes	Sub-sub themes	Number of references	Relevant extract(s)
Skills	Selecting, managing and evaluating sources and information	Researching	26	"The research aspect. There was lots of info online as my Q was quite topical"
		Selecting & evaluating sources	19	"I found it challenging when determining unbiased sources for my research online. For examples, I found information on my topic from a business who were trying to make money"
		Selecting information	19	"Organising and sifting through information in a short period of time: Trying to get all relevant info."
		Presenting information	19	"Success criteria: Be able to present scientific information"
	Questioning		16	"Thinking of a question. I found it difficult to come up with a specific question", "I would choose a better question, in order to find out more, and discuss the argument from both sides"
	Personal	Time management	4	"Filling in the research notes in a short period of time", "I would put more time into my research "
		Planning	9	"Set out goals before I looked up information"
Scientific Knowledge	Content knowledge		17	"Develop an understanding of what GPS is and how it works"
	Impact on society and the environment		27	"Developing an understanding of how GPS helps humans"

The PSTs' experience of the SSI was largely concerned with the development of skills, rather than simply gaining content knowledge. Within the theme skills, PSTs discussed selecting, managing and evaluating sources and information within those sources. PSTs discussed differentiating between biased and non-biased sources, reliable and unreliable sources and those supportive or unsupportive of their chosen question. They described the evaluation of information within these sources in similar ways, referring to bias, relevance and usefulness. The PSTs did not discuss using secondary data, although this is one of the aims of the SSI as stated by the NCCA.

PISA competencies of scientific literacy used in the Science in Society Investigation

The PSTs self-identified the competencies used when carrying out the SSI and justified their choice with an explanation. PSTs felt they used the full range of competencies when completing the SSI (figures 3 to 5). This ranged from an average of 93% of PSTs using *recall and apply appropriate scientific knowledge* to only 26% of PSTs using *describe and evaluate a range of ways that scientists use to ensure the reliability of data and objectivity and generalisability of explanations*.

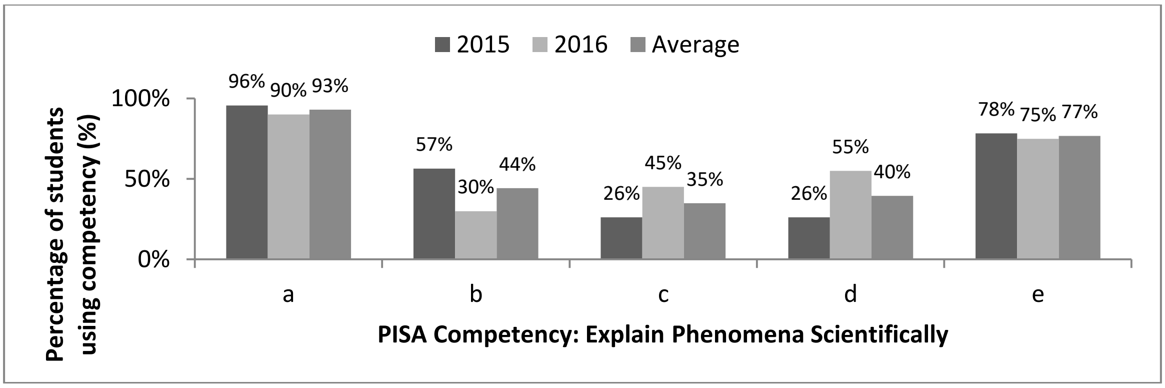

Figure 3: Competencies used by PSTs in the SSI: Explain phenomena scientifically

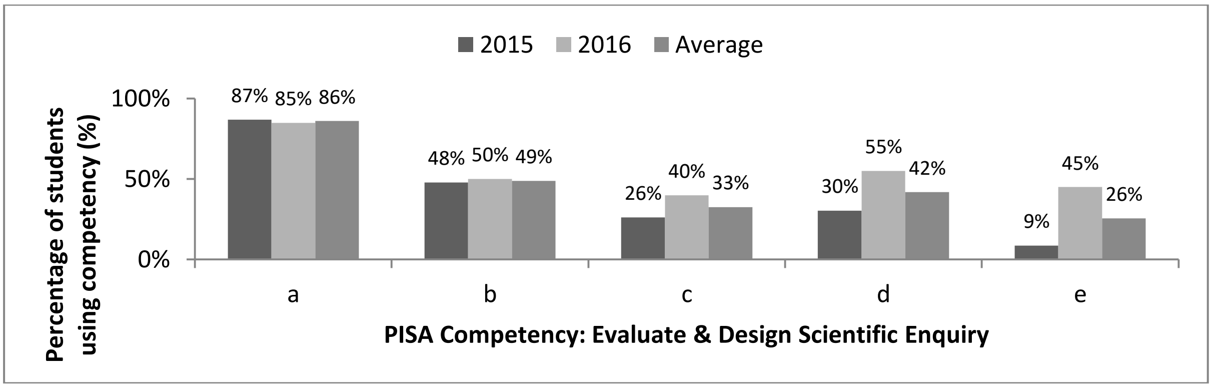

Figure 4: Competencies used by PSTs in the SSI: Evaluate and design scientific enquiry

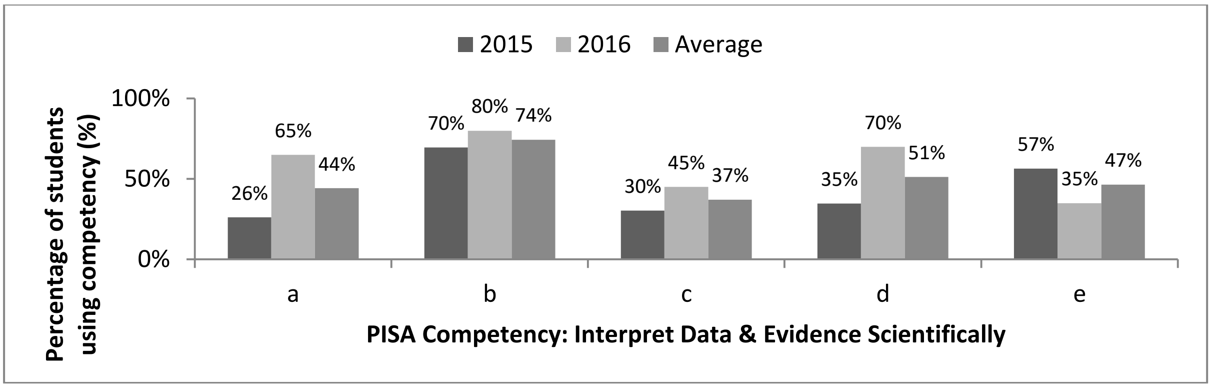

Figure 5: Competencies used by PSTs in the SSI: Interpret data and evidence scientifically

Table 3 compares the average percentage of PSTs choosing each of the three competencies between the 2015 and 2016 cohorts.

Table 3: Comparison of students using PISA competencies in 2015 and 2016 cohorts

PISA competency	Average number of PSTs using competency	
	2015	**2016**
Explain phenomena scientifically	56%	59%
Evaluate and design scientific enquiry	40%	55%
Interpret data and evidence scientifically	43%	59%

PSTs felt they used the competency *Evaluate and design scientific enquiry* least, only 40% in 2015 and 55% in 2016. Looking at the 5 sub-competencies, 86% of PSTs identified the question but fewer than 50% proposed their own investigation or carried out any evaluation of the process itself. This could indicate that the PSTs felt a lack of ownership over the design of the scientific enquiry process. It is also possible that the PSTs do not recognise this type of research task as scientific enquiry, because it isn't a traditional experimental investigation.

The cohort in 2016 felt they used more competencies of scientific literacy than the cohort in 2015. It is possible that this difference may be caused by a difference in the course with an increased focus on inquiry making PSTs more aware of the skills they are using in science.

CONCLUSIONS AND IMPLICATIONS

Pre-service teachers (PSTs) carried out a student-led socio-scientific inquiry modelled on the Irish Junior Cycle Science in SSI. Feedback from the PSTs on their experience mainly focused on the skills used during the SSI, with knowledge being a lesser focus. The PSTs self-identified that they used the full range of PISA scientific literacy competencies and sub-competencies in their SSI to a greater or lesser extent.

The Junior Cycle Science in Society Investigation will be carried out by students in their third year of secondary school. The findings of this study that their experience focuses on skills and a broad range of scientific literacy competencies is in line with the aims of the Irish Junior Cycle Specification. Importantly, the PSTs participating in this study will be at the forefront of the implementation of socio-scientific research (e.g. the SSI) in Irish Junior Cycle science. It is interesting to ask how the breadth of competencies experienced by the secondary school students themselves would compare to that of the PSTs in this study. The

PSTs acted here as learners but will be teachers. Would secondary school students experience be comparable? In this study the researcher acted as the facilitator or teacher. It would be interesting to question the role the teacher in the interplay between skills and knowledge development and the competencies of scientific literacy. The Junior Cycle Science SSI is an assessment of skills associated with socio-scientific inquiry. In order to develop of these skills the assessment must be used in a formative way, providing feedback for learning to students. It is likely that the development of such skills will be carried out in years one to three of secondary school, through similar but less in-depth inquiry tasks, and will culminate in the classroom based assessment, the SSI, in third year.

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The Temification of Science Teaching: using mysteries to initiate inquiry

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TEMI, Teaching Enquiry with Mysteries Incorporated, is an EU-funded FP7 project (www.teachingmysteries.com) which ran from 2013 to 2016. The project involved 12 European partners, nine of whom ran CPD workshops for second-level science teachers. In this paper we discuss the experiences of the Irish TEMI team, based at the University of Limerick, in running the workshops with experienced in-service science teachers (ISSTs) and pre-service science teachers (PSSTs). TEMI is based on four innovations:
a) The use of mysteries or discrepant events to engage students in science;
b) The use of the 5E learning model to structure inquiry-based science education (IBSE);
c) The use of showmanship to sustain student engagement;
d) The use of the Gradual Release of Responsibility (GRR) model to embed inquiry in a student's experience of science.

The project was built around the provision of CPD workshops for six cohorts of teachers; each teacher attended two one-day workshops, separated by 8-10 weeks. The first workshop introduced teachers to the TEMI idea, gave them examples of mysteries and introduced the 5E model. Teachers then worked in groups to devise a TEMI lesson to embed the idea in their practice. Between workshops, teachers were asked to try out five TEMI ideas, chosen from a bank of resources and also to create two TEMI lessons of their own. The TEMI teachers, PSSTs and the UL team formed a Community of Practice using a Google+ Forum.

The feedback from TEMI teachers was very positive. The discussions at the workshops between teachers, as they shared their experience of inquiry and the TEMI approach, were the most valuable parts of the workshops. The project in Ireland has built up a substantial bank of TEMI lessons (>100), including three TEMI-focused, eight-week Transition Year Modules. TEMI Taster workshops have been run for groups of teachers at various conferences and these will be offered to ISTA branches in the next school year (2016-2017). A special issue of *Chemistry in Action!* (#107) has been produced and has been sent to over 600 Irish teachers, as well as to the TEMI partners.

We hope that the TEMI approach will become another tool in the Irish science teacher's armoury and will have continued influence on Irish science education.

INTRODUCTION

In the previous SMEC 2014 conference we reported on the start of the TEMI project, Teaching Enquiry with Mysteries Incorporated (Broggy, 2014). The ongoing progress of the project has also been described (Broggy et al., 2015; Broggy et al., 2016). In this paper we provide an update on the project, which ran from 2013 to 2016 and finished in July 2016.

TEMI is an EU FP7 project involving thirteen partners from twelve countries, nine of whom were involved in running CPD workshops for teachers (see Table 1).

The overall aim of the project was to improve science and mathematics teaching across Europe by using scientific mysteries to engage second-level students in inquiry (www.teachingmysteries.eu). It aims to give teachers new skills to engage with their students, exciting new resources and the extended support needed to effectively introduce inquiry based learning into their classrooms. This has been done by working with nine teacher training institutions and teacher networks across Europe in the delivery of ‘inquiry labs’.

Table 1: The TEMI project consortium

TEMI Partners (bold – teacher training partners)
Queen Mary, University of London – UK (Coordinator)
Università degli Studi di Milano - Italy
Bremen University - Germany
University of Limerick - Ireland
Sheffield Hallam University - UK
Hogskolen I Sorost Norge - Norway
University of Vienna – Austria
Weizmann Institute - Israel
Leiden University - Netherlands
Charles University Prague - Czech Republic
Sterrenlab - Netherlands
TRACES – France
Cnotinfor - Portugal

These CPD workshops are based around the core scientific concepts and emotionally engaging activity of solving mysteries, i.e. exploring the unknown. TEMI has adopted a clear definition of inquiry in terms of a cognitive skills set and the 5E framework, and uses a stepwise progression to push students towards becoming confident enquirers. The project pays equal attention to the affective side of learning. The project aims to help teachers foster a deep motivation to learn, by bringing to the fore the sense of mystery, exploration and discovery that is at the core of all scientific practice. We wish to introduce a new word to describe this approach, temification: introducing inquiry into science teaching & learning through the use of mysteries or discrepant events to engage students in active learning.

DESCRIPTION OF THE PROJECT

The TEMI approach is based on using 4 innovations, integrated in a structured way into the CPD workshops. (www.teachingmysteries.eu).The four innovations are:

a) The use of mysteries or discrepant events to engage students in science;
b) The use of the 5E learning model to structure inquiry-based science education (IBSE);
c) The use of showmanship to sustain student engagement;
d) The use of the Gradual Release of Responsibility (GRR) model to embed inquiry in a student’s experience of science.

The Irish team, based at the University of Limerick, ran a series of workshops over the course of the project for six cohorts of in-service science teachers (ISSTs), and a number of preservice science teachers (PSSTs). Each cohort of teachers was involved in two workshops, separated by 8-10 weeks (see Figure 1). In the first workshop, teachers were introduced to the TEMI idea, and given examples of how mysteries can be used to introduce science topics.

The teacher’s prior experience of inquiry was explored through group discussion and they were introduced to the 5E model of inquiry (Bybee *et al*.,2006). Working in small groups comprising ISSTs, PSSTs and members of the UL TEMI team, teachers were encouraged to develop their own TEMI lessons starting from a mystery and linked to a topic in the junior cycle science curriculum. Finally, teachers were introduced to the Community of Practice and signed up to an on-line forum for sharing resources and ideas. Teachers were given access to a bank of TEMI lessons developed in Ireland by team members, PSSTs and previous ISSTs from earlier cohorts. This bank of TEMI lessons has been added to over the course of the project and over 100 lessons are available, including 3 full 8-week Transition Year modules.

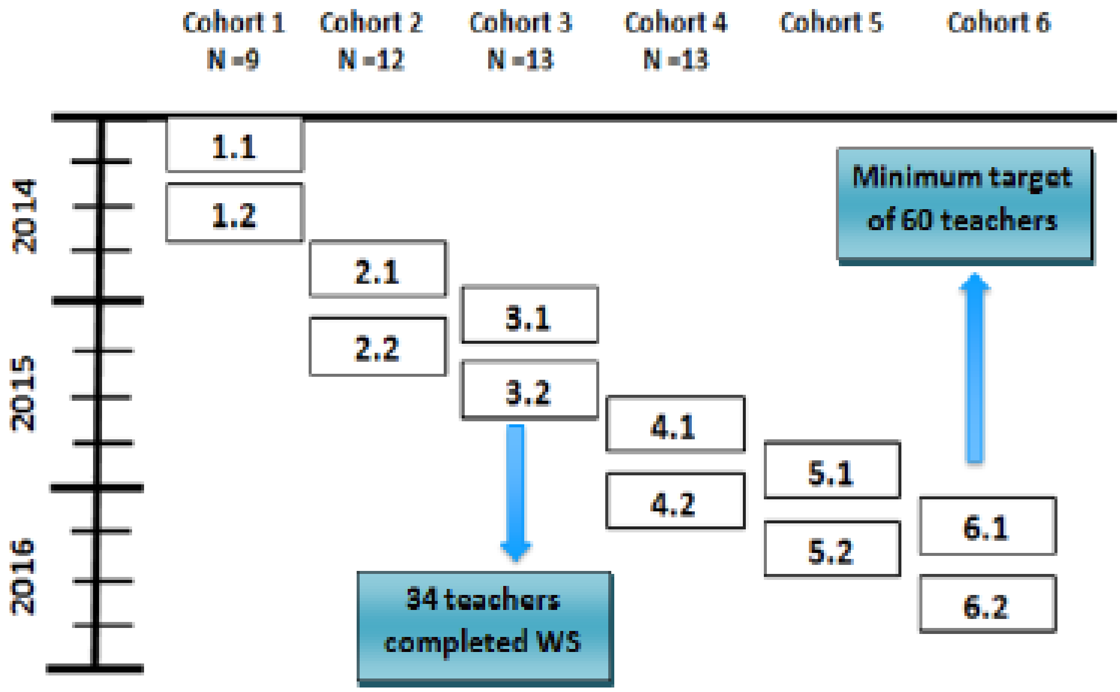

Figure 1: The structure of the CPD workshops

In between workshops, teachers were asked to try out five ideas from the bank of lessons provided and develop two of their own. In the second workshop, teachers were asked to report and discuss their experience of inquiry and their use of the TEMI approach in their schools. Each teacher then presented to the group one of their own ideas and how they had used it. The idea of showmanship was introduced by using an outside professional to talk and demonstrate how teachers could enhance their own presentation skills in introducing a mystery. Building on this, there was further discussion of the 5E model as a framework for inquiry and teachers were introduced to the Gradual Release of Responsibility (GRR) model, as a structured approach to transfer ownership of inquiry to their students. This cannot be done quickly and it was stressed that to develop inquiry successfully in schools, it must be started early, used routinely as a teaching approach and that teachers must gradually hand over ownership of inquiry to students.

Teachers were asked to complete a questionnaire after each workshop and after the implementation period in school, and also to give their students a questionnaire after a TEMI lesson to assess their reactions to the approach. Oral feedback was also given during the second workshop.

A cascade model was used whereby two teachers from a school attended workshops, one each in successive cohorts. The aim was to embed the TEMI approach in a school and teachers were encouraged to share their ideas with other science teachers in their school.

In addition to ISSTs the UL team also involved final year PSSTs. Over the course of the project 11 PSSTs were recruited to produce, implement and evaluate TEMI lessons in school during their 4th year school placement (SP). These lessons were made available to teachers through the Google+ platform and the PSSTs also took part in some of the cohort workshops, to share their experience of using TEMI with the ISSTs. The involvement of PSSTs was a valuable experience for them, which we have described elsewhere (McManus *et al.*, 2015; Broggy *et al.,* 2016), and also meant that a bank of TEMI lessons was available to use with first cohort and was added to as the project developed. The interaction between experienced teachers, the student teachers and the project team, was an important feature of the project in Ireland.

Teachers were recruited for the project in a number of ways: articles in science teacher magazines; talks and taster workshops at conferences; personal contact with the UL team members on SP visits.

In addition to the workshops done by the 6 cohorts, the team also ran taster workshops to introduce the idea of TEMI to a wider range of ISSTs and PSSTs. These workshops lasted from 1-2 hours and involved introducing the TEMI approach, giving participants examples to observe and try out and asking them to develop a TEMI lesson in groups. These taster workshops were also used to recruit teachers for the project.

IMPACT AND LEGACY OF THE PROJECT

Each partner was asked to run workshops for at least 6 cohorts of teachers, involving between 60 and 90 teachers per partner, a total of between 540 and 810. In Ireland we had 53 ISSTs and 11 PSSTs (total 64) involved in the workshops and related in-depth activities. Across all the partners providing CPD, a total of 924 teachers were involved, exceeding the initial target. In addition in Ireland we ran taster workshops for ISSTs and 4th year PSSTs in UL, totalling 245 participants. This considerably increased the impact of the project into schools and was an important part of the dissemination process. In addition articles were published in national and international journals and talks were given at national and international conferences. A special issue of *Chemistry in Action!* (#107, Spring 2016) was produced with articles from the TEMI partners and distributed to Irish teachers, project partners and posted online. It is intended to make the bank of TEMI materials, including 3 TY modules, developed by the UL team, ISSTs and PSSTs, will be made available on-line, free-of-charge, to all interested teachers. In addition it is planned to offer taster workshops around Ireland in the 2016-17 school year to local ISTA branches. This wider impact on Irish schools and teachers will be one of the legacies of the project.

DISCUSSION

The TEMI project has now finished and it is worth reflecting on its impact and achievements, as well as on its limitations. Like all FP7 projects TEMI had a limited duration (3 ½ years) and involved a limited number of teachers in the intensive CPD workshops. However, we increased the impact of the project in Ireland by introducing the TEMI approach to a large number of teachers and student teachers.

In terms of the legacy in Ireland, it is too soon to assess what impact the project has had on the teaching practices of TEMI teachers and the wider group of ISSTs and PSSTs exposed to the TEMI approach through taster workshops. We hope to do some follow-up studies of the TEMI teachers to see what long-term impact the project has had on their teaching.

Some of the comments made by teachers during the second workshop, after a period in school trying out the TEMI approach, are illuminating. Many of the teachers were unfamiliar with inquiry or had used it infrequently, and had not met the 5E model before. They enjoyed the TEMI approach and reported that their students also found it interesting and enjoyable. One interesting comment was that less academic students often entered in to the TEMI spirit better and found it helpful, compared to their more academic peers who wanted to know the answers for the exams. The pressure to cover the curriculum for external state examinations was often cited as a reason for not doing inquiry, which took much longer to cover the same material. Lack of resources for doing extensive student-led practicals and the uncertainty of not knowing all the answers, were also cited as problems.

It was stressed to teachers that using the TEMI approach did not require special equipment or a new curriculum, but was a way of teaching the existing science courses in a different and more engaging way. TEMI is not a silver bullet or universal panacea for all science teaching problems, but is recommended as another tool in the science teacher's armoury, which can be used at intervals, e.g. in introducing a new topic, in order to engage students more actively in their own learning. The idea of 'turning the lesson around' (Childs, 2016) was emphasised as a simple way of using familiar experiments and demonstrations, but using them in a different way to raise questions and stimulate inquiry, rather than to provide pre-digested answers and illustrate ideas already covered. This approach could be adopted easily by most science teachers.

The UL TEMI team valued the opportunity to work closely with ISSTs and PSSTs on the project and it revealed the importance of listening to teachers and involving them in active learning. The most valuable sessions for all participants were when teachers shared their own experiences of inquiry and of using the TEMI approach, and when they demonstrated their own TEMI lesson ideas. The close involvement with the 11 PSSTs in developing TEMI lessons as part of their final year research projects, was a unique feature of the Irish team's involvement in TEMI, and proved very valuable both for the students involved, the UL team and the cohorts of ISSTs. Between them the students developed over 40 TEMI lessons, for junior and senior cycle, and 3 8-week Transition Year modules (Ryan and Childs, 2016).

We believe that the 'temification' of science teaching, whether at junior cycle or senior cycle level, is a useful and practicable teaching strategy to improve student engagement and understanding of science, without drastic changes in curriculum or resources.

ACKNOWLEDGEMENTS

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Promoting and Advancing the Teaching of Science for Students with Special Educational Needs

Pauline Connolly and Madeline Hickey

Special Education Support Service (SESS)

The study of science in schools offers all students an opportunity to develop their curiosity and to understand better the world in which they live. Students with special educational needs (SEN) can and should benefit from the study of science in school. Current trends in inquiry based science education and in inclusive classrooms, present many challenges but also many opportunities for these students. This paper contends that the teacher has a significant role to play to ensure that all students (but particularly those with SEN) can access, participate in and benefit from the study of science in school. The Special Education Support Service (SESS) is committed to providing the best possible support to science teachers and to teachers generally in this regard (SESS, 2003).

INTRODUCTION

The notion of "science for all" suggests that all students—irrespective of achievement and ability—should engage in opportunities to understand the practice and discourse of science (Villanueva and Hand, 2011). The experience of science will enable students with SEN to develop a greater understanding of the world around them as well as developing a range of transferrable skills (SESS, 2008). Research findings consistently support the central role of the teacher in the education of students with SEN and there is evidence that the quality of teachers and their teaching are the most important factors in student outcomes (NCSE, 2013). Classroom teachers require the knowledge, skills and ability to understand and provide opportunities for all students, including those with SEN, to participate in and enjoy meaningful learning experiences in science.

Effective Continuous Professional Development (CPD) for all teachers is essential in order to realise the notion that students with SEN can access the science curriculum, participate in inquiry based science activities and benefit from the knowledge and skills gained from these experiences. The Special Education Support Service (SESS), as a support service for teachers, is committed to the development of teachers' knowledge and skills, so that students with SEN can reach their full potential (SESS, 2003).

Banks and McCoy (2011) indicate that almost 1 in 4 children in Ireland have some form of Special Educational Need (SEN) that hampers their learning. This prevalence rate is derived using the broad definition of SEN in the EPSEN Act:

> "Special Educational Needs means, in relation to a person, a restriction in the capacity of the person to participate in and benefit from education on account of an enduring physical, sensory, mental health or learning disability, or any other condition which results in a person learning differently from a person without that condition' (2004, p.6)"

The ESPEN Act also includes the aim that all children with SEN should be educated in an inclusive environment. Indeed, there are three recurring themes in recent legislation and literature, namely, access to, participation in and benefit from an appropriate education. While these themes appear in the legislation, focusing on them also reflects best practice. The role of the teacher in moving towards an inclusive education system is widely acknowledged. The World Report on Disability (WHO, 2011) stressed that:

> 'The appropriate training of mainstream teachers is crucial if they are to be confident and competent in teaching children with diverse needs.'

The NCCA strategic plan for 2012-2015 sets out six strategic goals. One of these goals relates to curriculum and assessment development and there is a commitment to innovative curriculum and assessment for engagement, progression, quality, inclusion and continuity across sectors. There is a commitment to having an 'Inclusive Curriculum' and the range of curricular options in relation to science is evident. Of particular relevance are the NCCA Guidelines for General Learning Disability, the Level 2 Learning Programmes (L2LPs) and the Short Courses at Junior Cycle.

In order to make science curricula accessible to all and to promote inclusion in STEM education, all teachers need to be equipped to meet the increasingly diverse needs of learners. Teacher education for inclusion has the potential to address many policy issues, such as, breaking down barriers experienced by learners with disabilities (TE4I, 2011). It is essential that teachers have a full understanding of the categories of special educational needs and how they impact on teaching and learning. SESS (2012) refer to these categories as 'Signposts'. Categorising the complex and diverse nature of disability in this form is not intended to equate individuals with disability labels. Rather, these categories act as signposts that enable teachers to negotiate the social, psychological and biological factors that affect each individual pupil's learning, strengths and unique needs.

SCIENCE FOR SCIENTISTS AND SCIENCE FOR ALL

We are in no doubt that scientists have made an enormous contribution to the advancement of human civilisation. Nurturing the next generation of scientists is a national priority and enhancing STEM education in Ireland is seen as a critical, multifaceted issue that requires serious engagement and investment from all stakeholders (MacCraith, 2014). The notion of 'Science for all' suggests that all students, including those with SEN, should have the opportunity to participate in science in inclusive classrooms. Science taps into a different way of thinking and exploring and this provides an excellent way for students who may have difficulty with other academic areas to have authentic inquiry based experiences and to be For students with SEN, science lessons can provide the benefits of concrete, real-world experiences, opportunities to work effectively in groups, the excitement of scientific observation and experimentation, and alternative methods of evaluation (McCann, 1998). Science education is in a strong position to meet the needs of students with SEN as curriculum adaptations can be made part of the regular variation within classroom instruction. Inquiry based teaching and learning can provide students with opportunities to construct their own meaning and engage in a stimulating learning environment that provides a wider context for understanding a concept. Research results indicate that inquiry-based science instruction benefits students' achievement, including students with SEN (Therrien et al, 2011).

There are many challenges to overcome in order to promote and enhance the potential of science as a vehicle for learning for students with SEN in Irish education as advocated in this paper. A critical issue rests with teacher education for inclusion. The TE4I project (European Agency for Development in Special Needs Education, 2011) findings argue for the need to improve teacher competences and promote professional values and attitudes in relation to inclusion. Four core values relating to teaching and learning have been identified as the basis for the competences for teachers working in inclusive education:

- Valuing pupil diversity
- Supporting all learners
- Working with others
- Continuing personal professional development

In order to promote and advance the teaching of science for students with SEN we need to focus on providing initial and sustained support and CPD, so that all teachers are equipped with the skills to include all learners in science classrooms. Part of teacher education for inclusion includes providing opportunities for teachers to understand the unique challenges and barriers to learning experienced by students with SEN. The NCCA (2007) produced a suite of guidelines designed to support teachers in meeting the needs of students with SEN in curricular areas including science. In the approaches and methodologies individual differences are emphasised and potential areas of difficulty and their implications for learning are outlined and linked with suggestions for possible teaching strategies. The SESS aims to mediate such guidelines and provide direct support to teachers of students with SEN. Some of the challenges pertaining to post-primary science students with general learning disability as outlined in the guidelines include:

- Safety
- Fear of Apparatus
- Developing Ideas
- Communicating Ideas
- Overwhelmed by course content
- Vocabulary & Language
- Motor Skills
- Dexterity
- Concentration
- Attention Span
- Writing Reports of Mandatory Experiments
- Time
- Poor Self-Esteem
- Behaviour

It is essential that teachers have in-depth knowledge of these challenges and barriers and learn the skills required to differentiate the curriculum in order to provide a broad and balanced experience of science education. It is important for teachers to have access to and explore the notion of inclusive pedagogy from the perspective of mutually beneficial instruction.

APPROACHES TO SCIENCE EDUCATION FOR STUDENTS WITH SEN

Accommodations, UDL and Differentiated Instruction

There are a number of approaches to making science lessons accessible to students with disabilities, Accommodations, Universal Design for Learning (UDL) and Differentiated Instruction.

Accommodations are alternative formats, assistive technology, and other adjustments for specific students once they are present in a class (Burgstahler, 2012). In science classrooms accommodations can range from low to high tech for students of all ages. Some examples include, braille labels added to laboratory equipment for students with visual impairment, the use of an FM system, interpreter, real-time captioning and visual warning devices for deaf students and a vast array of technology-based accommodations such as voice recognition software, switches and augmentative communication devices. It is imperative that schools and teachers understand the array of accommodations available to students with SEN and consider the accommodation needs of individual students. SESS advocates the use of the SETT (Student, Environments, Tasks and Tools) framework (Zabala, 2005) to plan for the use of Assistive Technology assessment and intervention. The framework is a tool to assist educators in gathering and organising information that can be used to guide collaborative decisions from the student themselves, the parents/guardians, the teachers and other relevant school personnel about practices that can improve outcomes and foster success for students with SEN.

Certain accommodations are designed for overcoming a specific barrier encountered because of a student's disability. However, the broader goal of accessible pedagogy can benefit students with and without SEN (Moon et al, 2012). UDL is an educational framework based on research in the learning sciences, including cognitive neuroscience. The UDL framework, first defined by Rose (1992) for creating a curriculum from the outset and provides:

- Multiple means of representation to give learners various ways of acquiring information and knowledge
- Multiple means of expression to provide learners alternatives for demonstrating what they know
- Multiple means of engagement to tap into learners' interests, challenge them appropriately, and motivate them to learn

UDL is a means of identifying and removing barriers in the curriculum while building scaffolds, supports, and alternatives that meet the learning needs of a wide range of students (Meo, 2008). Connecting UDL to science curriculum development is an important goal in promoting the teaching of science for students with SEN. The UDL framework enables the educator to remove barriers, by anticipating the needs of all students. In this way the strategies are 'frontloaded' as opposed to being 'retrofitted', as a proactive response to individual student needs. For example, consider how we can frontload laboratory environments to ensure that all students can achieve success in a safe environment. Targeted CPD for teachers in this aspect of inclusive practice is a key element for determining success in applying the principles of UDL.

Differentiated Instruction and UDL are not mutually exclusive and indeed are similar concepts sharing many of the same ideas about learning and classroom practices. Differentiated instruction is a process by which we can enable all students to engage in the curriculum by providing learning tasks and activities that are tailored to their needs and abilities (SESS, 2008). Teachers can differentiate the content (what is being learned by the student), the process (the way that students access the material) and product (the way in which students show what they have learned). Science lends itself very well to differentiated instruction and this is illustrated in the guidelines for students with General Learning Disabilities (NCCA, 2007), which present examples of differentiated instruction in the area of science. There is a vast array of strategies for differentiated instruction and a crucial aspect in determining the instructional strategy to be used is the consideration of the task, the individual and the environment. This is with a view to enabling the student to access the science curriculum at an appropriate level. The focus is enabling students to access, participate and benefit from the learning experiences.

Creating multiple pathways for learning through differentiated instruction as part of the daily learning experience is essential in advancing the teaching of science for students with SEN. Teachers can differentiate on the basis of learning style, flexible grouping, cooperative learning and specific differentiated instructional strategies such as key words, writing frames, choice boards, graphic organisers etc. A specific example of how to differentiate science content for students with SEN is by using readability to present a variety of options for students who have difficulty accessing text. Readability is defined as the level of ease or difficulty in which text material can be understood by a particular reader who is reading that text for a specific purpose (Pikulski, 2002). Teachers can calculate readability using readability formula or computer generated readability scores such as the Flesch-Kincaid which gives a readability score on a word document. Once readability is established, teachers can edit the text to suit the particular needs of individual students.

Blending the concepts of UDL and Differentiated instruction is the ultimate goal in terms of engaging students in opportunities to understand the discourse of science. Both approaches embrace the notion of diversity, have high expectations for all students irrespective of SEN and provide an abundance of support and suitable scaffolds to enhance and improve the learning experience. It is important that teachers have a full understanding of the principles of both concepts and how to implement them through practice in order to realise the goal of inclusion.

CONCLUSION

There are many students with SEN in mainstream primary and post-primary schools, special schools and special classes that can benefit from engagement and participation in inclusive learning environments within the discourse of science. The benefits of authentic science experiences for students with SEN (Melber, 2004) are far-reaching and can promote the development of transferable skills and a curiosity and understanding of the world around them. There are many considerations in promoting and advancing the teaching of science for students with SEN including; the ongoing development of inclusive curricula at all levels, the identification of the professional development requirements of teachers and the delivery of sustained high quality CPD and support to all schools. The importance of teacher education in effecting change and moving towards inclusive education is well documented. Effective initial teacher training and sustained in-career development is a crucial factor in unlocking the world of science and achieving success for students with SEN. It is fundamental to the successful inclusion of students with SEN and should be protected and, where possible, increased.

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STeP into Science Project: Engaging Students, Teachers and Parents in Debates

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This project aims to facilitate the teaching and learning of Irish lower second-level curricular objectives on Nature of Science, through engaging teachers, students and guardians in school debate events on socio-scientific issues. The Junior Cycle science specification promotes skills such as communication and argumentation which are also required for engaging in debates. Yet the kinds of pedagogical strategies demanded by debates are not typically part of teaching practice (Osborne, Erduran & Simon 2004). The first stage of this project therefore is CPD supporting science teachers to implement argumentation into their teaching of science in order to provide students with a foundation for the kinds of skills they need to draw on when debating scientific issues. Argumentation has been a significant area of research in recent years (Erduran, Ozdem & Park, 2015) and has been advocated in science teacher education (Erduran, 2006). The teachers involved will subsequently implement argumentation activities into their teaching and coordinate a debate event in autumn 2016. Involving the community in school science is a critical element of this project. Hence students will prepare for their debate event with the support and involvement of a family member with targeted homework activities, provided to teachers during the CPD workshop. Evaluation instruments will be used to assess (i) teacher perspectives on the CPD and (ii) teacher, student and guardian perspectives on participation in debates. This paper will outline the overall design of the project and report on initial findings from the teachers' evaluation of the CPD element of the programme.

INTRODUCTION

The STeP into Science project aims to facilitate the teaching and learning of the Irish lower second-level curricular objectives on Nature of Science, through engaging teachers, students, and guardians in school debate events on socio-scientific issues. Effective engagement of students in STEM requires addressing a range of issues such as the curricular context, the teachers, and the guardians. The proposed project is thus needed to address coherence between the curriculum, teaching and guardian involvement in a coordinated fashion. The project is funded by Science Foundation Ireland, and is led by Professor Sibel Erduran at EPI-STEM, The National Centre for STEM Education at University of Limerick with the partnership of Junior Cycle for Teachers (JCT).

The new Irish lower second-level science curriculum, referred to as the science specification, aims to develop key skills, two of which are "*being literate*" and "*communicating*". A student learning activity that encompasses being literate is stated as "*Students will plan, draft and present scientific arguments, express opinions supported by evidence, and explain and describe scientific phenomena and relationships*". The student leaning activity associated with communicating is "*Students will interpret, compare, and present information and data using a variety of charts/ diagrams fit for purpose and audience, using relevant scientific terminology"*. Furthermore, the Nature of Science Learning Outcomes state that pupils should be able to "*conduct research relevant to a scientific issue, evaluate different sources of information including secondary data, understanding that a source may lack detail or show bias; organise and communicate their research and investigative findings in a variety of ways fit for purpose and audience, using relevant scientific terminology and* *representations and evaluate media-based arguments concerning science and technology"* (NCCA, 2015, p. 16). It is proposed that socio-scientific debates can provide learning opportunities that meet these criteria. The inclusion of socio-scientific issues in STEM Education is a goal that has been promoted internationally (Zeidler, et al., 2009). Examples of socio-scientific issues include alternative sources of energy and genetically modified foods. It is proposed that students' participation in debates around socio-scientific issues will engage them in ways that will raise their interest and motivation in STEM. While some students may not be drawn to STEM subjects from a disciplinary perspective in learning STEM knowledge, they are likely to be interested in STEM when it is situated in meaningful, socially relevant contexts that have an impact on everyday life. Pedagogical strategies required for school debates (e.g. mediating role play and argument evaluation) are not typically part of traditional teaching practice (Osborne et al. 2004). Hence the project has two main aims: (a) to facilitate science teachers' professional development in teaching of socio-scientific debates; and (b) to engage students and guardians in socio-scientific debates.

This project invites guardians to assist in preparing pupils for the debate by involving them in homework tasks. Including guardians in homework tasks can assist family members in getting an insight into their child's learning (Walker, et al., 2004). Although there is much research to indicate the positive impact of facilitating school-family partnership (Walker, et al., 2004), these partnerships deteriorate in second level education. Simon (2004, p186) suggests that "*parents may become less involved because, with high schools' complex environment and complicated curricula, they do not know how to be involved as their adolescents progress through high school"*. Teachers providing ideas to guardians about how they can contribute to pupil homework can increase family member participation (Walker, et al., 2004). This project includes a very close link between formal (school-based) and informal (home-based) learning opportunities.

METHODOLOGY

Considering both socio-scientific issues and the coordination of debates are aspects of pedagogy that are relatively unfamiliar to teachers (Sadler, 2004), the training aspect is crucial. In order to facilitate the debates, thirty three science teachers were trained nationally in May 2016 to learn about effective pedagogical strategies for coordinating debates in class and as an event. Relevant resource packs were developed for teachers, students and guardians by EPI*STEM in consultation with JCT and the workshops were facilitated by the JCT. In September 2016, teachers will implement lessons on debates and set homework tasks for students to complete with guardians. The project will engage guardians by providing resources that students will take home for their input. Debate events will be coordinated by the teachers during Science Week 2016 where guardians will be invited to attend as audience members. The debates will take place in schools and will be mediated by teachers. Hence, the project will promote engagement of students, teachers, and guardians in STEM related debates in the context of socially relevant issues.

This research takes a case study approach, collecting data from multiple participants to explore the impact of the programme (Leedy and Ormrod 2001). Four questionnaires were generated with the intention of evaluating the impact of the project**.** Evaluation instruments will be used to assess (i) teacher perspectives on the CPD (ii) teacher perspectives on debates (iii) student perspectives on debates (iv) guardian participation in debates. Existing tools and ideas were modified for context and used (e.g. Sadler, 2004;

Zeidler et al., 2009) for an evidence-based approach and for ensuring robust analysis. The first questionnaire assesses the impact of the teachers' engagement in the CPD workshops. The second questionnaire will explore the impact the debate intervention had on the teachers teaching and their view on the student learning. The third questionnaire will focus on students and their evaluation of engagement in the preparatory lesson for debates, the homework in preparation of the debates and their attitude towards the tasks following the debates. The fourth questionnaire will be prepared for evaluating the impact of the project on guardians' attitudes towards their engagement in the debate topics and their assessment of their children's learning through debates. Participation in and preparation for the debate was part of the classroom teaching and learning but participation in the evaluation/research was voluntary.

Open ended questions will be transcribed by the listed investigators. Thematic analysis will be performed according to Braun and Clarkes (2006) six phases: data familiarization, produce initial codes, look for themes, review themes, name themes and report themes. Closed questions will be analysed using SPSS. Perspective triangulation will be performed on survey data collected from teachers, pupils and guardians to check the consistency relating to their attitudes towards the use of social scientific debates. The success of the project will be measured for the quality of impact on teachers', students', and guardians' attitudes and understanding of socio-scientific issues and their engagement with socially relevant STEM topics.

INITIAL RESULTS

The teachers' evaluation questionnaire consisted of 16 questions, with 10 closed questions and 6 open questions. The following results are from the first phase of the data collection, to assess (i) teacher perspectives on the CPD (N=33). This data was collected after teachers completed the workshop sessions. Thirty two teachers answered the question "*Do you think argumentation is a relevant skill for students studying science?*" All of the teachers responded *yes*. One teacher commented "*It (argumentation) is a relevant skill for students studying science to further develop scientific thinking and a better understanding*". When the teachers were asked how often they used argumentation (Figure 1), 13% (n =32) of teachers responded *yes frequently*, 53% responded *yes infrequently* and 34% responded *no*. Teachers who selected infrequently referred to time constraints and argumentation not being part of the old curriculum. Another teacher who responded *no* stated "*Never thought of it, not my comfort zone*"

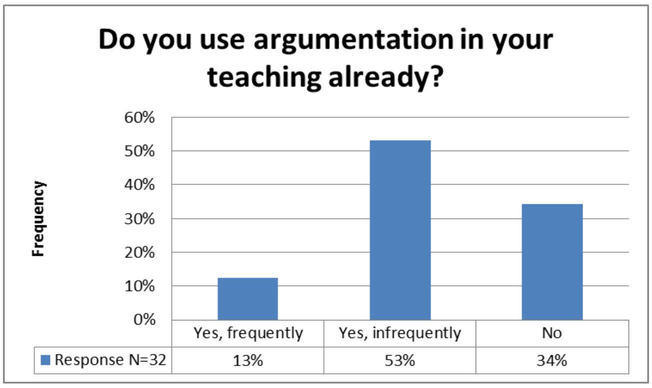

Figure 1: Teacher response to "Do you use argumentation in your teaching already?"

Teachers were asked if the resources supplied for the workshop were adequate for carrying out the project (Figure 2). Approximately 57% (N=33) of teachers *agreed*, 24% were *undecided* and 18% *disagreed*. Teachers who disagreed claimed that the language was too difficult for the pupils. One teacher stated "*The resources are far too advanced for junior cycle. The literacy level of some students is quite poor and the resources are very wordy*". In contrast, a teacher who agreed the resources were adequate said "*activities are very insightful about how to introduce argumentation into the classroom*".

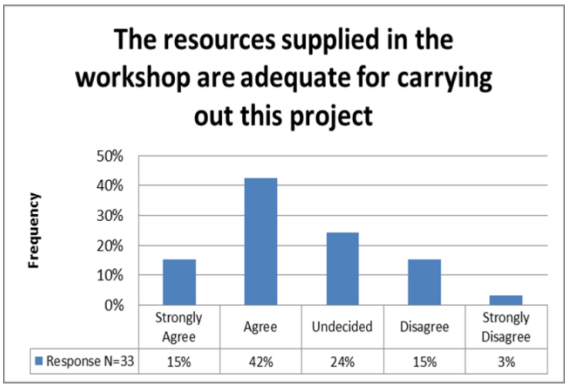

Figure 2: Teacher response to "The resources supplied in the workshop are adequate for carrying out this project"

The teachers were asked what their initial attitudes to running a debate were (Figure 3), 56% (n=32) said *positive*, 43% said *positive and negative*, 6% were *neutral* and 3% were *unsure*. No teacher responded that they had negative feelings. Teachers who had mixed feelings towards the use of debate could see the benefits however they were concerned about the amount of work it would require and also how students with learning difficulties would cope. One teacher who selected both positive and negative responded "*Good for average and bright students. Students with low literacy skills, not sure*". A teacher who responded positive said "*Exciting and engaging for students, empowering*"

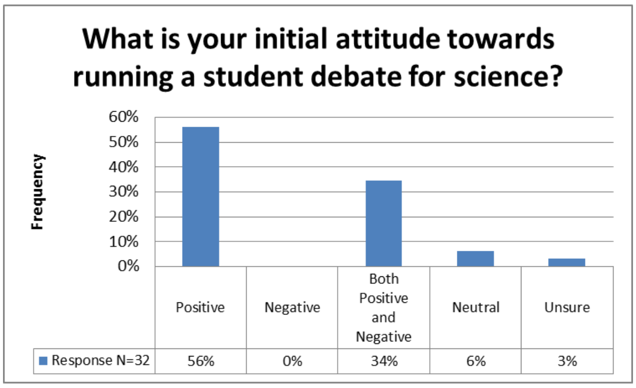

Figure 3: Teacher response to "What is your initial attitude towards running a school debate?"

The teachers were asked what their initial feelings towards involving guardians in homework tasks and attending the debate were (Figure 4), 28% (n=32) said *positive*, 66% said *positive and negative*, 3% were *neutral* and 3% were *unsure*. No teacher responded that they had negative feelings. One teacher who selected both positive and negative stated "*Some parents* *are very involved in students learning. Others would know very little of what students do in their lessons*". Another teacher who answered *positive* noted "*Getting parents involved is extremely important to help 1st years settle into school"*.

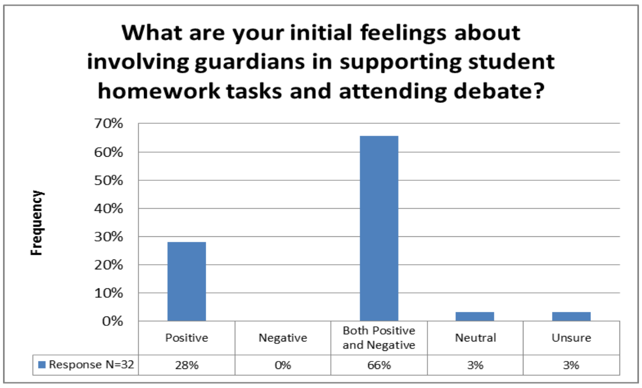

Figure 4: Teacher response to "What are your initial feelings about involving guardians in supporting student homework tasks and attending debates?"

CONCLUSION

It was intended to investigate if the CPD workshops support teachers' implementation of debates. Overall, the teachers believed the use of argumentation to be relevant, however prior to the workshop the majority of teachers infrequently used this strategy. Negative comments regarding the complexity of the language used in the resources were addressed by simplifying the text used. This revision increases the suitability of the resources hence improving their use in teachers' generic teaching styles. Teachers' initial attitudes towards the use of debate are positive as it assumes a student-centred approach in teaching and hence, it is likely to encourage teachers to adapt these strategies for use in their everyday science teaching as well. Furthermore, teachers' initial attitudes towards guardian involvement indicate that this project can provide a positive step to developing relationships between teachers and guardians with homework tasks. It can be considered an example model for schools, guardians and teachers in forging collaborations to ensure coherence between students' learning in different contexts. Project schools will have access to this model to implement in future years.

POTENTIAL LONG TERM IMPACTS

There are several potential long term impacts of the project: (a) Impact on teachers: The project will produce innovative resources and pedagogical strategies that are likely to influence teachers' generic teaching styles. In this sense, the project has the potential to contribute to teachers' subject knowledge. (b) Impact on students: The project will be based on a student-centred teaching and learning model. Empowering students in their learning processes is likely to improve motivation and engagement in STEM particularly when the issues have relevance to society. The skills of communication and argumentation that will be fostered through the debate lessons and the actual debates are transferrable not only to STEM topics but also more widely. (c) Impact on guardians: Target resources produced especially for guardians will be distributed which can act as guidelines for guardians which can potentially support guardians in supporting their children's STEM-related homework in the future.

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A CPD Programme for ‘out-of-field’ mathematics teachers in Ireland: Programme outline and initial evaluations by participants

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This paper outlines an innovative Continuing Professional Development (CPD) programme established in the Republic of Ireland for out-of-field mathematics teachers in second-level education. Research on out-of-field mathematics teachers in Ireland conducted in 2009 (Ní Ríordáin & Hannigan) motivated the development of a unique two year, part time Professional Diploma in Mathematics for Teaching (PDMT). The PDMT was first offered in 2012 jointly by the University of Limerick (UL) and the National University of Ireland, Galway and currently has 550 graduates. The main research question that this project aimed to address was: Are teachers enrolled in the PDMT satisfied with the programme and what strengths and weaknesses of the programme have teachers identified? An online survey was developed by the PDMT at the National Centre for STEM Education (EPI·STEM), together with the Centre for Teaching and Learning in UL, to assess participating teachers’ evaluation of the programme. Initial findings regarding teachers’ opinions of this unique programme indicate an increasing satisfaction with the PDMT over time (52.5% of survey participants) after some preliminary technical difficulties. While the programme requires a significant time and work commitment which can be stressful for participants, the general consensus is that the programme is a positive means of achieving professional development and advancement as a mathematics teacher.

INTRODUCTION

In recent years, mathematics education in Ireland has experienced a period of change, chiefly, the introduction of a new mathematics curriculum at second-level education in 2010 entitled ‘Project Maths’. This new curriculum was introduced in an attempt to address Irish students’ poor mathematics performance (both nationally and internationally), inadequate conceptual understanding of mathematics, over-reliance on rote-learning and insufficient problem-solving skills (Conway & Sloane, 2006; Faulkner et al. 2010). There was a concern that mathematics education at second-level in Ireland focused on a didactic pedagogy with little emphasis on problem-solving (Lyons et al., 2003). The ‘Project Maths’ curriculum aims to “focus on developing students’ problem-solving skills. Assessment will reflect the different emphasis on understanding and skills in the teaching and learning of mathematics.” (Irish National Teachers Organisation, 2013, p.20). With the focus of the new mathematics curriculum being on conceptual understanding, there was a requirement to have suitably qualified mathematics teachers who possessed the necessary content and pedagogical knowledge in order to teach mathematics for understanding.

For the purpose of this paper, out-of-field teachers are defined as “teachers assigned by school administrators to teach subjects which do not match their training or education” (Ní Ríordáin & Hannigan, 2011). In Ireland, the problem of out-of-field mathematics teaching exacerbated the difficulties experienced by teachers in adapting their teaching to the demands of the new ‘Project Maths’ curriculum. According to Ingvarson et al. (2004), content knowledge and pedagogical skills play a vital role in a teacher's classroom practice. Ní Ríordáin and Hannigan (2009) surveyed 324 second-level mathematics teachers in Ireland and discovered that 48% of these teachers did not have a mathematics teaching qualification. The majority of out-of-field mathematics teachers were qualified science or business studies teachers, and had subsequently been assigned to also teach mathematics classes in their schools. The out-of-field mathematics teachers surveyed, primarily taught mathematics at Junior Cycle – the first three years of second-level education in Ireland (Department of Education and Skills, 2015). While qualified mathematics teachers tended to teach exam years and Senior Cycle students (the last two years of second-level education), there was clearly a need for specialized mathematics teachers at Junior Cycle, particularly crucial to improve student learning and to increase the number of students studying mathematics at higher level (Ní Ríordáin & Hannigan, 2009). The dearth of expertise in mathematics teaching at Junior Cycle may also be seen in the lack of significant change in students' mathematics test scores between entry to second-level school and the Junior Certificate (Kenny et al, 2009).

THE PROFESSIONAL DIPLOMA IN MATHEMATICS FOR TEACHING

Continuing professional development (CPD), previously called in-service education or training, is understood to include all forms of professional learning undertaken by teachers beyond the point of initial training (Craft, 2002). Some of the main reasons for undertaking CPD include: to improve the job performance skills of an individual teacher; to develop the professional knowledge and understanding of an individual teacher; and to enable teachers to anticipate or prepare for change (Craft, 2002). As a means of addressing the issue of out-of-field mathematics teaching in Ireland, as well as the new demands of 'Project Maths', the Professional Diploma in Mathematics for Teaching (PDMT) was designed and implemented by the National Centre for Excellence in Mathematics and Science Teaching and Learning (NCE-MSTL), now the National Centre for Stem Education (EPI·STEM) based in the University of Limerick (UL). This unique program was specifically designed to upskill teachers who are currently teaching mathematics, but whose teaching qualification does not include mathematics. This university accredited professional diploma (Level 8) has been delivered nationally since 2012, in a blended learning mode through local nodes in 14 associate partner institutions located throughout Ireland, in face-to-face and/or on-line modalities. The PDMT is offered through the medium of Irish and English and is funded by the Department of Education and Skills (DES). The aims of the PDMT are to ensure that successful candidates:

- acquire the extensive and complex integrated knowledge base including mathematical and pedagogical knowledge that is necessary for effective mathematics teaching at post-primary level with special reference to 'Project Maths',
- demonstrate an ability to integrate this mathematics knowledge for teaching into professional practice as mathematics teachers,
- develop a high standard of practical competence in mathematics teaching as reflective practitioners during their programme of study.

There has been a trend in the field of CPD towards a greater emphasis on needs identification (prior to the CPD event) and evaluation and follow-up (after the CPD event) (Craft, 2002). The PDMT was specifically established to address the national need to upskill out-of-field mathematics teachers and for each cohort of teachers who have enrolled in the course, participants were asked to complete an online evaluation of the programme after completing their first of two years. The value and importance of evaluating CPD initiatives for international learning has been highlighted in research (Goodhall et al, 2005). In the following section, the online evaluation of the PDMT by participants is outlined.

METHODOLOGY

An online survey was developed by the PDMT, together with the Centre for Teaching and Learning in UL, to assess teachers' evaluation of the programme under the headings of:

- Programme particulars,
- Module specifics,
- Overall satisfaction.

The survey is chiefly quantitative in nature, consisting of fixed-response, Likert-type items within each of the three headings. In completing the survey, teachers were requested to rate various elements of the programme using the scale: 1 = Strongly Disagree; 2 = Disagree; 3 = Unsure; 4 = Agree; 5 = Strongly Agree. All items were positively worded and thus, a higher score on the survey indicates greater satisfaction with the programme. The teachers' responses to the online survey were coded and analysed using Microsoft Excel. The survey also included two open-ended items that asked teachers for any additional comments they had regarding the programme and for any advice they would offer to future participants of the programme. The responses to these open-ended items were qualitatively reviewed and trends in responses were identified using the constant comparative method of analysis.

Teachers enrolled in the PDMT were requested to complete this online survey after their first year on the programme, and to date, this constitutes three cohorts of teachers. Of these three cohorts, 65.6% completed the online survey.

The first research question that we aim to address in analyzing the data from the online survey is: "Are teachers enrolled in the PDMT satisfied with the programme and what strengths and weaknesses of the programme have teachers identified?". The 'teachers' refers to those teachers enrolled in the PDMT. In attempting to address this research question, this paper focuses on teachers' responses within the 'Overall satisfaction' section of the survey which includes the responses to the two open-ended items.

FINDINGS

In the 'Overall satisfaction' section of the online evaluation survey, participants of the PDMT were asked to rate their satisfaction with Year 1 of the Professional Diploma in Mathematics for Teaching. Of the teachers in the first three cohorts who completed the questionnaire, a significant proportion of them (33.5% on average) stated that they were unsatisfied or neutral in their opinion of the programme as a whole. In order to identify possible reasons for this dissatisfaction, qualitative responses from teachers to the open-ended items were examined. The major themes which emerged in relation to dissatisfaction with the programme include:

- Compulsory attendance was too demanding when in full time employment.
- Too demanding with regards to time and work load resulting in a lot of stress for the participants.
- Inconsistencies with regard to the teaching conducted across different centres and issues with the technology breaking down from time to time were also highlighted.

On average 52.5% of the participants either agreed or strongly agreed that they were satisfied with the programme as a whole, with the largest proportion of students agreeing with this statement coming from the latter years of the programme's implementation. Again, the open-ended items provided further insight into the strengths of the PDMT according to its participants. The major themes which emerged in terms of positive comments about the programme include:

- Support for the tutorial structure and comments on how helpful it was to engage with the tutors and other participants within this context.
- Participants envisaged the course positioning them well for career advancement.
- Many participants detailed the improvements in their self confidence in mathematics stating that they found the course both beneficial and enjoyable.

Advice to Future Participants

As mentioned previously, teachers were asked to provide advice for future participants of the PDMT. The main themes which emerged from teachers' responses are as follows:

- Potential participants should make themselves aware of the high level of pre-requisite mathematical knowledge that is required for the programme. Current participants also felt that consideration should be given when applying for the programme due to the high level of commitment combined with having a full time job and potentially a family.
- Another piece of advice that came through as a theme was an emphasis to future participants of the importance of attending tutorials (as they were found to be very helpful) and encouragement was given to read lecture notes prior to attending lectures.
- The final theme that emerged was a positive one and was evident throughout all cohorts' comments, and this was the assertion that the programme was an advantageous career move.

Overall, the advice given highlighted the substantial commitment which the teachers felt this demanding course required and that this should be given due consideration prior to signing up for the programme. In spite of this, the programme was still something that they felt was worth undertaking and something which was good for your career going forward.

DISCUSSION

Are teachers enrolled on the PDMT satisfied with the programme?

Findings from the online survey indicate that while there were some issues in the initial years of the PDMT, participant satisfaction with this unique programme has increased over time, particularly as preliminary technical difficulties were overcome. That a majority of teachers reported satisfaction with the PDMT is an acceptable outcome as given the blended-learning modality of the programme, there is the potential for an increased drop-out rate. Research has highlighted higher participant withdrawls for online or distance learning courses compared with traditional face-to-face courses (Nash, 2005; Wojciechowski and Palmer, 2005).

What strengths and weaknesses of the programme have teachers identified?

While the programme requires a significant time and work commitment, which can be stressful for participants as they are also teaching full-time, the general consensus is that the programme is a positive means of achieving professional development and advancement as a mathematics teacher. Similar difficulties in completing distance-learning courses, i.e. in terms of time and workload have been found by other researchers (Nash, 2005). The tutorial aspects of delivery were found to be of most benefit, as were the availability of lecture notes online prior to lectures. In examining the methods that students of distance-learning courses were most willing to try to improve their success, Nash (2005) found that tutoring was the one method that the majority of students were favourable towards. The tutorial system employed on the PDMT is evidently advantageous in terms of participant satisfaction. Technological glitches were one of the greatest deficiencies of the programme in its infancy, but the majority of these issues have been addressed as the programme developed. Perhaps one of the greatest strengths identified in the PDMT, is the increase in teachers' self-confidence. Philippou and Christou (1998) acknowledge that teachers' beliefs and conceptions about mathematics are a vital factor in the process of teaching and learning, and an essential aspect of teachers' beliefs or conceptions is the teacher's self-confidence or self-efficacy. According to Bandura (1992), efficacy beliefs play a central role in the effort made in the pursuit of one's personal goals, in persistence when faced with adversity, and the ability to rebound from temporary setbacks. Thus, increased confidence in their mathematics ability is a key step in teachers' future mathematics teaching success.

CONCLUSION

This paper presents some initial evaluation of the Professional Diploma in Mathematics for Teaching in terms of participating teachers' satisfaction and identified strengths and weaknesses. The increase in programme satisfaction in more recent cohorts is an indication of the PDMT's development (particularly with regards to technology) and the acknowledged strengths may well have played a significant role in the success of 528 teachers in graduating from the PDMT to date. Currently, various aspects of the PDMT are being investigated, not only in terms of CPD, but also with regards to blended-learning, mathematical content knowledge, mathematics pedagogy, action research and teacher identity. As this programme is a novel initiative, it has the potential to provide the education community with invaluable information and feedback that could be of benefit not only in Ireland, but on an international level.

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Using physics and technology in mathematics lessons to encourage a growth mind-set

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This action research project investigated the use of ICT equipment, normally associated with the Physical Sciences, to: facilitate the aims of Project Maths; foster a greater appreciation of the links between Maths and Physics; and to promote the development of a growth mind-set. As part of the research process 10 students participated in a series of lessons primarily centring on Functions and Calculus, while involving other strands of the Project Maths syllabus. The main findings suggested that the use of ICT equipment associated with Physics:

(i)heightened student awareness of the use of mathematics in tackling real world problems,

(ii)allowed learners to see the connections within mathematics and between mathematics and other subjects, and

(iii) generated a greater enthusiasm for searching for creative solutions among students who already had an essentially growth mind-set.

INTRODUCTION

I believe that teaching is an art as well as a science: we teach and learn with our heart, our head and our hands. Mathematical rigour is a necessary but by no means sufficient condition for mathematical growth.

"The Leaving Certificate Mathematics Syllabus for Examination" (2015, p.6) states:

> *By teaching mathematics in contexts that allow learners to see connections within mathematics, between mathematics and other subjects, and between mathematics and its applications to real life, it is envisaged that learners will develop a flexible, disciplined way of thinking and the enthusiasm to search for creative solutions.*

I share that belief. I was the product of the marriage between the modern mathematics movement and the points system which viewed rigour in procedural tasks, correct answers and quantitative analysis as the only respectable outputs of a function that ignored the characteristics of its inputs. I was not an only child. Lyons, Lynch, Close, Sheerin and Boland (2003) describe how students were given no meaningful opportunities to appreciate the applications of mathematics in the real world. The NCCA (2005, p.18) refer to Nickson (2000) and the implicit "*didactical contract*" made between students and their teacher. This "contract" has the student assuming: "*I am here to get my exams., you are here to teach me to do it".* They also mention "*problems with the teachers' knowledge base*" (p.20). They go on to point out that when "*developments emerge through particular computer applications*", or as our understanding of the way students learn evolves, teachers should be given opportunities to familiarise themselves with these developments.

This project aims to explore, and in some way measure, the effect of using ICT equipment associated with the Physical Sciences, complimented by the promotion of a growth mind-set, on the teaching and learning of mathematics.

There now appears to be a paradigm shift in Irish education involving: the advent of Project

Maths; the current work the NCCA are doing in the proposed revised curricula across the Maths and Sciences; and the possible introduction of reforms in modes of assessment for all examinations. The literature and present discourse suggest my project is relevant and timely.

LITERATURE REVIEW

The Use of ICT in Maths and Science Teaching and Learning

Brunbaugh, Ashe, Ashe and Rock (1997, p.119) state how in the "*...near future, if not now, mathematics and science study will be mandatory for all students because of the demands of our technological times*". In 2016 we are living in that future.

Ferrini-Mundy and Breaux (2007) quote the NCTM saying: "*Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning*" (NCTM, 2000, p.24). They also point out that teachers are unlikely to utilise "*technology-rich activities*" without proper professional development on "*instructional technology*" and appropriate "*curriculum materials*".

Dunham and Hennessy (2008) note that as more technology-related material is introduced into state examinations, those without adequate access to the technology will be at a disadvantage.

Jablonka and Gellert (2007, p.11) offer implicit salutary advice: they suggest that in certain technical situations, technology may facilitate the use of mathematics by freeing the user from the details of the mathematics involved. However they also posit the argument that technology can be characterised by making the underlying "*mathematical abstraction process invisible*".

The Use of ICT in Project Maths

In 2012, the NCCA issued a report in response to what they referred to as the "*current debate*" relating to Project Maths. In it, they refer to the Eurydice report in 2011 which states:

> *...professional development for teachers in a range of different methods, and allowing them to make decisions about what can be applied, when and why, is the best approach for improving teaching. (Eurydice Network (2011), p.52)*

The Educational research Centre (ERC) (2012, p.10) refer to Kelly, Linney & Lynch (2012), who reported a "*general increase in the use of ICTs*" during teaching. They also mention how teachers believed that "*the examinations were impacting negatively on the new teaching and learning approaches*" in Project Maths. In a table showing teachers' use of ICT resources in Project Maths lessons, general software and Geogebra are among the items listed. No specific mention is made of ICT associated with physics which could be used to complement the teaching of mathematics. They also say that there is a lack of information on "*the relative effectiveness of various types of ICT usage*" (p.46).

Promoting a Growth Mind-Set in Mathematics Classrooms

The importance of a growth mind-set has been documented in many research papers indicating its benefits in achievement and awareness of learning. Dweck (2008) defines a fixed mind-set as one which believes that talent and intelligence are innate to an individual. She defines a growth mind-set as a belief that innate talents and intelligence can be cultivated and encouraged through hard work.

Researchers, like Dweck (2000), often set out a series of questions, the aim of which is to measure the respondent's growth mind-set. Several researchers, like Abd-El-Fattah and Yates (2006), have used a 4-point Likert type scale ranging from 1 (Strongly Disagree) to 4 (Strongly Agree) in measuring the presence of a growth as opposed to a fixed mind-set.

In her paper "Is Math a Gift? Beliefs That Put Females at Risk" (2006), Dweck refers to "*females' greater sensitivity to setbacks*". She finds this "*vulnerability*" appears to be present in girls who "*see their ability as something that is fixed and that can be judged from performance – so that when they hit challenges, their ability comes into question*".

Blackwell, Dweck & Trzesniewski (2007) carried out a study involving hundreds of students entering 7th grade. They monitored the mathematics grades of these students over a two year period. Those with a growth mind-set consistently achieved higher mathematics grades than those with a fixed mind-set. They found that similar results hold true for premed students. In the latter scenario, all cared about grades, but those with a growth mind-set cared even more about learning, and earned higher grades.

METHODOLOGY

Introduction

When observing a particle, the Heisenberg Uncertainty Principle enters the equation: the act of observing the particle affects the particle being observed. What is true for the quantum world is, in a way, true for the real world. As an action researcher, not only am I observing the students, I am also observing myself. Therefore, how can I measure what I observe if my observation alters the reality of what I am attempting to analyse and interpret? My observation of the students will need to be discreet.

Here, I investigate the effect of using technology, normally associated with physics, in mathematics lessons so as to promote a growth mind-set. The main participants in the project are a group of 10 fifth-year mathematics students, all of whom study physics.

The Research Design

This action research project was carried out in a voluntary all-girls secondary school located in an affluent area of the city. The students come from a wide variety of backgrounds and are of mixed abilities.

10 fifth year students make up a small sample size. A separate but associated survey on mind-sets has already been undertaken involving approximately 160 students – all first year and fourth year students in the school.

To accommodate all elements of the research project, I have decided to use a pragmatic mixed-method approach.

Three sets of questionnaires were administered. All three were focused on growth versus fixed mind-set, and based on the work of Carol S. Dweck (2008). I inserted particular emphasis on mathematics, physics and technology in all three. The initial questionnaire was administered to the first and fourth year students only, where it was slightly modified to suit the first and fourth year mix.

The two remaining sets of questionnaires, identified from here on as Questionnaire 1 and Questionnaire 2, were administered to the 10 fifth-year students only. Questionnaire 1 was administered prior to the intervention classes. Questionnaire 2 was administered immediately following the intervention. Questionnaire 1 and Questionnaire 2 were identical so as to enable the researcher to measure any difference in the students' growth mind-set, which may have occurred because of the intervention.

The seven class periods of the intervention explored the use of physics and technology in mathematics lessons in encouraging a growth mind-set and in helping to achieve the aims of Project Maths. The main areas of focus involved: simple mathematical modelling, algebraic manipulation, percentage error and linking algebra to calculus. The physics technology included: computers, data logging systems involving photogates and motion sensors, spherical objects, pendulums and data which our Comenius group had generated when studying the Kariba asteroid.

In addition, I also designed a test in order to further assess and cross reference the students' response to the intervention. This test was given out immediately prior to Questionnaire 2. The key assessment modes of this test looked at conceptual understanding, procedural fluency, strategic competence, adaptive reasoning and productive disposition. Part of the rationale behind this test was to assess what affect assessment has on growth/fixed mind-set.

The 10 fifth year students then formed the oral interview focus group and participated in a relaxed informal interview (incorporating a blended approach – without audio or visual recording) two days after the final questionnaire was completed by the students. I chose this approach to encourage better participation and authenticity.

FINDINGS

The Background Context of Growth versus Fixed Mind-Set in the School

Approximately 95% of all first-Year and fourth-year students completed the initial questionnaire.

Table1 and Table 2 are based on the initial Questionnaire, where the possible range of scores went from 0 – 60 - a higher score indicates a stronger growth mind-set.

Table 1: Initial Questionnaire for First Year – Fixed versus Growth Mind-Set

Class Group Fixed	Strong Growth	Growth with some Fixed	Fixed with some Growth	Strong Growth
1 π	4	17	2	0
1θ	9	17	0	0
1ζ	5	21	0	0
Total	18	55	2	75

The data in Table 1 and Table 2 refer to three first year class groups and three fourth year class groups respectively: 1π, 1θ, 1ζ and 4π, 4θ, 4ζ.

The data for 1st Year is very slightly skewed. The data for 4th Year is even more symmetrical.

Table 2: Initial Questionnaire for Fourth Year – Fixed versus Growth Mind-Set

Class Group	Strong Growth	Growth with some Fixed	Fixed with some Growth	Strong Fixed
4π	2	20	2	0
4θ	4	19	4	0
4ζ	4	10	8	0
Total	10	49	14	73

The statistics for the initial questionnaire, concerning the presence of growth versus fixed mind-set, gave a first year average score of 42.573 and a fourth year average score of 38.342.

Data from Fifth Year Mind-Set Questionnaire 1 and Questionnaire 2

A summary of the results of the 10 fifth-year students' response to Questionnaire 1 and Questionnaire 2 is given in Table 3.

Table 3: Fifth Year Data for Questionnaire 1 and Questionnaire 2

Statistic	Questionnaire 1	Questionnaire 2
Mean Score	61.333	61.556
Median	61	58
STDEV	6.852	7.248

Nine out of the ten fifth-year students completed both questionnaires.

Here the possible range of scores went from 16-80. Again, a higher score indicates a stronger growth mind-set.

One way to compare how each of the three year groups did, relative to each other, is to adjust their respective scores:

First Year Mean Score: 100(42.573 ÷ 60) = 70.955%

Fourth year Mean Score: 100(38.342 ÷ 60) = 63.903%

Fifth Year Mean Score (adjusted for comparison):

Questionnaire 1: 100(61.333 – 16)/64) = 70.833%; Questionnaire 2: 100(61.556 – 16)/64) = 71.118%

Findings from the Test on Completion of the Intervention

The test I designed consisted of seven questions. Here is a summary of the findings:

- A relatively high number of answers lacked accuracy.
- Some students did not answer all questions, even though the questions only required very short answers.

- Only one of the nine students who completed the test showed evidence of lateral thinking.
- Five out of the nine students chose the simplest question as their favourite question, despite it being designed to be the most "boring".
- Four of the nine students chose a question which it seems they believed they would have got full marks for, but which they may also have found interesting.
- The three students who finished the "test" earliest - after 7 minutes,7 minutes, and 12 minutes - all scored marginally lower in Questionnaire 2 than Questionnaire 1, which might suggest a fixed mind-set at work.

The Focus Group Session

All ten students viewed the use of ICT equipment, normally associated with Physics, as being very useful in helping them to understand mathematics better. They believed it helped them to understand certain concepts better. Most of the participants believed the use of the ICT equipment made the lessons more enjoyable. However, some students confirmed that they preferred the easy questions because they believed such questions would allow them to improve their grade.

DISCUSSION

Following the advice of Jablonka and Gellert (2007), I attempted to ensure that *"frozen mathematics"* in the form of technology did not impede my students in developing an informed, flexible and enthusiastic approach to searching for correct and creative solutions. I had to use technology so as to develop their mathematical proficiency.

Tall et al. (2008) refer to those who believe meaningful experiences are needed for conceptual understanding and insight. The word "experience" is significant. The French word "experience" means "experiment", and is derived from the Latin word "experiri" meaning "to try". The word "expert" comes from Middle English and refers to someone who has tried and found out about something. I believe that, for most students, experiential learning can lead to rigour and precision in mathematical thought and not vice versa. However, teacher and student regard for accuracy and discipline is also important.

The average score in the mind-set questionnaires for the 10 fifth-year students before and after the intervention was statistically significantly higher (t-test, $\alpha < 0.01$) than the corresponding average score for the 73 fourth-year students. Does studying Physics tend to attract those with a growth mind-set? Does studying Physics help to develop a growth mind-set? If the latter is true, then this may further validate introducing projects like this one.

Growth versus Fixed Mind-Set - The Initial Questionnaire

The average score of the first Year group appeared to be higher than the fourth Year group (42.573 compared to 38.342). One fourth year group, 4Z, fared less well in the mixed mind-set categories than the other two. One reason for this could be that students, in this case female students, tend to form a group mindset. It could also be due to the type of teaching they have experienced. In responding to the current debate concerning Project Maths, the NCCA (2012, p. 13) mention the need for Maths teachers to introduce new approaches and to build on their own *"confidence and expertise"*.

Questionnaire 1 and Questionnaire 2

For the fifth Year group, the mean score for Questionnaire 1 was 61.333 and the mean score for Questionnaire 2 was 61.556. The increase in average score is negligible. One must consider the relative brevity of the intervention. The medians score reduce from 61 to 58, and the standard deviation going from 6.852 to 7.248. The grades have become more spread out.

If I divide the students into two groups comprising of the five students who scored lowest in Questionnaire 1 and the four who scored highest in Questionnaire 1, then we find some interesting results. Of the five students who scored lowest, four did better in Questionnaire 1 and one did better in questionnaire 2. Of the four students who scored highest, all four did better in Questionnaire 2 than they did in Questionnaire 1.

This suggests that the use of ICT equipment, normally associated with the physical Sciences, may build on the growth-mindset of those who already have an essentially growth mind-set, but it may also impact negatively on the mind-set of those who tend to have more of a fixed mind-set.

These findings may go some way in responding to the report of the ECR (2012, p.73) which recommended that "*the use of ICT in teaching mathematics be examined carefully*" so as to identify which tools and strategies are most effective.

The Test added to Questionnaire 2

A significant number of participants tended to dislike questions which they perceived to be difficult or when uncertainty was involved. It seems a fixed mindset kicks back in when students feel they are undergoing summative assessment. This may reflect the views of some teachers, mentioned in the report by the ERC, who believed examinations impacted negatively on teaching and learning.

"The Leaving Certificate Mathematics Syllabus for Examination from 2015" (p.44) states that, in relation to assessment, a high level of achievement may be characterised by a learner who presents "*a reasoned justification*" and considers a range of approaches *"including the use of technology"*. Interventions like this one can help prepare students for what may be expected of them.

The Focus Group

All of the focus group students said they found the lessons exciting and enjoyable. Those with a greater growth mind-set said they really benefited from the lessons; those who exhibited less of a growth mind-set were not as sure. They all exhibited some tendency to create performance goals as opposed to learning goals, especially in tests.

CONCLUSION

In the opening paragraph of their discussion paper on mathematics in post-primary education, the NCCA (2005,p.2) mention: "*William Ronan Hamilton...mathematicians and scientists...wave mechanics...computer users...graphics technology...International Year of Physics...Albert Einstein*". In their response to what they termed the *"current debate"* concerning Project Maths, the NCCA (2012, p. 11) describe how, in the 2011 examination, students (and many teachers) were *"unable to do a question,"* on graphs of functions which was not as predictable as theretofore. Exploiting the links between mathematics, physics and technology should help.

The NCCA through the syllabus it has worked on, the SEC through the questions it sets, and teachers through the way they design and teach their lessons, must all set out a variety of *fruits* for students to choose from. By implementing ICT in such a way that it respects all mind-sets, we cater for diversity.

Quantum mechanics suggest that reality works according to rigorous and precise mathematical formalism, but it also asserts that it can only determine the probability that a particular future will happen. A growth mind-set might find hope in that uncertainty: we can use our free will to shape our destiny. Armed with the courage of that conviction, my next project is how I motivate those with a fixed mind-set.

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Pre-service mathematics teachers' concerns and beliefs on implementing curricular reform

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In 2010, a major reform of the Irish post-primary mathematics curriculum was introduced. In tandem with this reform, in-service professional development has been made available to all post-primary mathematics teachers, with over 4,000 teachers attending such training (Project Maths Implementation Support Group, 2014). However, as these specialised professional development programmes are presently drawing to a close, newly qualifying mathematics teachers will not have an opportunity to participate in such in-service initiatives. In this research, we investigate the concerns and efficacy beliefs of a cohort of pre-service teachers (PSTs) towards the curriculum reform. 41 PSTs from post-graduate initial teacher education in four third-level institutions in Ireland participated in the research. Preliminary data based on their concerns regarding the reform (Charalambos and Philippou, 2010) and additional qualitative responses are presented in this paper. Findings suggest that at the commencement of their initial teacher education, this group of PSTs are concerned about their knowledge of the reform, have mis-information about the reform, and do not yet show significant concern for the impact of the reform.

INTRODUCTION

In the past two decades there has been wide-scale, international reform of mathematics curricula at primary and post-primary levels (Charalambos & Philippou, 2010). These reforms have often emphasised approaches to teaching and learning which have deviated from the norm and, instead of a didactic tradition of introducing mathematics, now incorporate students' communication of mathematical thinking and incorporate problem solving approaches to mathematics (e.g. Doorman et al., 2007; NCTM, 2000; Reiss & Torner, 2007). With such reform comes a focus on classroom practice and on the integral role of teachers in implementing curriculum innovation (Datnow, 2002).

Teachers' personal theories about learning and teaching influence how they value and implement reform curricula (Manouchehri & Goodman, 1998) and enacting a new curriculum may require a transformation of teachers' ideas on teaching and learning of their subject (Roehrig & Kruse, 2005). Such change inevitably leads to concerns about pedagogical issues such as the reasoning behind a curriculum reform, the implications for their classroom practices, the consequences for their students, and their sense of efficacy in implementing a new curriculum are integral elements of the success of such initiatives. Teachers' perceptions of being involved in any curriculum innovation are therefore integral to the reform process (Senger, 1999) and it is important for policy-makers and educators to have a picture of teachers' concerns and beliefs before and during the implementation of a reform (Fullan & Hargreaves, 1992).

In Ireland, a revised post-primary mathematics curriculum was introduced in 2010 which, as well as incorporating new content, places greater emphasis on problem solving approaches to teaching and learning (Ni Shuilleabhain, 2014). This curriculum reform constitutes a deviation from the tradition of teaching mathematics in a procedural and didactic way (Lyons et al., 2003), to one which emphasises student communication and collaborative classroom practices. Recognising the importance of teachers' roles in reform, from the introduction of the revised curriculum in-service professional development was offered to all teachers of mathematics in the form of day-long workshops and modular courses (Project Maths Implementation Support Group, 2014). However, as these specialised professional development programmes draw to a close, newly qualifying mathematics teachers will not have an opportunity to participate in such in-service initiatives. Furthermore, pre-service teachers (PSTs) who commenced study for a post-graduate teaching qualification prior to 2015 have no experience of learning this new curriculum, having progressed from second level education prior to the introduction of the new curriculum. Similarly, other PSTs entering such post-graduate courses in future may not have any knowledge or experience of this reform if they are changing career etc.

In this research the authors investigate the concerns and efficacy beliefs of post-graduate PSTs towards the revised curriculum and investigate how these concerns evolve during their initial teacher education. Specifically, in phase 1 of the research project, we investigate:

1. What are the concerns of Irish post-graduate pre-service teachers of Mathematics relative to the revised curriculum at the beginning of their initial teacher education?
2. How efficacious do they feel implementing this reform as pre-service teachers?

THEORETICAL FRAMEWORK

The Concerns Based Adoption Model (CBAM) has been used to describe, measure and explain educational reforms relative to the beliefs and concerns of teachers. Originally based on a hierarchy proposed by Fuller (1969) of self, impact, and task concerns, this model has been expanded to suggest that teachers move through several 'Stages of Concern' when adopting a reform (Hall & Hord, 1987). Charalambos and Philippou (2010) adapted the CBAM model to incorporate teachers' efficacy beliefs about implementing curriculum reform. They wanted to address research which suggested that teachers with high efficacy beliefs were more willing to adopt innovations and more likely to focus on the impact of the reform on student learning (e.g. McKinney et al., 1999). In their adaptation of the CBAM survey instrument, Charalambos and Philippou suggested five factors of concern (see Table 1) which they structured into three levels (p. 13).

Table 1: Five factors of concern (Charalambos & Philippou, 2010)

Factors	**Level**
Awareness	Level 1
Informational	
Management	Level 2
Consequences on students	Level 3
Refocusing (negative critique)	

They found that the more aware teachers felt about the reform, the more efficacious they reported on using the reform. In addition, they found that teachers' concerns about managing the reform in their classroom and their concerns about the consequences of reform reduced according to how confident teachers were in implementing the reform.

Focusing on teacher beliefs, Luft and Roehrig (2007) investigated the beliefs of pre-service and newly qualified science teachers on implementing reform curricula. Utilising a framework based on teacher interviews (or TBI), Luft and Roehrig categorised participants' beliefs on teaching and learning as: traditional, instructive, transitional, responsive, and reform-based. While this framework does not specifically refer to concerns with regards to curriculum reform, it does provide an additional cross-categorisation of teacher efficacy when analysing their beliefs around teaching and learning of mathematics. 'Traditional' and 'instructive' beliefs are categorised as teacher-focused, where a teacher provides all information in a structured environment or views students as recipients of knowledge. 'Transitional' beliefs refer to those which involve the student, but do not merit the importance of the students' own experiences in the classrooms. 'Responsive' and 'reform-based' teaching refers to beliefs where the student is at the core of all teaching and learning activities. Referring to the initial stages of implementation of the mathematics curriculum reform in Ireland, and with the authors' specific focus on PSTs, the TBI framework provides additional insight into these PSTs' attitudes and beliefs as related to the reform of the post-primary mathematics curriculum.

METHODOLOGY

Students participating in Mathematics Pedagogy modules in post-graduate initial teacher education courses in four third-level institutions across Ireland were invited to take part in the research. A total of 41 PSTs participated in this first phase of the study. Within the initial two weeks (September 2015) of their course, participants were asked to complete a written questionnaire reflecting their concerns and efficacy beliefs regarding the curriculum reform. Completed questionnaires were returned by 97.56% (n = 40) of the participants.

Data Collection Instrument

The adapted CBAM instrument produced by Charalambos and Philippou (2010) was given to participants. The instrument consists of 35 questions focusing on 7 factors: awareness of the reform, information regarding the goals and implementation of the reform, management concerns, consequences for students, refocusing concerns, efficacy beliefs about teaching without the reform, and finally efficacy beliefs about incorporating the reform in teaching. Additional open questions were asked in order to provide students with opportunity to articulate their level of awareness and knowledge of the curriculum reform and respond to any concerns they might have with regards to the implementation of the reform.

Data Analysis

Quantitative data from the questionnaires regarding PSTs' concerns and efficacy beliefs were entered into IBM SPSS Statistics for analysis. Means and standard deviations were used to explore the intensity of the PSTs' concerns and efficacy beliefs while Kendall's coefficient of concordance W (cf. Sheskin, 2003, p. 1093-1108) helped rank teachers' concerns according to their intensity. Due to the non-normal distribution of PSTs responses to the attitudes, questionnaire medians and inter-quartile ranges were used to explore these results.

Analysis of qualitative responses was undertaken utilising the framework of teacher concerns and efficacy as outlined in Charalambos and Philippou's (2010) research. In addition, the TBI framework (Luft & Roehrig, 2007) was utilised in further analysing these PSTs' concerns with regards to the curriculum reform. Results of this mixed-methods approach are reported below.

FINDINGS AND DISCUSSION

Factor scores for each of the seven factors were calculated and the means and standard deviation scores for each are presented in Table 2. The Likert scale used was a 5-point scale and it is evident that the PSTs did not consider themselves overly concerned regarding their level of awareness of the curriculum reform ($\bar{x}$ = 2.55). However, from an informational viewpoint it is clear that the PSTs feel they need more information in relation to the goals and the implementation of the reform within the classroom ($\bar{x}$ = 4.45). While it might be expected that these PSTs would have informational concerns at the beginning of their initial teacher education programmes, the qualitative analysis provides further insight into these concerns (see below) which includes incorrect information regarding the curriculum reform.

While management concerns ($\bar{x}$ = 3.49) and concerns of the consequences of the reform on students ($\bar{x}$ = 3.48) are relatively high, these are much lower than participants' informational concerns. This is likely due to participants' lack of familiarity with teaching and learning in the classroom and their lack of experience in managing student learning in general. The low refocusing concerns are likely also due to these participants' lack of experience in engaging with the revised curriculum. The same may be said for participants' efficacy beliefs around teaching without the reform ($\bar{x}$ = 3.53) and teaching with the reform ($\bar{x}$ = 3.57). These factors will be further investigated as our investigation continues into year 2 of their initial teacher education and into their practices as newly qualified teachers.

Kendall's W was calculated to measure the level of consensus among the PSTs in ranking the intensity of their concerns. The result (W = 0.55, p < .000) suggests that there is good agreement among the PSTs in terms of the overall ranking of the concern factors.

Table 2: Mean and Standard Deviation scores for the concerns and efficacy beliefs factors

Factors	Mean[a]	Standard deviation	n
Awareness	2.55	0.77	39
Informational	4.45	0.41	40
Management	3.49	0.38	38
Consequence on students	3.48	0.54	38
Refocusing (negative critique)	3.11	0.47	39
Efficacy beliefs about teaching without using the reform	3.53	0.56	39
Efficacy beliefs about incorporating the reform in teaching	3.57	0.49	39

[a]On a five-point scale (1 = strong disagreement; 5 = strong agreement)

Qualitative analysis provides us with insight into the quantitative data. Responses provided by the PSTs were primarily related to Level 1 concerns: awareness and informational. The majority of PSTs (n = 23) demonstrated a lack of awareness or expressed a personal need for more information.

> *"I'm not aware of much of the changes but it mostly depends on how it is taught and examined. I think a major change did have to be made to the syllabus, but I don't know enough about Project Maths specifically to fully agree with it yet"*

It is worthy of note that some PSTs saw the introduction of the new curriculum as something introduced by third level institutions and private industry to increase the level of skilled graduates. Participants' responses to the question "What do you believe the purposes of introducing Project Maths were?" included beliefs such as:

“Increased participation at higher level. Response to demand from third level institutions and service sector employers for higher-skilled graduates”,

and *“to get students into STEM careers.”*

Furthermore, a number of PSTs incorrectly considered the introduction of bonus-points (incorporated within the allocation of point scores of students’ final assessments in 2012) part of the introduction of the revised curriculum, listing “*25 extra points*” as the changes incorporated as part of the reform. This incorrect information on the reform should be noted by policy-makers and mathematics educators in the design of initial teacher education.

While not all of the commentary was positive, all participants were aware of the reform and the majority (n = 25) articulated a recognition for change in relation to mathematics education in the system.

Differing to the quantitative analysis of Level 2 concerns, none of the participating PSTs expressed management concerns relating to the impact on daily classroom practices in implementing the curriculum. However, as noted above, the absence of emphasis by participants on these concerns is likely influenced by these PSTs lack of classroom experience at this stage of their initial teacher education. It is interesting to note, however, that despite an evolutionary theory of concerns related to reform (van den Berg and Ros, 1999), 18 participants expressed concerns related to the consequences of the reform (Level 3). Investigating these responses further, utilising the TBI framework (Luft & Roehrig, 2007), the majority of these participants (n = 12) demonstrated transitional views representing affective responses towards student-learning, but not incorporating student-centred beliefs around teaching and learning. For example, one participant demonstrated an understanding that the reform was introduced to

“Make maths more interesting for students, increase its relevance, increase higher level maths uptake and integrate the primary and post primary maths.”

Only a small number of participants demonstrated responsive views of the reform, valuing the student at the centre of the learning process. This analysis would lead us to believe that these PSTs had not yet fully engaged with the aims and objectives of the reform curriculum and there remain important nuances in the Level 3 concerns expressed by these PST participants.

Summarising the qualitative responses, despite the higher level of concerns expressed, the majority of responses were focused on the implications of the curriculum reform on the summative post-primary assessment, in particular in relation to assessment and the structure of the examination papers. Very few participants referenced students or student learning in their responses and none referenced any impact on classroom practices or students' experiences of learning mathematics.

CONCLUSION

McKinney et al. (1999) suggest that the success of any reform depends on teachers’ concerns moving from the personal to impact concerns. In this research, the authors have established a baseline level of concern for these PSTs commencing their post-graduate initial teacher education and can now trace the evolution of their concerns as a longitudinal study over their initial teacher education and as newly qualified teachers. Participating PSTs show high informational concerns with regards to the revised curriculum and demonstrate lack of information or mis-information related to the reform. In their study of the introduction of adaptive teaching, van den Berg and Ros (1999) found that teachers initially mainly express concerns related to their personal capabilities to implement the proposed changes. Van den Berg and Ros (1999) found that, over time, teachers' concerns become more focused on the classroom implications of the reform both for teacher and for the class of students. In this research, we found that PSTs showed strong personal concerns, equivalent to Level 1 concerns, little management concerns (Level 2), but strong impact concerns (Level 3). While the lack of management concerns might be expected for a cohort with no classroom experience, the high impact concerns of these PSTs is of interest. It is worthy of note, however, that for this cohort of PSTs, these impact concerns are very exam-focused and show little evidence of valuing the learning experiences of the student.

Our findings have implications for mathematics teacher educators who may wish to further emphasise the philosophical underpinnings of curriculum reform for PSTs and focus on the impact on classroom practice (as perhaps contrasting with their own learning experiences) of such reforms. It remains for further investigation how these concerns may evolve over their initial teacher education and, as newly qualified teachers, and how these concerns may manifest in classroom practice.

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Interdisciplinary science and mathematics teacher education in Denmark

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Traditionally science teacher education for primary and lower secondary schools in Denmark has been conducted as a four years programme at university colleges. These educational programmes have been structured in a way that you as a teacher can be specialized in three domains of teaching. In the light of the new educational focus on 21st Century Skills (Pellegrino & Hilton, 2013) it becomes clear that many competencies are generic and therefore could be developed in more than one domain. The consequence of this is seen in curricula all over the world where inquiry skills of both science specific and generic character are written in to national standards (Bevins & Price, 2016). An analysis of the presence of inquiry skills in European curricula has shown a heavily presence of such foci (McLoughlin, Finlayson, & van Kampen, 2012). Content specific arguments towards interdisciplinary science education can also be found in Lattuca, Fath, and Voigt (2004) and Michelsen (2010) who highlights that interdisciplinary teaching can be both motivating, present content in a broader view, help overcoming overlapping content knowledge and develop thinking among students.

In this paper we highlight the importance of and the opportunities in educating future teachers to be capable of conducting interdisciplinary science and mathematics teaching. We do that by introducing the Danish teacher education system and map our new teacher education programme to this. Next we present the framework for this new programme. Finally we present tentative data from the first cohort of pre-service teacher attending the programme and discuss these data towards our hopes and expectations for the programme.

CURRENT STATE OF DANISH SCIENCE AND MATHEMATICS TEACHER EDUCATION

The Danish teacher education and thereby science and mathematics teacher education is divided between two different levels of teachers and two different levels of teacher education institutions.

Primary and lower secondary teacher training

Teachers for primary and lower secondary school are trained at a university college. Here they undergo an educational programme with focus on pedagogics and some specialization into subject areas. University colleges are institutions where students are educated to the degree of professional bachelor. The university colleges are not part of the regular university sector, so teacher education is still generally separated from the research-based university tradition.

Teacher training at a university college is a four years programme of in all 240 ECTS. Subject areas constitute 30 ECTS each of the programme (except for Danish and mathematics which constitute 40 ECTS each). The remaining part of the education is general pedagogics and practical training. Teachers for primary and lower secondary school end their education with a specialization in three subject areas (see table 1). These areas do not have to be connected.

Upper secondary teacher training

Pre-service teacher training for upper secondary level is placed at universities. Teaching is traditional university teaching and there is no specialized teacher education. For science and mathematics master students studying two subjects there is a mandatory course in science education of a minimum of 5 ECTS. Students at the universities seldom have the opportunity to go in to practical teacher training. Instead, there is a one year in-service teacher training course for educated masters teaching in upper secondary schools. Teachers typically attend such course within their first years of teaching.

At the master programmes in science and mathematics at University of Southern Denmark there is mandatory course of 10 ECTS in science and mathematics education and interdisciplinary teaching and modeling. Furthermore, some of the master students follow an elective course with practical teacher training, and several of students elect an educational theme for their master thesis.

Table 1: Structural overview of Danish science teacher education at primary and secondary level including the new interdisciplinary science and mathematics teacher education.

Science teacher education	*Primary & lower secondary schools*	*Upper secondary schools*	*Interdisciplinary science and mathematics teacher education*
Intended for pupils aged	6-15	15-18	6-15
Located at	University College	University	University College & University
Title	Professional bachelor	Master	Professional bachelor
Length of study	4 years including practical training	5 years with no practical training	4 years including practical training
Focus of study	General pedagogics combined with course specific didactics	Content	General pedagogics combined with interdisciplinary science didactics
# of special subjects	3	1-2	4

THE INTERDISCPLINARY SCIENCE AND MATHEMATICS TEACHER EDUCATION PROGRAMME

In Table 1 it is shown that the structure of the new interdisciplinary science and mathematics teacher education is fitted to the official frames for primary and lower secondary pre-service teacher training. The students will still acquire a professional bachelor degree and main parts of the programme are similar to the ordinary teacher education programmes at university colleges.

Structure and content of the programme

The new interdisciplinary programme is offered in collaboration between the university and the two university colleges in the Region of Southern Denmark. In this way, the programme can be viewed as the first step towards transcending the gap between on primary and lower secondary teacher education and upper secondary teacher education and establishing a common research based foundation for a comprehensive teacher education from primary to upper secondary education. For example it should be noted that the above mentioned 10 ECTS course in science and mathematics education and interdisciplinary teaching and modeling for master students is mandatory for the teacher students of the new programme. Like this future primary, lower secondary and upper secondary teacher teachers are gathered together in a common course, and offered the possibility to gain insight in the different levels of the educational system in Denmark and develop a comprehensive understanding of educational challenges across the different levels.

The ordinary teacher education programmes involves two or three main subjects, e.g. Danish, mathematics. Contrary to the ordinary teacher education programmes the new interdisciplinary programme focuses solely on science and mathematics, and involves mathematics as the main subject. Besides mathematics, the teacher students must chose three subjects among the following subjects: physics/chemistry, biology, geography and nature/technology. Consequently, the teacher students of the new programme have four teaching subjects contrary to the three subjects of the ordinary programmes. This does not mean that the teacher students are confronted with four different subjects. On the contrary, the programme is structured and balanced around subject specific as well as interdisciplinary activities. The aim is to open up for a more interdisciplinary approach to mathematics and science based on the idea of modeling as an interdisciplinary activity that transcends the traditional subject boundaries. Modeling is accepted as an important issue of mathematics and science education at all levels (Gilbert et al 2000, Lesh et al 2010). This fact is used to address modeling as a common and not a subject specific activity, and hereby including an extra subject.

The didactical framework of horizontal linking and vertical structuring proposed by Michelsen (2006) supports this approach. The didactical framework consists of two phases: horizontal linking and vertical structuring. In the phase of horizontal linking, thematic integration is applied to connect concept and process skills of mathematics and natural sciences by modeling activities in an interdisciplinary context. The vertical structuring phase is characterized by a conceptual anchoring of the concepts and process skills from the horizontal linking phase by creating languages and symbol systems that allow the pupils to move about logically and analytically within mathematics and the relevant subject(s) of natural sciences without reference back into the contextual phase. The shift from the horizontal linking to the vertical structuring phase might thus concur with a shift from interdisciplinary teaching to subject-oriented teaching. The process of the two phases is iterative. Once the concepts and skills are conceptually anchored in the respective subjects, they can evolve in a new interdisciplinary context, as part of a horizontal linkage. In this way, the framework highlights the interplay between contextual interdisciplinary and context-transcendent subject specific teaching and learning.

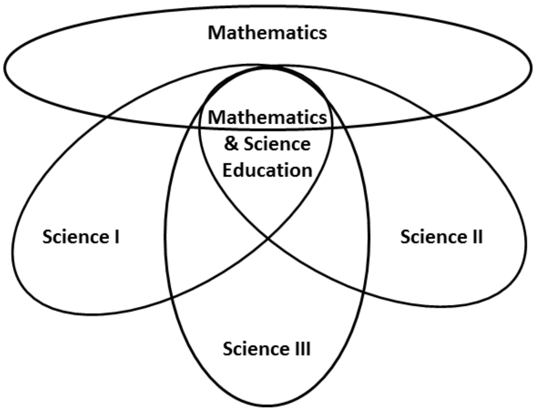

Figure 1: The structure of the four specialized areas with a focus on the interplay between the three domains of science and mathematics

Moreover the didactical framework of the new science and mathematics teacher education underpin the new Danish curricula and standards for science and mathematics education in primary and lower secondary school. Each of the four areas for specialization is described as four general competencies namely i) investigation, ii) modeling, iii) discussion and perspectives, and iv) dissemination. The latter three competencies also appear in the curriculum for mathematics. The focus on an interdisciplinary and context-trancendent teacher education in science and mathematics can thereby also be clarified through the official standards.

TENTATIVE RESULTS FROM THE FIRST YEAR OF COHORT ONE

The new science teacher education started out in autumn 2015. In all 28 students applied for starting on the education through two different university colleges. The teachings in the first year were solely conducted at the university colleges. At the end of year one the students were asked about their experiences in the first year.

In general the students thought that it had been a very rough year to overcome. Many of the students would not recommend the education in its present form since there was too much studying compressed in the first year. Many students though also said that they were glad that they had gone through with it and that they were proud to be on this new education focused on science.

Their expectancies for the next three years were mainly focused the semester at the university. In the students' opinion this semester was the primary reason for feeling proud of attending the new science teacher education instead of an ordinary teacher education.

From an organizers and educators point of view it is of course not satisfying that the students will not recommend the study. A more smooth first year study is prepared for the future cohorts of student teachers. The influence of the university semester on students view on their study was surprising. We were aware of a low status of being a teacher. But we did not expect the structure in itself to have such influence on students' beliefs. Our aim was that teachers, through a more interdisciplinary focus, would become more proud of the competencies they acquired during their education.

PERSPECTIVES FOR THE FUTURE TEACHERS

In the above presentation of the new science teacher education we address several topics that we hope to see in action among the future teachers following the education. In this section we will list the opportunities that we expect to grow out of this new structure.

We would like to follow up on the perspective of teacher beliefs and attitudes towards being a science and mathematics teacher. We did not expect to find the focus at such early stage of the education.

Furthermore we expect to educate teachers who can work vertically deeper and horizontally wider (Michelsen, 2006) than teachers do with the current teacher education for primary and lower secondary school. In such work we expect that the future teachers are capable of working with modelling instead of models. This means that the teachers have the content knowledge of their specialized areas and the interdisciplinary perspective to develop educational landscapes for their students where these can develop and explore their own models instead of working with pre-fixed models. The future teachers will in doing so educate their students towards the 21st Century and skills and the national standards and curricula. The vertical deepening is in the new science and mathematics teacher education secured in the research based anchoring in attending university courses while the horizontal perspectives are introduced though the interdisciplinary science educational teaching.

Another perspective of this new education is the possibility of establishing networks and knowledge on science teaching in two traditionally distinct areas. When teacher students for primary and lower secondary and upper secondary school attend the same courses they also share a common knowledge. In such courses we see the possibilities of exchanging knowledge of the two different teacher educations and the two different types of schools. In time this might help problems in transition between lower secondary and upper secondary school.

DISCUSSION

When the students graduate from the teacher education they enter into a school system that is being continually reformed aiming at a more interdisciplinary curriculum. Effective instruction will depend on a curriculum that introduces important topics in both science and mathematics in a suitable order with appropriate linkages between them. Mathematics and science teacher education must be reformed to prepare the students to think mathematically and scientifically beyond school. Meeting this need requires development of an appropriate educational strategy involving development of teacher education programs addressing the interdisciplinary aspects of the subjects. It is this gap between the need and the current state of teacher education that we try to minimize through the new science and mathematics teacher education. In the sections above we have argued that this is a possibility with the education. In the upcoming years we will follow the students and the education to see if these possibilities flourish in the future. We will do so by making longitudinal studies of the students attending the new teacher education. These studies will focus on students' capability to establish modeling activities for pupils in school. We will do so by using mixed methods like interviews, content analysis of written assignments and analysis of modeling activities in practical training.

Furthermore we will do a mapping on teacher beliefs and attitudes towards being a science and mathematics teacher to find out if this new education in practice fosters teachers more proud of being science teachers than the current state teachers. We expect that a success for the new education is embedded within a more positive attitude towards being a science and mathematics teacher. A challenge in this approach is that we are changing a paradigm in traditional Danish science and mathematics education. Students attending the education have a lack of experience with modeling and interdisciplinary teaching. So there will be no quick solutions. We as teacher educators are forced to do our experiences with the first cohorts too. Even that we consider ourselves as highly experienced in the area of interdisciplinary teaching we still expect that we need to adjust the education according to both students' modeling and interdisciplinary capabilities and findings form the research approaches. Nevertheless, a deeper understanding is still needed of the distinctive features of teaching and learning in particular subjects and interdisciplinary contexts as well.

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EDUCATIONAL POLICY REFORM DOCUMENTS: 'OUGHTERING' THE DESIGNATED IDENTITIES OF MATHEMATICS TEACHERS

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Teacher professional identity can be envisaged as a dynamic construct shaped by, and shaping of, the structural and cultural features of society, school and classroom. Seen in this way, teacher professional identity is viewed as a discursive construct that can be expressed through stories. Policy documents are also discursive productions circulating the dominant discourse within a particular context and have the capability to construct, - that is to afford and/or constrain, teacher professional identities. In this article, a narrative perspective on identity is employed. The relationship between narrative and identity is much discussed in the literature, highlighting narrative as a viable theoretical base for researching teacher professional identity. Thus, for this study, teachers' professional identities are equated with their stories – be they narrated by teachers or others. Adopting Sfard and Prusak's (2005) definition, teachers' actual identity consists of the stories told about the current state of affairs, while teachers' designated identity comprises the stories expected to be told in the future. Critical Discourse Analysis (Fairclough et al. 2011) was employed to examine the construction of the actual and designated identities of teachers in a pivotal post-primary mathematics educational policy document in the Republic of Ireland i.e. Review of Mathematics in Post-Primary Education: a discussion paper' (NCCA 2005). Findings indicate that this document articulates a narrative of Irish post-primary mathematics education. The analysis demonstrates that this narrative's plot may be to 'oughter' the designated identities, counterpointed against the perceived actual identities, of post-primary mathematics teachers in the Republic of Ireland.

INTRODUCTION

It is evident that in recent years educational research has shifted its attention firmly towards identity (e.g. Akkerman and Meijer 2011, Beauchamp and Thomas 2009, Kaplan and Flum 2012). More specifically, the notion of sub-identities (Beijaard *et al.* 2004) has fostered the possibility for plausible research on mathematics teacher identity (e.g. Bossé and Törner 2015, Brown and McNamara 2011, Darragh 2016, Sfard and Prusak 2005). This surge in teacher identity research may be partly due to Gee's (2000) advocacy for identity to be used as an analytic tool in educational research. Thomas (2005) and Morgan (2011) bridge this emphasis on teacher professional identity, as an analytic tool, with curriculum reform and innovation. This idea that government policy impacts, and potentially impinges, on teacher professional identity is not a new one (see Lasky 2005). However, the insights offered by the work of both Thomas (2005) and Morgan (2011) describe how identity and Critical Discourse Analysis (CDA) can be utilised as tools to examine educational policy reform policy documents. Therefore, it is our aim to build on these authors' work to examine the (re)construction of mathematics teachers' identities in a pivotal educational policy reform document for post-primary mathematics education in the Republic of Ireland.

LITERATURE REVIEW

Teacher professional identity can be envisaged as a dynamic construct shaped by, and shaping, the structural and cultural features of society, school and classroom. Seen in this way, teacher professional identity is viewed as a discursive construct (Gee 2000) that can be expressed through stories (Sfard and Prusak 2005). Centralised government interventions, discursively produced in policy documents, are greatly changing the professional environment of teachers. These curriculum reforms, and their accompanying policy documents, are having an impact on the professional identities of teachers which can result in teachers leaving the profession (Morgan 2011). Day et al. (2002) share this perspective noting that teacher retention issues arise when reform fails to address essential matters involving teacher professional identity. Hence, it is important to examine pivotal policy reform documents as they circulate the dominant discourse within a particular context giving them the capability to construct - that is to afford and/or constrain - teacher professional identities.

Therefore, in a similar manner to both Thomas (2005) and Morgan (2006), who limited their focus to one key document, this paper will concentrate on the *Review of Mathematics in Post-Primary Education: a discussion paper* (NCCA 2005). This was a significant document that paved the way for post-primary mathematics curriculum reform in the Republic of Ireland. Building on the work of Thomas (2005) and Morgan (2011), this paper will undertake a discourse analytic approach to this documentation employing CDA. Moreover, we draw on Sfard and Prusak's (2005) notion of 'Telling Identities' as an operationalisation of identity as an analytical tool. This narrative take on identity equates teachers' actual identity with stories about the actual state of affairs and teachers' designated identity with "narratives presenting the state of affairs, for one reason or another, is *expected* to be the case, if not now then in the future" (Sfard and Prusak 2005, p. 18, emphasis in original). Sfard and Prusak (2005) remark that these identities are produced by the diffusion of circulating discourses, with some narrators, known as 'significant narrators', having a greater influence than others owing to their position of power and authority. Thomas (2005) demonstrates that the discursively produced educational policy documents have the capacity to privilege a particular discourse over others. To investigate this, they recommend and provide an exemplar of Chouliaraki and Fairclough's (1999) framework for CDA. In the same manner as Thomas (2005), we applied this framework for CDA to the *Review of Mathematics in Post-Primary Education: a discussion paper* to address the following research questions:

To what extent, if any, do the policy documents of Project Maths, a reformed post-primary mathematics curriculum in the Republic of Ireland, act as a significant narrator of the designated identities of post primary mathematics teachers in Ireland?

In what ways might the implementation of Project Maths have instigated change in the actual identities and designated identities of Irish post primary education mathematics teachers?

EMERGING FINDINGS

The emerging findings indicate that privileged discourses circulated in the document, *Review of Mathematics in Post-Primary Education: a discussion paper*, may serve to 'oughter' the designated identities of teachers. The preliminary analysis demonstrates that the designated identity of post-primary mathematics teachers in the Republic of Ireland is counterpointed against their perceived actual identity. This dichotomy of post-primary mathematics teachers' identities is being portrayed through the emerging themes of resources, pedagogy and assessment.

Sfard and Prusak (2005) discuss the notion of individualisation and collective identity. The participationist perspective on identity perceives the reciprocal nature of one's identity as being constructed by, and of, the collective. This perspective is shared by Wenger (1998) on his work on communities of practice and is well cited in mathematics teacher identity literature (Darragh 2016). In the documents we are currently analysing, the collective identity of teachers is constructed with the use of the terms "uniformity" (NCCA 2005, p.17) and the repeated use of "tends to" (NCCA 2005, p.17 and p.21). Elsewhere in the document, statements such as "suffered from a 'tell and drill' or 'busywork' approach (bereft of meaning)" (NCCA 2005, p.18) paints a particular picture of the actual state of affairs. Sfard (2006) explains that their focus on identity centres on the translation of stories of action into statements about states and properties of the actors. Analysing the policy document in this context promotes the notion that the collective actions of the group translate to the actual identity of the group members, in this case, post-primary mathematics teachers.

This policy document frequently uses the phrase, "rather than" (NCCA 2005, p.4, p.5, p.11, p.12 (twice), p.14, p.16, p.17, p.18, p.21 (three times), p.22, p.23, p.26 (twice)) setting the scene for a preferred discourse. Thus by providing this contrast, the dichotomy of teacher identities, actual and designated, is narrated by the policy document.

Zembylas (2006) articulates that the poststructuralist perspective highlights the relationship between emotion and identity. The NCCA (2005, p.20) state:

> There is a need for teachers to recognise the emotional dimension to learning… The sense of failure (and, possibly, of frustration) that some students feel at an early stage in relation to mathematics must be acknowledged and addressed if these students are to engage successfully with later learning in the subject.

This suggests the emotional aspects of the teacher are being challenged. Thomas (2005) notes that as part of Chouliaraki and Fairclough's (1999) framework, there is a focus on what 'ought' to be. In our opinion, there is a relationship between this 'ought' to be, and, Sfard and Prusak's (2005, p.18) definition of designated identity that can be recognised by words such as "should, ought, have to, must". If this is the case, then the statements in the policy documents referring to the teacher's emotional capacity have the potential to 'oughter' their designated identity.

CONCLUSION

The emerging findings indicate that the discussion paper is a narrative of post-primary mathematics education in the Republic of Ireland. This narrative has a plot to (re)construct the designated identity, the stories expected in the future, of mathematics teachers. The current state of affairs is portrayed in the paper as a foil to highlight a particular story for the future. This expected story for the future is the designated identity of mathematics teachers narrated by a significant narrator, the policy document, *Review of Mathematics in Post-Primary Education: a discussion paper*.

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Student teachers' identity perceptions in the beginning of professional practice: pre-service versus in-service

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Aiming to understand how student teachers develop their professional identity perceptions throughout their practice, we developed a research project using the qualitative methodology of case study. In this paper we focus our attention on the development of two Portuguese final student teachers (one pre-service and one in-service) throughout their school placements. Based on the preliminary analysis of the student teachers' written narratives, and on the preliminary analysis of the fieldnotes, which resulted from the observations of their performances during the first four lessons they taught in the beginning of their final school placements, we have compared their identity perceptions. This shows that there are significant differences between pre-service and in-service student teachers.

INTRODUCTION

"The process of becoming a teacher is linked to the acquisition of an identity"

Danielwicz (2001, cited by Schultz and Ravitch, 2013)

Knowing that the quality of education depends on the quality of teaching (Hollins, 2011), which in turn is related to the development of a professional identity (Schultz & Ravitch, 2013; Forbes & Davis, 2012; Lopes & Pereira, 2012; Hollins, 2011), we decided to study initial teacher education (ITE) programmes and how they can contribute to the development of the professional identity perceptions of its student teachers.

The Overall Research Study

This paper is part of an ongoing PhD study funded by *Fundação para a Ciência e Tecnologia* (SFRH/BD/111488/2015). Having the higher education area at heart, our goal with this research is to understand how ITE of science teachers is done in two European higher education institutions (a Portuguese institution and an Irish institution). We intend to comprehend in what way the ITE curricula (that confer qualification for secondary science teaching) of these two institutions embody the European guidelines, and how the introduction to professional practice (school placements) influences the professional identity perceptions of student teachers.

About this paper

We are currently following, in Portugal, the development of four student teachers throughout their final year. In this paper, we focus our attention on the identity perceptions of two of these Portuguese student teachers in the beginning of their school placements, highlighting their identity perceptions and enactments before and during their teaching practice.

DEVELOPING A PROFESSIONAL IDENTITY WHILE LEARNING TO TEACH

Learning depends on individual capability, which comprises personal commitments, will to learn how to teach and understanding of learning as a continuous process (Lasky, 2005). It also entails individual beliefs, identities, values, content and pedagogical knowledge, previous experiences and emotions (idem). Therefore, ITE plays an important part in promoting reflection and professional development.

Educating a teacher involves the development of a professional identity. Individuals build their identities in practical contexts. Hence, professional identity is enacted in concrete professional settings (Schultz & Ravitch, 2013) and depends on the relationships that are established with other educational actors.

Identity

Developing an identity entails a dynamic and permanent social process that involves the (re)interpretation of values and personal experiences (Flores & Day, 2006; Beijaard, Vermoot & Verlup, 2000). Rodgers and Scott (2008) state that identity depends on and is developed in multiple contexts from self-awareness regarding others (Sherry in Given, 2008, p. 415); it involves emotions and is constantly changing; it is an unstable construct, which encompasses the development and redevelopment of meanings from stories throughout time.

Identity is, therefore, a relational phenomenon (Rodgers & Scott, 2008). According to Timoštšuk and Ugaste (2010), each individual's personal identity has a major influence in what that individual will (or will not) learn during ITE and it will also shape the kind of teacher that same individual will be – the way he/she will teach and how he/she will respond to the constant contextual changes of teaching (Timoštšuk & Ugaste, 2010). Assuming the vigotskian perspective presented by the authors, the goal of ITE is the development of the professional identity of student teachers.

Professional Identity

The development of a professional identity is a complex, incomplete, continuous, multidimensional, relational, interactive, dynamic and changeable learning process (Lopes & Pereira, 2012; Davis, 2012; Izadinia, 2013; Pinho & Andrade, 2014), which involves building a representation of the professional self (Oliveira, 2004). Therefore, professional identity is determined by a set of internal factors, such as motivation and emotions, and external variables, for instance the context and previous experiences (Izadinia, 2013).

According to Lopes and Pereira (2012), the first professional identity is the identity of a teacher immediately after the ITE programme is completed. It is provisional and derives from the interaction between the student's psychosocial identity (which was developed through the interactions with its family, school and pears) and the curricula of the ITE programme (specifically, introduction to professional practice, that is, the school placement). This identity derives from a personal projection into the future (Lopes & Pereira, 2012), based on a set of personal and professional expectations, which arise from the contact with practical contexts (Feiman-Nemser, 2008; Alarcão & Tavares, 2010). Timoštšuk and Ugaste (2010) state that identity perceptions of student teachers are pivotal foundations to their future professional performances.

Schultz and Ravitch's (2013) study shows that student teachers enact a professional identity that is based on different starting points and contexts, according to their life courses. This study indicates that by the end of the ITE programme student teachers were no longer ambivalent regarding their professional identities with their growing sense of professionalism being clear although not linear.

TEACHING IN PORTUGAL

To contextualize those who are unfamiliar with the Portuguese context, we elaborate on what it takes to be a teacher in Portugal and the challenges new qualified teachers must face.

Teaching Qualification

Currently, in Portugal, a teaching qualification is required for those who want to teach. This means that both teachers who have not yet completed their professionalization – in-service student teachers – and individuals who have never taught before but want to become teachers – pre-service student teachers – must now have a Master's degree for teaching (Decree-Law 43/2007). All of the above are together in the same ITE programmes.

Secondary science teachers, in Portugal, must choose the following subject areas: (a) Biology and Geology; and (b) Physics and Chemistry. You can either be a Biology and Geology teacher or a Physics and Chemistry teacher (Rodrigues & Mogarro, 2015). No other combinations are allowed. You cannot be, for example, a Biology and Physics teacher. Therefore, individuals who want to teach in secondary schools must have either a Masters for Teaching the subject areas of Biology and Geology (MTBG) or a Masters for Teaching the subject areas of Physics and Chemistry (MTPC). To be able to access each of the previously mentioned Masters for Teaching, teacher candidates must have a Bachelor degree in those same subject areas.

Teaching Circumstances for New Qualified Teachers

In Portugal, nowadays, there is a surplus of teachers. Hence, new qualified teachers will most likely face unemployment. Due to that fact, teaching degrees do not have many students each year. Most of the students that do enroll in these Master's degrees are in-service teachers, both individuals that already have a teaching position at a given school, but know that in order to continue being a teacher they must have the required teaching qualification or individuals that have been tutoring for some time and want to try to get a position (even if it is just part-time) in a school. The other few students are young people who have never worked, but somehow have a passion for teaching.

METHODOLOGY

In this study we are using the qualitative methodology of case study research with a narrative approach. With the purpose of understanding how student teachers develop their professional identity perceptions throughout the contact with professional practice, we have asked student teachers, before they began their practice, to write a narrative about their perceptions on school, teachers, students and teaching. Afterwards, during their school placements, we observed most of the lessons they taught (at least eight from each teacher candidate). We have also interviewed these student teachers and their cooperating teachers (school supervisors). Furthermore, we were present in some of the meetings student teachers had with their cooperating teachers and university supervisors. Some field notes derived from these meetings as well.

In order to analyse the field notes, we developed a semi-inductive coding frame, following the qualitative content analysis method proposed by Schreier (2012). In the adopted coding frame the categories were adapted from the literature (Borich, 2011) and the subcategories were inductively built. For the purpose of this paper we only focus our approach on some dimensions of the coding frame; hence, we have chosen one subcategory from each category (see in Table 1 the subcategories highlighted in grey). Field notes were firstly coded by hand, using Excel as an auxiliary tool, in order to better make sense of their content, and then they were coded using NVivo, which helped us get a better sense of the progress of the student teachers' performances over time.

The study's credibility is ensured, among others, by the following: (a) triangulating sources and techniques; (b) asking for participants' feedback to avoid researcher bias; (c) doing the data analysis simultaneously with data collection; and (d) ensuring a detailed description and documentation of the entire process of planning, collecting and analysing the data (Yin, 2003, 2011). Ethical issues were taken under consideration; therefore, all participants volunteered for the study and gave their informed consent for the use of the acquired information. Also anonymity and confidentiality was guaranteed. Consequently, the names of the participants that appear in this paper are fictitious.

MASTERS FOR TEACHING AND STUDENT TEACHERS

Now we present a broad overview of the ITE programmes (MTBG and MTPC) under study, specifically regarding their teaching practice, and we characterize the participants. It is worth mentioning that due to the previously mentioned unemployment circumstances of newly qualified teachers, the final year of the MTBG under study has only one student and the final year of the MTPC has only three students.

ITE programmes under study

From all the courses of the Masters for Teaching under study, only two of them include actual teaching practice (Rodrigues & Mogarro, 2015). These courses are called *Introduction to Professional Practice* (IPP) *III* and *IV*; these are respectively in the third and fourth semesters of the ITE programme, i.e., in the final year. In IPP I and II student teachers go to the schools to get to know the environment but they do not observe nor teach any lessons.

In IPP III and IV student teachers have classes at the university, where they are supported by their scientific and pedagogical supervisors and where they plan the lessons they are going to teach; the planned lessons are taught at a real school, under the supervision of a more experienced teacher – the cooperating teacher. It is worth mentioning that according to the institutional regulations that govern the ITE programmes under study, student teachers are only obliged to teach the following lessons in actual schools (in one of the classes of their cooperating teacher): (a) three lessons in IPP III; and (b) five lessons in IPP IV. However, they usually teach a few more if the cooperating teacher allows (Rodrigues, 2013).

Participants: Sofia and Rodrigo

For the purpose of this paper we decided to choose only one student from each ITE programme. Our choice was due to the fact that one is a pre-service student teacher and the other is an in-service student teacher; also because they both privilege student centred approaches, but use different teaching methods.

Regarding participants' characterization, Sofia, the teacher candidate from MTBG, is a pre-service student teacher. She has a Bachelor in Biology with a minor in Geology and she is in her early twenties. Rodrigo, the chosen teacher candidate from MTPC, is an in-service student teacher. He has a PhD in Physics and he is in his forties.

PRELIMINARY RESULTS

Here we present some preliminary results from the analysis of the narratives student teachers wrote and the field notes that resulted from the observations of the first four lessons they taught.

Table 1: Semi-inductive coding frame used for the preliminary analysis of the field notes.

CATEGORIES	SUBCATEGORIES	CATEGORIES	SUBCATEGORIES
Learning environment	Teacher/student(s) relation	**Student engagement**	Stimulates student collaboration
	Students' behaviour		Promotes discussions
	Use of students' contributions		Promotes practical work
Classroom management	Planning	**Teaching strategies**	Gives feedback
	Manages student behaviour		Corrects assignments
Lesson clarity	Contextualizes activities		Collaborative teaching
	Explains content		Interdisciplinarity
	Relates different content		Science epistemology
	Revises content		Emphasises content
	Uses examples		Monitors student achievement
	Systematizes content		Alters usual oral discourse
	Relates CTS		Teaching resources
	Clarifies doubts		Teacher's movements
			Student's movements

Sofia

In her written narrative, Sofia says that she wanted to be a teacher because she wanted to teach someone to be. She states she "thought about being a journalist, but no teaching was involved" (S_NE_UC4), so she decided on the MTBG. Sofia admits that the ITE programme (MTBG) has influenced her ideas of what it means to be a teacher. She also confesses being doubtful and afraid of what is to come.

For Sofia to be a good teacher

> *is to be also psychologist, politician, friend and often parent or the older brother students do not have. Being a teacher means more than being able to teach, or to transmit knowledge. Being a teacher means minding the needs of each student, as an individual and in the group. Being a teacher is something that is constantly growing and evolving. Every day, a teacher educates and learns with his/her students. It is, therefore fundamental that the teacher knows how to motivate his/her students (S_NE_UC4).*

Sofia declares she wants to be like her Biology teachers, which involved their students in the class and implemented hand-on-activities (for example: laboratory experiments, role playing activities, and so on).

Regarding the selected subcategories (see Table 1) for the analysis of Sofia's lessons, we can see that Sofia makes progresses in managing student behaviour. She is able to increasingly stimulate students' collaboration during the lessons and she monitors their achievement (Figure 1). Her teaching strategies are mainly focused on content explanation using images and schematics with the active collaboration and involvement of students in its interpretation. In Figure 1 we can see that there is an increase, from the first to the forth lesson, on the use of the different strategies, which shows the development of Sofia's self-awareness.

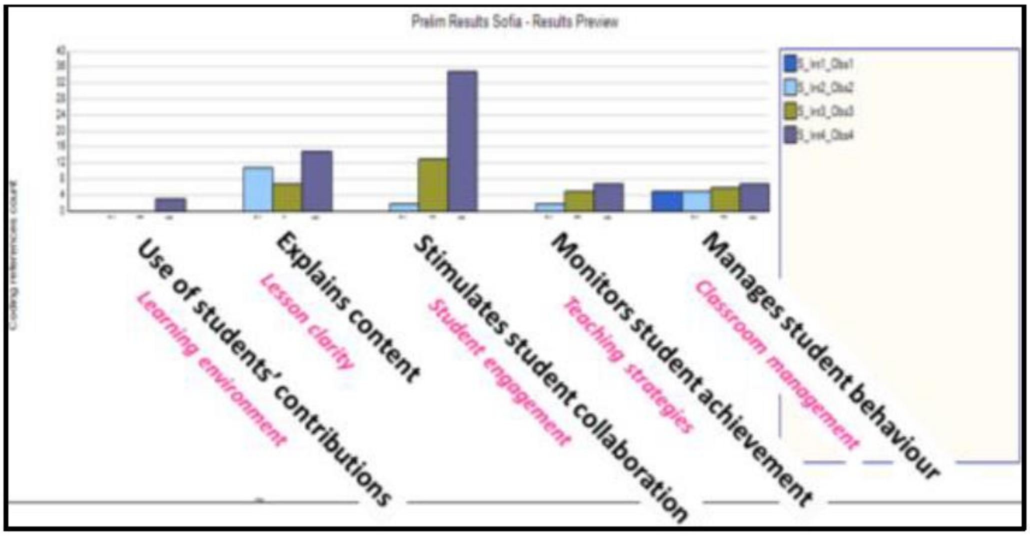

Figure 1: Preliminary analysis, using NVivo, of the fieldnotes of the first four lessons Sofia has taught.

Crossing the analysis of the field notes with the written narratives, we can conclude that Sofia uses language that is close to the one students' use, which is consistent with her idea of a teacher as a friend and a brother. She is not afraid of admitting she does not know some things, which shows that she grows and evolves with her students. She also tries to involve students in the learning process by motivating them.

Rodrigo

In his written narrative, Rodrigo says that choosing to teach was a chance based on a decision to get a job. He confesses "it was a difficult but unforgettable experience" (R_NE_UC2), because it was very enriching.

Rodrigo states that a good teacher

> *needs to be someone willing to learn: learn from his pears (...), his students, or anyone else he may find. He needs to be a person that is aware of his limitations, but at the same time knows that he has more content knowledge than his students and therefore can help them learn and develop their skills (R_NE_UC1).*

He clearly affirms that he is aware of the difficulties that he needs to overcome to become a good teacher and he declares the following:

I think I can only be a good teacher if I'm able to keep an open mind and if I'm open to others, which would help me be an adequate instrument to stimulate in my students the desire and the commitment to learn, and develop their skills (R_NE_UC8).

Concerning the selected subcategories (see Table 1), our analysis allowed us to see that Rodrigo monitors student achievement and behaviour, but he privileges group work as a learning strategy. Figure 2 shows some development throughout the lessons Rodrigo has taught, but his progression is not sequential, with him having better performances on his first and third lessons (the latter being the one where he has shown the best performances yet) than on his second and fourth lessons.

Intertwining the analysis of the field notes with Rodrigo's written narrative, we can conclude that he focuses his lessons on pear work and student reasoning, which enables the development of the students' skills. By doing so he involves students in learning. Rodrigo also privileges laboratory work, which stimulates and involves students' commitment in learning.

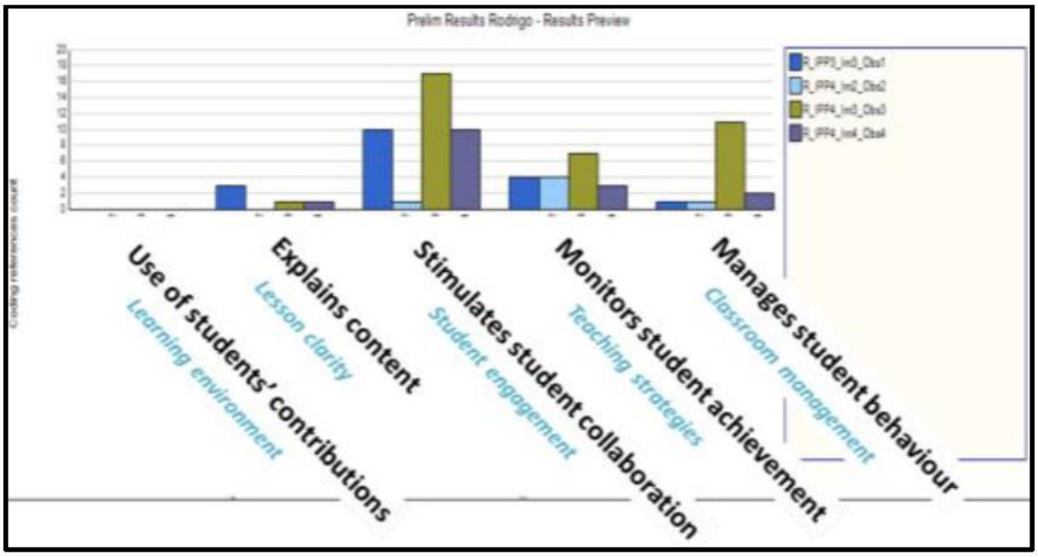

Figure 2: Preliminary analysis, using NVivo, of the fieldnotes of the first four lessons Rodrigo has taught.

Comparing Sofia's and Rodrigo's performances and perceptions

From the data presented in the previous sections and from our fieldnotes of the formal and informal meetings Sofia and Rodrigo had with their cooperating teachers and supervisors, we can see that, on the one hand, Sofia is not completely aware of her performances; on the other hand, Rodrigo is noticeably conscious of his performances. Both of them are able to reflect on critics made by their respective cooperating teachers and university supervisors, but only Rodrigo clearly points out improvements that must be made before being told by his supervisors. Nevertheless, Sofia tries to and is successful in correcting the performances that were criticized by her cooperating teacher and university supervisor, whereas Rodrigo, although being clearly aware of his performances and of what needs to be improved, is not always able to change his performances in the following lessons.

CONCLUSIONS

Based on these preliminary results, we conclude that there are noteworthy differences between these student teachers. Sofia, the pre-service student teacher, lacks awareness of her performances, but is able to reflect on her practices by mobilizing scientific and pedagogical knowledge, altering the way she plays her teacher part, showing a clear and linear evolution from her second lesson onward. In Sofia's case, according to the vigotskian perspective of identity presented by Timoštšuk and Ugaste (2010), the ITE programme (MTBG) seems to be clearly fulfilling its mission, contributing to the development of the professional identity of this teacher candidate.

Rodrigo, the in-service student teacher, despite being conscious of his performances, appears to have some difficulty in changing them even though he has previous professional experience. Rodrigo's development in his first four lessons is nonlinear, which is consistent with the conclusions of the study conducted by Schultz and Ravitich (2013).

Why the previously mentioned differences between pre-service and in-service student teachers occur eludes our understanding and the overall purpose of this study. These differences could be the foundation for another research study. Nonetheless, both Sofia and Rodrigo are developing their first professional identities, as suggested by Lopes and Pereira (2012).

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To Develop, Implement and Evaluate a Transition Year Module Based on the Principles of the Teaching Enquiry with Mysteries Incorporated Project

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The research project focused on developing teaching and learning resources for Transition Year Science in accordance with the Teaching Enquiry with Mysteries Incorporated (TEMI) guidelines. The TEMI project aimed to work with schools across Europe to develop and implement innovative training programs. Its goal was to provide teachers with new resources and methods to teach STEM subjects (Science, Technology, Engineering and Mathematics) using mysteries and discrepant events as a starting point (Childs, 2013). This research project was focused on Transition Year (TY) science. TY is a gap year in the Irish education system between the junior and senior cycles, and as such it has no set curriculum. A TY Science module was created which contained 8 different units. The units were developed based on Bybee's 5E model of Inquiry which included the stages: Engage, Explore, Explain, Elaborate and Evaluate. The 'Engagement' stage focused on the use of discrepant events or mysteries, following the TEMI approach.

INTRODUCTION

The aim of this research project was to develop science teaching materials specifically for the Irish Transition Year (TY) as part of a Final Year research project (FYRP) done by a Pre-Service Science Teacher (PSST). The module follows the same lesson structure as the previous TY science modules created at the University of Limerick (UL) (Childs *et al.*, 2013). However, the lessons were designed to use the Teaching Enquiry with Mysteries Incorporated (TEMI) approach, which uses mysteries to engage students. TEMI is an EU-funded project running from 2013-2016 (www.teachingmysteries.eu). The TEMI-based TY module offers schools a self-contained module that covers a range of topics from Biology, Physics and Chemistry, and includes a Students' Workbook and Teacher's Guide. The module shows teachers how to carry out inquiry effectively by *"bringing to the fore the sense of mystery, exploration and discovery that is at the core of all scientific practice"* (TEMI, 2013). The TEMI method of teaching can be linked in to many topics of science and can be extended to both Junior Cycle and Senior Cycle science courses.

The main research questions in this project were:

1. Does the TEMI approach promote students' motivation to explore science concepts further?
2. Does the TY TEMI module encourage students' intentions to pursue a Leaving Certificate science subject?

LITERATURE

The TEMI innovations:

The overall aim of the TEMI project is to develop teachers' inquiry-based teaching skills in science and mathematics (TEMI, 2013). The goal is to provide teachers with the support needed to achieve this, which includes the production of exciting new resources (TEMI, 2013). The UL TEMI team are the core of the Irish project, however, "they see themselves as facilitators of pre-service and in-service science teachers' professional development" (Broggy et al, 2014). What makes TEMI unique is how it has conceptualised IBSE in terms of 4 innovations. These are:

1. The use of mysteries to engage students.
2. The use of the 5E model to structure inquiry.
3. The use of showmanship to sustain student engagement.
4. The use of the Gradual Release of Responsibility (GRR) model to develop students' inquiry skills.

The first innovation involves using 'Mysteries' to create curiosity and engage students. According to Bybee and Landes (1990), "the objective in a constructivist program is often to challenge students' current conceptions by providing data that conflict with students' current thinking or experiences that provide an alternate way of thinking about objects and phenomena" (p. 96). If used correctly, such 'discrepant events' (Liem, 1990) can promote students' motivation, causing students to be active participants in their own learning and to create new knowledge for themselves (Longfield, 2009). The TEMI CPD workshops showed teachers how to use mysteries to start off an inquiry (innovation 1) and then use the 5E model of inquiry to structure the lesson (innovation 2). The 5E cycle is a model to help teachers and students develop their understanding of scientific concepts through a process of enquiry (TEMI, 2013) and it includes the stages: engage, explore, explain, elaborate, and evaluate (Bybee & Landes, 1990). González-Espada, Birriel and Birriel (2010) state that careful planning and preparation is required in order for inquiry to be successful. However, they go on to state that the "pedagogical rewards are worth it" (p.510). After a mystery or discrepant event, the follow-up is equally important. It is not enough to show the students a mystery or discrepant event and just leave it at that; they need to ask questions and explore possible explanations in order for them to come up with the answers. It is vital that the students learn from the process and engage with the material and not just stop at the initial mystery. The third TEMI innovation is the use 'Showmanship' to help to introduce the mystery and sustain students' efforts in inquiry-based learning (Sherborne, 2014). TEMI CPD workshops use performers like magicians or actors or science presenters to support teachers to transform science lessons using a range of showmanship techniques (TEMI, 2013). The fourth and final innovation is the Gradual Release of Responsibility (GRR) model, used to embed and develop inquiry: this involves three stages encapsulated in the statement - 'I do it, We do it, You do it'. In principle it is a transition from the teacher as the master, through the student as apprentice, to the student as the problem solver (TEMI, 2013). Gradually increasing the challenge to students aids in the development of their problem-solving and reasoning skills (TEMI, 2013).

The Irish Transition Year

While TEMI is the guiding focus of the project, the target group of the module is a TY science group. The Transition Year Programme (TYP) is a one year optional programme for Irish students in their 4th year of second level education. It is designed as "a bridge to enable students to make the transition from Junior to Senior Cycle.” (Department of Education, 1993, p. 3). The TYP is a curriculum-free “gap” year, unique to the Irish secondary education system, and is aimed at promoting students’ social and personal development (Clerkin, 2012). There is no prescribed curriculum for the TYP, and according to previous research there is a shortage of suitable teaching materials in science for use within this year, and “teachers must decide their own programme and produce their own resources” (Childs, 2007, p.14). The curriculum content is decided by the individual school and thus differs for each school. It offers students a year that is not solely focused on examinations, unlike the rest of their post-primary education (Jeffers, 2011). Clerkin (2012) offers the view that “Transition Year is intended to be an opportunity for students to learn about the world outside academia” (p.3). However, science is not considered a core subject in the TYP; it is a subject that can be ‘sampled’ by students to allow them to *“make informed choices when making their subject choices”* (PDST, nd). The fact that doing the TYP defers students’ Leaving Certificate choice by one year provides teachers with an opportunity to ‘sell’ the sciences through suitable TY experience (Childs, 2007). Thus, TY schools either offer a taster course in one or more of the senior cycle Sciences or they offer a general science course (Hayes, Childs, & O’Dwyer 2013).

METHODOLOGY

With the research questions in mind, it was decided to use both qualitative and quantitative research methods to evaluate the materials. It was essential to gather responses from both students and teachers during School Placement as these were the target groups. School Placement is a 10 week teaching block for PSSTs. The brief time-span of the research project meant an emphasis was placed on time-efficient research methods.

This action research project had three phases. Phase 1 involved the development of the Transition Year module and the questionnaires. The Transition Year module was developed in accordance with previously developed modules (Childs *et al.*, 2013). Eight science topics were chosen, covering biology, chemistry and physics, and each unit consisted of a single lesson, a double lesson and an optional single lesson (see Table 1 for the list of units and topics.) Figure 1 is an outline of how the module is ran**.**

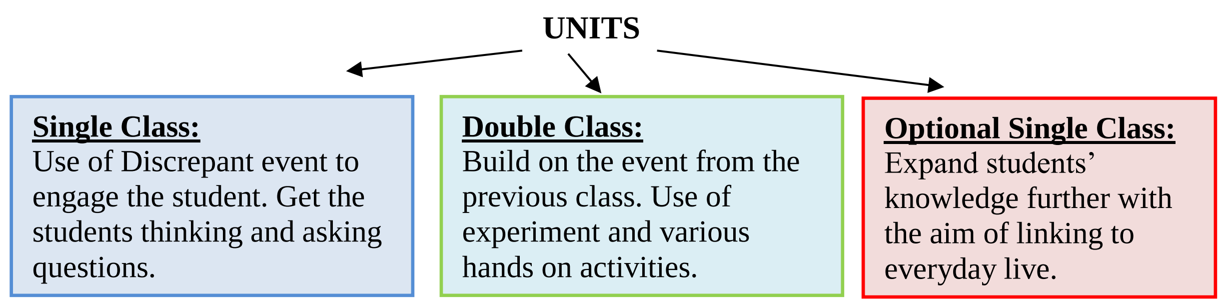

Figure 1: Outline of TY unit structure

Phase 2 was the implementation of this TY module by both the researcher (LR) and other PSSTs from the University of Limerick. Pre-and post-questionnaires were given to the students and the other PSSTs were asked to complete a teacher’s diary, as well as completing a final questionnaire.

Table 1: List of TEMI topics in the Homemade Heroes TY module

Topic Title (scientific topic covered)
1 What floats your boat? (Density)
2 Bubble trouble (Surface Tension)
3 Move your body (Centre of Gravity)
4 Food for thought (Enzyme denaturation)
5 The disappearing act. (Absorbent Polymers)
6 Now you see it! Now you don't! (Acids, bases and Indicators – hidden messages)
7 Ice, Ice baby (Depression of fpt. of Ice)
8 What's going on? (Alcohol Fermentation)

Phase 3 was the analysis and evaluation of the data collected. The research methods included pre- and post-questionnaires designed for the TY students taking the module. The participating PSSTs, including the researcher, also kept a diary of the lessons they trialled, along with completing a teacher questionnaire at the end of the implementation. Figure 2 which follows outlines the methods used for data collection. In total 7 teachers took part, one of whom was the researcher (LR), with their TY class sizes varying from 9 to 27 students, with a total of 102 students. The researcher's own student questionnaires were analysed separately and then combined with the others, to identify effects due to prior TEMI training and the researcher's bias. The school backgrounds varied between mixed, all-girls and all-boys. The collected data was analysed using the IBM SPSS Statistics (Version 22) software.

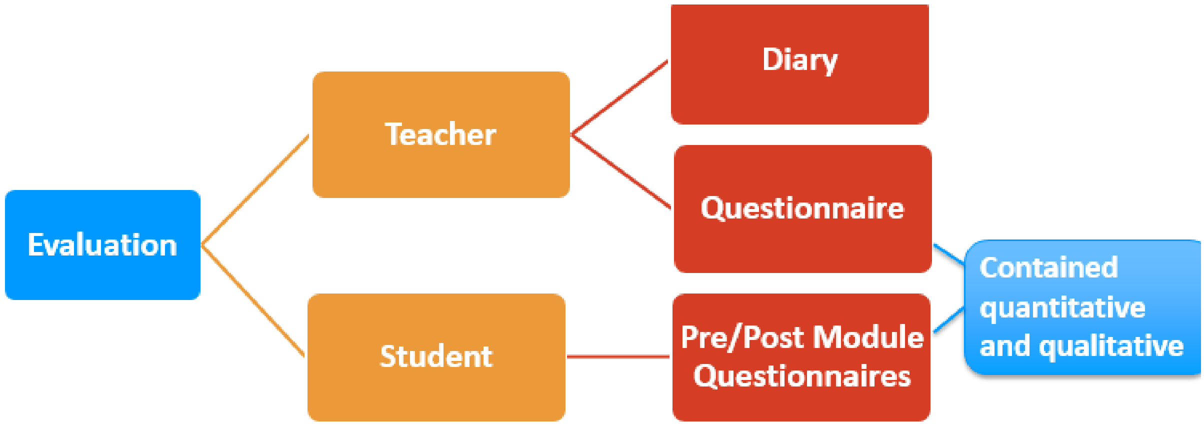

Figure 2: Methods of data collection used in the research project

RESULTS

Research question 1

The key findings of the research showed that using the TEMI approach has significant motivational effects, and students were willing and eager to explore scientific concepts further. The students were asked to state if they were encouraged to carry out further investigations on their own after seeing a discrepant or puzzling event. The results of the researcher's pre-questionnaire showed that 20% of students stated '*Yes*'; in the researcher's post-questionnaire, the students were asked the same question after doing the TY TEMI module and 64% chose '*Yes*', an increase of 44%. In the other 6 PSSTs' pre-questionnaires, 37.5% of the students voted ‘Yes’, and in the post-questionnaire 57% stated that they were encouraged to carry out their own investigations after a puzzling event, a 19.5% increase. The teacher diaries also indicated that students were motivated to investigate themselves after the initial TEMI lesson, and 83.3% of the PSSTs stated that students learn more when they are given responsibility for their own learning.

Research question 2
There was also a large increase in the number of students who intended to carry out a Leaving Certificate (LC) science subject after doing TY module, from both the PSSTs and the researcher’s data. In the researcher’s pre-questionnaire only 44% of students stated they were interested in doing a Leaving Certificate science subject, whereas after the module the figure was 68%, a 22% increase. The results from the PSSTs students’ responses were similar: in the pre-questionnaire, 44% of their students wanted to pursue one or more science subjects in Leaving Certificate, compared to 64% of students after doing the module. This was despite the short time period the researcher/PSSTs had with their class groups. This implies that students’ interest in science is increased after the experience of the TY TEMI module. All PSSTs commented on how modules similar to this one could help students’ understanding and interest in science.

DISCUSSION

TEMI had a large impact on the students’ motivation in all the student groups. The TEMI approach was seen as an opportunity to involve students in unexpected and relevant activities. The researcher had an advantage over the other PSSTs in terms of experience with TEMI, the 5E model and discrepant events, and this shows the value of such training in order to carry out IBSE effectively in the classroom. In order for the implementation of IBSE/TEMI approach, teachers need to feel confident and have training in the area (Kim et al., 2013). This emphasises the need to implement CPD programmes which will help teachers in carrying out IBSE and have a focus on using it in the classroom. The researcher created and researched many discrepant events in order to choose the ones deemed to be most effective for the students. The percentage of students who intended to take a LC science subject increased after doing the TY module. This shows that students are drawn towards science when a suitable pedagogy is used and when science is made more relevant to the students. The results, despite the limitations of the project, show that by using inquiry-based and student-active teaching strategies, science is made more appealing to the student. Approaches like TEMI, which are more focused on the student’s experience, can improve their motivation and interest in science. The limitations of this study should be noted: the sample of teachers and students is small and there was a limited time to implement the materials during the 10 week school placement.

TY is a chance to promote science to Irish students in a way they may not have experienced before (Hayes et al., 2013). The TEMI TY module is a new and stimulating way to present science topics and allow students to experience inquiry. The research suggest that the use of the discrepant event is vital in terms of creating a ‘need to know’ (Wright & Govindarajan, 1992) and motivating students to find the answer themselves, since they aren’t being told what to learn or just provided with the answers. All units in the TY module began with a discrepant event to engage the class and the aim of this was to promote students’ motivation, causing “students to be active participants in their own learning and to create new knowledge for themselves” (Longfield, 2009). The teacher had to become a facilitator, and the TEMI method combined with 5E model ensured that once the students were engaged they had to take over and find out the answer for themselves. This led to students having increased responsibility over their learning. The discrepant event or mystery is effective in motivating students because in engages the students in cognitive conflict (Gonzalez-Espada et al., 2010) and this meant that the students had to work towards the answer using their previous knowledge

This was a short-term intervention project, with a small sample, and the long-term impact of TEMI and IBSE approaches in general were not looked at. A copy of the module can be obtained by sending an email to the researcher (LR).

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