16th – 17th September 2010

SMEC 2010

Inquiry-based learning:
Facilitating authentic learning experiences in science and mathematics

CASTeL
Centre for the Advancement of Science Teaching and Learning

St Patrick's College · Coláiste Phádraig

Science and Mathematics Education Conference
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SCIENCE AND MATHEMATICS EDUCATION CONFERENCE

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Thursday Morning Session, 16th September 2010

Centre for the Advancement of Science Teaching and Learning

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Science without Literacy: A Ship without a Sail?

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INTRODUCTION

Let me start with some basic facts – research shows that scientists read for 553 hours per year or 23% of total work time. When the activities of speaking and writing are included as well, the scientists in their study spent on average 58% of their total working time in communication or working in the coordination space (Tenopir & King, 2004). More importantly, scientists and engineers consider reading an essential element of their work and a primary source of creative stimulation. Thus the dominant practice in science and engineering is not 'hands-on' manipulation of the material world but rather a 'minds-on' social and cognitive engagement with ideas, evidence and argument. Reading, for instance, is an act of inquiry into meaning – an attempt to construct sense from the multiple forms of representation used in science – words, symbols, mathematics, charts, graphs and visualizations. Each individual must engage in a process of using their existing knowledge to interpret texts and generate new understandings. Hence, a vital and important role for any education in the sciences and engineering is to explore how words and symbols are used to construct scientific meaning. It is not much of a leap to conclude, as Tenopir and King did, that because "time is a scarce resource, this amount of time spent was an indicator of the value of the information gained from reading".

Nobody puts the significance of reading more eloquently than one of the leading communicators of science, Scott Montgomery (Montgomery, 2003):

> Science exists because scientists are writers are speakers. We know this, if only intuitively, from the very moment we embark upon a career in biology, physics or geology. As a shared form of knowledge, scientific understanding is inseparable from the written and spoken word. There are no boundaries, no walls between the doing of science and the communication of it; communicating is the doing of science. If data falls in the forest and no one hears it... Research that never sees the dark of print remains either hidden or virtual or nonexistent. Publication and public speaking are how scientific work gains a presence, a shared reality in the world. (p. 1)

However, "Traditionally science teachers have had little concern for text... [R]eading is not seen as an important part of science education" (Wellington & Osborne, 2001). Other research shows that the opportunities to engage in the activities of reading, writing and discussing scientific ideas form less than 5% of lesson time (Newton, Driver, & Osborne, 1999) and that group work is a rare activity (Sands, 1981). Why? Key to the notion of science education is that its aim is to offer explanations of the material world, *e.g.*, Why is the sky blue? Is the Universe infinite? Why do species evolve? Or what is an electric current? (Ogborn, Kress, Martins, & McGillicuddy, 1996). Teachers of science live with the belief that answering such questions begins, not with reading talking and writing but through manipulating the material world – basically going out there, controlling variables, sticking instruments in, and gathering data. Commonly this is not seen as a language dependent activity.

I want to argue that this is a mistake. For, like all disciplines, science and engineering are a way of knowing where whatever is known is communicated through the symbols (mostly words) in which the knowledge is codified. Reading and interpreting those texts is a fundamental practice of science. Any education in science or engineering needs, therefore, to develop students' ability to read and produce written text. And, just as it is impossible to learn a language without engaging in its oral production, learning such a technical practice requires significant opportunities to talk the language of science and engineering, to write in its standard genres, and to listen to others using such linguistic forms. As a written form, science text is challenging. It is expository rather than narrative and is often linguistically dense and reliant on multiple logical connectives. Hence the ability to read scientific text can only be developed through sustained practice and support. Fluency with scientific texts will only improve through practice at both reading scientific text (constructing and interpreting meaning); writing scientific text where language is used to express scientific ideas and thinking; and opportunities to engage in extended discussion and oral presentations about scientific ideas.

More importantly, being a critical consumer of the sciences and the products of engineering, either as a lay citizen or a practicing scientist or engineer, requires the ability to read scientific or scientifically related texts and recognize the salient science; to identify sources of uncertainty and methodological flaws; and to distinguish observations from inferences, arguments from explanations and claims from evidence. Judging the validity of knowledge claims also requires knowledge to be contextualized in its socio-historical context with new knowledge claims examined in the light of previous research and the potential biases of the researcher(s). None of this can be achieved unless taught explicitly.

THE SIMPLE VIEW OF READING

At the heart of the issue is that as teachers of science, too many of us are misled by the simple view of reading (Hoover & Gough, 1990). This perspective avers that reading comprehension is the product of word reading and comprehension skills typically requiring little more than a knowledge of vocabulary. As such it is an excellent summary of the relatively superficial comprehension skills tapped by most standardized comprehension assessments (Cutting & Scarborough, 2006). More importantly, the Simple View downplays the academic language skills that are foundational to success on the higher order task of critique, evaluation and synthesis, including learning from sometimes recalcitrant texts. These often require the ability to follow a complex argument about scientific causality and are often multi-modal using charts, graphs, symbols and mathematics to communicate meaning (Kress & Van Leeuwen, 2001; Lemke, 1998).

The simple view of reading also conceals the critical importance of content-specific literacy skills where reading is dependent on an appropriate level of background knowledge and familiarity with the standard genres of the discipline. Hence, reading must be seen as a process of inquiry which requires the critical interpretation of text in a specific context (Norris, Phillips, & Osborne, 2008) to explore the meanings presupposed, implied, and reasonably justified by the text. To undertake this process, background knowledge is essential to the process of interpretation enabling the forging of inferential links between the reader's knowledge and the text, a process that emphasizes that reading is a constructive process and not simply one of decoding the meaning of individual words. A reading of the text beneath and an attempt to answer the questions beneath illuminates this point:

QUANTUM DAMPING

We assumed that the atomic energy levels were infinitely sharp whereas we know from experiment that the observed emission and absorption lines have a finite width. There are many interactions which may broaden an atomic line, but the most fundamental one is the reaction of the radiation field on the atom. That is, when an atom decays spontaneously from an excited state radiatively, it emits a quantum of energy into the radiation field. This radiation may be reabsorbed by the atom. The reaction of the field on the atom gives the atom a linewidth and causes the original level to be shifted. This is the source of the natural linewidth and the Lamb shift.

1. According to the passage, observed emission lines are: A. infinitely sharp, B. of different widths, C. of finite width, D. the same width as absorption lines.

2. According to the passage, the most fundamental interaction that may broaden an atomic line is: A. the Lamb shift, B. the action of the atom on the radiation field, C. the emission of a quantum of energy, D. the reaction of the radiation field on the atom.

3. It can be inferred that when an atom decays it may: A. return only to a state more excited than the original one, B. not return to its original excited state, C. return to its original excited state, D. return to a state less excited than the original one.

Whilst it is possible to answer each of these questions without much difficulty, explaining what the texts is attempting to communicate is much harder – indeed many a reader may find themselves at a loss for words. Rather, the text requires a fundamentally different approach. Whilst it is important to ask what each word and sentence means, the key question is what meaning does the text convey as a whole? Or what is the text about? This requires us to make a shift to see reading text as an inquiry into meaning. And, if so, then the act of exploring possible interpretations of their meaning becomes vital to the process of constructing an understanding. Text then becomes something which must be deliberated over. What then are the specific features of texts in science that make reading and writing science something that must be explicitly taught?

THE DIFFICULTIES OF SCIENCE TEXT

Reading as a Constructive Act

The first and foremost point is that reading is a constructive act (Norris & Phillips, 2003). Understanding science requires a body of appropriate background knowledge (Hirsch, 1987) – a point made by the cartoon of Figure 1.

Unless, you know what the words 'orbit', 'planet' and 'elliptical' refer to, what Copernicus is saying here has no meaning. Even if you know the meaning of the individual words, the sentence does not mean anything until you construct a picture of a planet going round the Sun (a feature not mentioned in the sentence but which is assumed knowledge) in a shape that resembles the shape of a lemon. The mistake, however, is to think that what must be taught to the child is the meaning of each of these separate terms in isolation. Whilst that has value, what is essential is to explore with students the meaning of the combination of these words in this context.

Figure 1: Copernicus explaining his new Theory.

This is what the programme Wordsift (available at wordsift.com) developed by one of my colleagues at Stanford, Kenji Hakuta, permits students and teachers to do. What this site does is sift words looking for the most frequent and then providing a visual thesaurus. For instance, entering the sample text taken from a report in the Economist (Economist, 2010) on new research on the relationship between dinosaurs and mammal produces the screen on the right (Fig. 2).

In days gone by, paleontologists thought that the reason dinosaurs became extinct was that the big, lumbering reptiles were outcompeted by small, nippy mammals who ate their eggs and generally ran rings around them. This quasi-anthropocentric view of the inevitable rise of humanity's ancestors took a knock when a closer examination showed that dinosaurs, too, were often nimble and warm-blooded. Then it was found that the extermination was an accident, caused when an asteroid hit the Earth. Until that moment the dinosaurs had reigned supreme and mammals were just an afterthought.	

Figure 2: WordSift Screen Shot with Accompanying Text.

The text can be sifted for the scientific words, the most common to the most rare and the words that appear in Averil Coxhead's list of 570 academic word lists – specifically words that are used in academic discourse. In short, Wordsift becomes a tool for inquiring into language (Coxhead, 2000). What is more, each word clicked on is illuminated in the visual thesaurus with visualizations drawn from Google. Thus Wordsift is a tool for exploring meaning helping students to visualize its intent and construct their own understanding – in essence a practical illustration of Wittgenstein's dictum that language only has meaning in the context of its use.

The genres of science text

For students, the familiar form of writing is that of the narrative. But what of science and, more pertinently, what of science education? Here the personal is excised and pupils are encouraged to write in the passive voice. So rather than writing 'we took the Bunsen burner and heated the copper sulphate', the standard genre of science would use the wording 'the copper sulphate was heated' resulting in the excision of any sense of an actor or the personal. From a functional perspective, which sees language as a communicative tool, this is legitimate as the locus of interest is not what the person did but what was heated and what happened. Such language also enables science to sustain a sense of objectivity and bring to the fore what matters to the scientist.

However, this cold, impersonal language 'sets up a barrier between those who can speak and understand and those who cannot reducing the discourse to one of incomprehensibility. This is a feature captured by the writer Sylvia Plath in her novel The Bell Jar (Plath, 1966). What did she have to say about her initiation into the language of physics?

> 'The day I went into the physics class it was death. A short dark man with a high lisping voice, named Mr Manzi, stood in front of the class in a tight blue suit holding a little wooden ball. He put the ball on a steep grooved slide and let it run down the bottom. Then he started talking about let a equal acceleration and let t equal time and suddenly he was scribbling letters and numbers and equals signs all over the blackboard and my mind went dead.'

The point at issue is not whether this is justified or whether alternative modes of communication might be more effective, rather it is that that is how science is written. We do our students no favours in oversimplifying the language to one where the language loses the purpose it was designed to serve – effective communication of complex ideas. As Montgomery points out (Montgomery, 1996):

> '... toning down the use of technical terminology in scientific discourse invariably means the elimination of detail and subtlety. Details in science, however, are not embellishments; they are information, facts, points of logic, twists of theory, and the like, and their deletion means, without exception, loss of knowledge.' (p. 10)

For instance, one of the major features of science is its use of logical connectives – words like 'therefore', 'because', or 'as a result'. These words or phrases appear because the study of causal relations within science is of the major feature that science attempts to answer. However, such relationships are demanding requiring the student to construct a relationship between two ideas. For instance, why is the sky blue? Because white light consists of all colours. Longer wavelength light, such as red, is scattered more by the atmosphere than shorter wavelength light such as blue. *Therefore* when looking at the sky, all the red light has been scattered and does not reach your eye so the sky appears to be blue.

Remove all the connectives and ask yourself if the text would be harder or easier to read? Understanding such text can only be achieved by engaging in a process of reflective reading – reading that requires the text to be read several times, where the meaning of the individuals words are discussed or explored and then the possible meanings of the text considered as a whole. Unless the teacher of science recognizes that science texts are unfamiliar, complex and difficult and require scaffolding, how is the student of science ever to learn how to engage with such material? In case you doubt this argument, compare the lexical density (lexical terms being terms which refer to concepts) of an everyday sentence –'my *sister* is getting *married* next *weekend*' which contains 3 lexical terms to one of the sentences in the quantum damping text: 'There are many *interactions* which may *broaden* an *atomic line*, but the most fundamental one is the *reaction* of the *radiation field* on the *atom*' – a sentence which contains 6 lexical terms.

Recognizing the need for reading to be reflective, Davies and Green (1984) developed and tested a set of directed activities related to text – otherwise known as DARTS. Their insight was to recognize that there were two paths to engaging young people with text – one by asking them to reassemble or complete texts that had elements missing – restructuring DARTS. The second is by asking them to engage in the process of deconstructing text for its meaning – analysis DARTs.

Restructuring DARTS	Analysis DARTS
Sequencing	Underlining
CLOZE	Tabulating
Diagram Completion	Labelling

CLOZE procedures requiring student to discuss and insert words in key gaps in text are common and familiar. Rarely are they used effectively for discussing with students or for discussions between students. Diagram completion requires students to fill in the labels on diagrams by referring to an adjacent text. Alternatively, the activity can be simplified by providing a list of words and asking students to complete the labeling. Again, such an activity is aided by discussion and a consideration of why some alternatives are wrong. This is because knowing why the wrong answer is wrong matters as much as knowing why the right answer is right (Hynd & Alvermann, 1986). Underlining requires scanning the text for significant concepts that match specific criteria such as single underlining those bits of text which tell you about the movement of the particles and double underlining those which tell you about what happens when the substance is compressed in the text beneath.

Solids, Liquids and Gases

The particles in a solid must be held in fixed positions; otherwise solids would not retain their shapes. Moreover, the particles in a solid must be very tightly packed together. This is evident from the fact that solids are very difficult to compress. Even at very high pressures, the change in volume is very small indeed.

In most liquids, the particles are less tightly packed than in a solid. This is evident when a solid is melted as there is usually an increase in volume on the change from solid to liquid. However, since liquids are also difficult to compress, the particles must still be very close together. The main difference between solids and liquids is that liquids have no shape. They take the shape of the container and are free to move about and can be poured.

Obviously, the particles in a liquid are not fixed in any definite position. They are able to move about, rolling over each other like grains of sand.

Gases not only take up the shape of the vessel that contains them but also spread out to occupy the whole vessel. This is easily seen by using a coloured gas like bromine. Our picture of a gas is one in which the particles are free to move about and there are quite large spaces between them. Increasing the pressure on a gas brings the particles closer together. If this increase in pressure is large enough then the particles become as close together as in a liquid. The gas will then change into a liquid.

	How Particles Move	**How easy to compress**
Solid		
Liquid		
Gas		

Constructing a table such as the one suggested for this example is a way of summarizing its principle features whilst labeling is a technique of annotating each paragraph for its main point. I have chosen to illustrate how just one scheme affords ways of supporting the strategies needed to engage with expository text. There are, however, many others such as the work of Goldenberg on instructional conversations (Goldenberg, 1992); Palinscar & Brown's approach based on reciprocal teaching (Palincsar & Brown, 1984); Core Orientated Reading Instruction (Guthrie & Ozgungor, 2002); or Questioning the Author (Beck, McKeown, Sandora, Kucan, & Worthy, 1996). In short, as teachers of science we have much to learn from our colleagues working in humanities who have struggled with the issue of how we can help students to read for understanding or read to learn. Such activities are part of the basic repertoire of any teacher of language, yet they remain foreign and alien to most teachers of science.

Argumentative Text

Research conducted by Penney *et al* (2003) has shown that, depending upon the book, 90% to 99% of the statements in science textbooks examined presented science as truths; the text was either expository or narrative—there was absolutely no argumentative text; between 51% and 77% of statements provided facts or conclusions; about 2% of space was devoted to what prompted scientific research to be done; 3% to how the research was done; and less than 2% of the text was devoted to providing reasons. In a similar vein, Ford (2005) found that the vast majority of children's trade books were non-fiction accounts of factual information. Any tentativeness in the books was expressed with such subtlety that it likely would be lost on most readers, and scientific knowledge production was represented more as a procedure than as reasoning from evidence. Yet, reasoning in science requires the:

- identification of patterns in the data, such as covariation, and making inferences;
- coordination of theory with evidence and the ability to discriminate between evidence which supports , does not support or is simply indeterminate;
- capability to construct evidence-based explanatory hypotheses or models of scientific phenomena and to justify their validity; and
- ability to resolve uncertainty which requires a body of knowledge about concepts of evidence such as the role of statistical techniques, the measurement of error and the appropriate use of experimental designs such as randomized double-blind trials.

Furthermore, understanding science requires a knowledge of the variety of forms of argument which may be abductive (inferences to the best possible explanation) such as Darwin's arguments for the theory of evolution; hypothetico-deductive such as Pasteur's predictions about the outcome of the first test of his anthrax vaccine; or simply inductive generalizations archetypal represented by 'laws'. Students can only begin to understand the significance of argument in science if they are asked to read appropriate texts and construct written arguments. As well as exploring arguments such as why the following counter-arguments to the scientific explanation of day and night are all flawed:

1. The Sun moves
2. If you jumped up you would not land on the same spot
3. If the Earth was spinning, it is 25,000 miles around the equator. This would require somebody at the Equator to be moving faster than the speed of sound. Surely they would be flung off?

What is needed is an exploration of argumentative texts such as the one beneath. Here it is possible to ask students questions such as:

1. What is the hypothesis?
2. What are the arguments for the hypothesis?
3. What is the data to support their arguments?
4. What are the counter-arguments?
5. Why do they not succeed?

Dinosaurs and mammals

Velocisnack

Evidence that ancient mammals were dinosaurs' prey

IN DAYS gone by, many palaeontologists thought the reason the dinosaurs became extinct was that the big, lumbering reptiles were outcompeted by small, nippy mammals who ate their eggs and generally ran rings around them. This quasi-anthropocentric view, of the inevitable rise of humanity's ancestors, took a knock when closer examination showed that dinosaurs, too, were often nimble and warm-blooded. Then it was found that the extermination was an accident, caused when an asteroid hit the Earth. Until that moment, the dinosaurs had reigned supreme and mammals were just an afterthought.

Just how supreme is suggested by work carried out by Edward Simpson of Kutztown University in Pennsylvania and his colleagues. Dr Simpson's analysis indicates that the relationship between dinosaurs and mammals was actually that of a diner to his lunch.

His study, just published in Geology, is of two burrows fossilised in sandstone near Escalante, Utah. The rock in question is 75m-80m years old: 10m-15m years older than the cataclysm that did for the dinosaurs. One burrow is 22cm (9 inches) long, 5cm wide and includes a 15cm-wide chamber. The other has a funnel-shaped opening that tapers down to a width of 5cm and runs towards what must once have been another opening. If these burrows had been made recently, they would instantly be recognisable as the work of small mammals. And that is exactly what Dr Simpson thinks they are.

Which is interesting, but not extraordinary. Fossil teeth, and the occasional skeleton, show that small mammals were common at this time. That they should have lived in burrows is no surprise. But animals dig burrows for protection. The question is, from what was this protection sought?

The clue which Dr Simpson thinks answers this question is signs of digging near the burrows. When he and his colleagues analysed these scrapings they realised that their shape suggested they had been made by the claws of predatory, feathered dinosaurs related to a well-known species called Velociraptor. The claws of Velociraptor and its kin had hitherto been regarded as weapons to be deployed against beasts of the aggressor's own size—either other Velociraptors, in fights over territory or mates, or large items of prey. Dr Simpson's work suggests the predators were not above going after small prey, too, just as coyotes will dig for prairie dogs.

Dr Simpson and his colleagues reject alternative explanations—that the diggings might have been scrapes created by dinosaurs seeking to mark their territories, or perhaps to give themselves dust baths to help clean their feathers, as their relatives the birds do to this day. The digging, they think, is too deep for either of those explanations to make sense. It is possible that the dinosaurs' intentions were to build nests for their eggs, but the researchers argue that this is unlikely because known nests are of a consistent size that does not match that of these diggings. What is left, then, is the likelihood that the dinosaurs were digging up snacks—hard as that thought may be for those snacks' human descendants to digest. ■

What's on the menu today?

CONCLUDING THOUGHTS

My aim here has been to demonstrate that science without literacy is like a ship without a sail. Language is not some peripheral feature of science, but rather, central to the way in which ideas are built and communicated. So just as it is impossible to construct a house without a roof, it is impossible to build an understanding of science without exploring the how the multiple languages of science are used to construct meaning. That this is so has at least been recognized by the Americans where the new common standards for literacy are for literacy in the language arts, history and social studies AND science (Common Core State Standards Initiative, 2010). By age 11, American students will be expected to do such things as:

- Explain how an author uses evidence to support his or her claims in a text, identifying what evidence supports which claim(s).
- Compare and contrast information drawn from two texts on the same subject.

As Pearson *et al* argued in a recent special issue of the journal *Science* devoted to the theme of literacy in science (Pearson, Moje, & Greenleaf, 2010) – just as the learning of science can benefit from an focus on how to read and write science, so can the acquisition of literacy benefit from being embedded in scientific enquiry.

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How a first year enquiry-based approach affects student attitudes and beliefs about Physics

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As well as prior study experiences and subject content knowledge, the attitudes and beliefs about their subject that students bring to university can have a profound impact on their learning. Furthermore, institutional practices such as new learning styles and differing methods of assessment can also strongly influence how they view their chosen subject.

The Colorado Learning Attitudes about Science Survey (CLASS) is a widely-used evaluation instrument that examines changes in student attitudes and beliefs towards science. Students are asked to respond to a series of 42 statements and rate them on a 5-point Likert scale. The student survey answers are then compared to those of physics academics in order to give an overall percentage of "expert-like" thinking.

This talk will discuss the impact of a year of instruction through enquiry-based learning on student attitudes towards physics study. Data has been collected over two academic years, from 2008-2010. Around 500 undergraduate students completed the CLASS survey in their first years of study at the University of Edinburgh, both pre and post instruction. The first year courses have a history of using enquiry-based learning to enhance student engagement and understanding. The effect on student attitudes will be discussed, with specific attention to the differences between physics majors and non-majors and between genders. In addition the survey was completed by pupils studying physics in their final year of school, both those intending to study physics at university and those not. The implications of the changing student attitudes will be discussed, with thoughts towards selecting physics undergraduates and course design for teaching non-majors.

A Problem Based Approach to Sound Propagation in Different Materials

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In this paper we present a problem-based approach to the study of sound propagation devoted to pre-service physics teacher education at University of Palermo, Italy. Small groups of trainee teachers are posed with real life situations and must organize themselves, define objectives, conduct researches, analyze results, and present conclusions. In particular, the problem of wave propagation in different materials is discussed, by starting from the real life situation of soundproofing a house. Examples of experiments performed by the trainee teachers with Real Time Laboratory (RTL) equipment and of interpretative models built and tested by using computer simulation environments are reported, together with considerations on their pedagogical efficacy in shifting pre-service teachers' attention from the "Concept to Context" educational approach to the "Context to Concept" one.

INTRODUCTION

It is well acknowledged that a learning environments' effectiveness is proportional to its ability to stimulate students' interests and deal with real life situations". As a consequence, recommendations on school curricula and instruction are today more and more oriented on integrated, community-based tasks and activities for learners arising from real life problems (Rocard *et al*, 2007; Linn *et al*, 2004).

Actually, many curricula try to face the concrete complexity of real objects and situations (context) giving them meaning by reorganizing disciplinary contents (concepts, phenomenological facts, etc.). However, very often, concepts relevant for the understanding of scientific facts are introduced by following a traditional didactical approach, without any benefit for the understanding of the physics implicit in real life phenomena. On the contrary, physics education research has shown that students' active exploration and manipulation is effective in helping them to gradually make such physics explicit and formalized in a simplified but, at the same time, rigorous way.

The key point for teachers is to be able to propose different arguments as problematic situations, questions to be solved, with the aim to guide students towards contents through a pathway of inquiry related to the chosen context. Teachers are supposed to act as tutors rather than as information providers: they have to pose problems, questions and general problematic situations, taking advantage of all the circumstances (also accidental and not expected) to introduce relevant contents and aid pupils' investigations. This means that teachers must hold disciplinary as well as pedagogical competences that allow them to face unforeseen problems and questions.

In the following, we present the guide lines of a Workshop (W) for pre-service physics teacher education, designed and experimented at University of Palermo, aimed at developing a conceptual understanding of the disciplinary concepts appropriate for teaching (Pedagogical Content Knowledge (PCK) (Shulman, 1986)) as well as pedagogical knowledge adequate to guide Trainee Teachers (TTs) toward a tutoring role. The W approach takes into account the characteristics of the Italian organization for Science Teacher Education, which can be defined as a "sequential" organization. This means that the acquisition of the disciplinary knowledge is intended as a pre-requisite to education for teaching. Pre-service education is intended as a Postgraduate Program that follows a degree. As a consequence, our hypothesis about PCK construction involved that TTs had a basic knowledge of the physics subject matter.

THE STRUCTURE OF THE WORKSHOP

The W has been organized in different phases, each focused on a different aspect of the disciplinary as well as of the pedagogical education of TTs. It was decided to develop some relevant concepts in the area of acoustic phenomena. Its structure has been experimented for two successive academic years with two groups of TTs attending the University Program for physics teaching qualification. They had graduated in Mathematics (≅ 80%) or Physics, so they had attended at least a calculus based course in introductory physics (including the topic of mechanical wave propagation).

Phase I: Selection of an appropriate context

The context selection has been the result of a classroom discussion involving the analysis of situations concerning real life phenomena that, for some reason, have captured TTs' attention and, at the same time, could be considered particularly effective in activating a teaching learning environment (Aiello and Sperandeo-Mineo, 2000; Fazio et al., 2008). From this point of view the choice was addressed towards phenomena that have a relevant physics content and are useful to support the evolution of TTs' future pupils from a common sense knowledge to more structured and formalised models, up to abstract concepts.

After some informal discussions, TTs' attention focused on the following problematic situations related to sound propagation through different media:

1. to develop a project to soundproofing a house;
2. to provide explanations about the well known situations, from classical western movies, in which red Indians rested their ear to the ground (railway) to better hear the arrival of bison (trains);
3. to provide explanations about some familiar devices whose physical mechanism of functioning is sometime obscure:
   - ultrasound devices (sonar), making ships able to detect underwater obstacles or motion sensors tracking the motion of objects;
   - ultrasound apparatuses used in medical echo-graphic scans.

Each of the defined contexts has been elaborated by building up a concept map outlining the physics concepts involved as well as issues, features or events associated with the context. These are intended as *key concepts* (or facts) that are arranged in *thematic investigations* that are developed through *key ideas* coming from syllabus (or specific objectives defined for the secondary school level). We here give an example (see Fig. 1) of one of the maps elaborated for the analysis of the first context and report some details about the development of one of the thematic investigations (sound speed in different media) through which the inquiry has been structured. In this sense, our approach develops a paradigmatic turn in physics education by shifting pre-service teachers' attention from a "Concept to Context" approach to a "Context to Concept" one (Whitelegg and Parry, 1999).

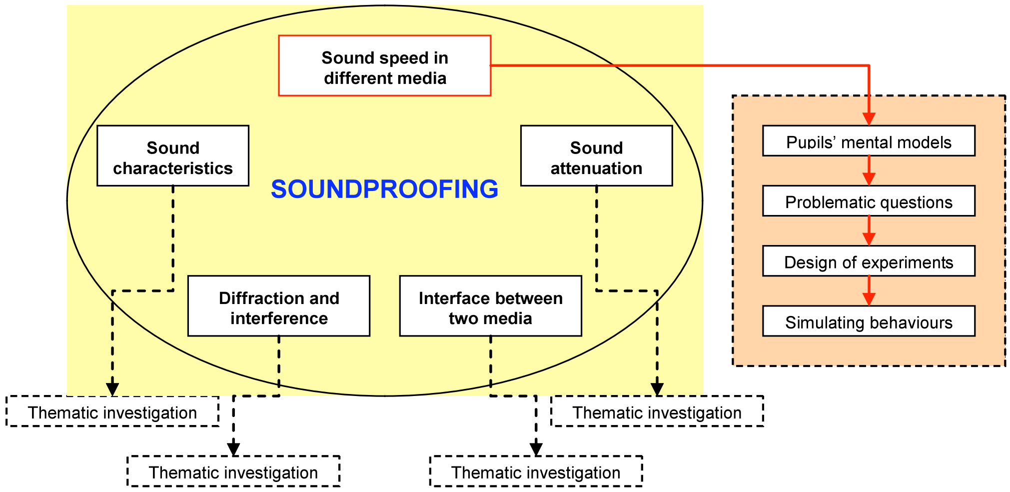

Figure 1: Map of the soundproofing context and detail of the thematic investigation about sound speed in different media.

Phase II: Pupils' common knowledge about the context

After the choice of the context, different groups (max 5 people) of TTs started to work at a particular thematic investigation that begins by analyzing the common sense knowledge about the selected key concept. The main objective was in making TTs aware of some common conceptions, held by high school pupils, concerning the functioning of some phenomena. TTs analyzed some questionnaires and interviews, results of researches conducted in different countries with pupils of different age, concerning the topic they were interested in. They were supposed to analyze the explanations supplied by pupils (reported in literature and/or in the answer sheets of the questionnaires) in order to draw pupils' common conceptions, ideas and reasoning (mental models). In the following we give an example of the kind of analysis performed by TTs on the following question:

> A 3 meters long metallic rod, fixed at a lab desk by means of vices, is hit with a small hammer. The produced sound pulse is detected by two microphones, A and B, placed as in Fig.2. Will both microphones detect the pulse at the same time or not? Explain your prediction.

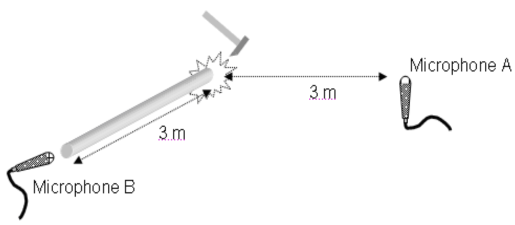

Figure 2: Experimental setting designed to compare the speed of sound in air and in a metallic rod.

From the analysis of pupils' answer sheets, the mental models reported in Table 1 have been identified. TTs have been consequently involved in the organization of an investigation aimed at describing and explaining the role of different media (air and metal) in determining the speed of sound.

Table 1: Pupils mental models about sound pulse propagation in different media.

No Propagation	▪ *The pulse reaches both microphones at the same instant because sound propagates only through air.* ▪ *As the distance is the same, sound reaches the two microphones at the same instant.* ▪ *The pulse reaches microphone B first. The rod vibrates as a whole. Microphone B is closer to the rod's end.*
Passive Medium	▪ *The pulse reaches microphone A first. The metal rod is much denser than air and, then, it offers a greater physical obstruction.*
Closer particles means faster propagation	▪ *The pulse reaches microphone B first because particle in metals are closer. Then, sound is better propagated.* ▪ *The pulse reaches microphone B first. In fact it is better transferred from a particle to another one if they are closer each other.*
Elastic Properties	▪ *The pulse reaches microphone B first due to higher elasticity of metal rod with respect to air.* ▪ *The pulse reaches microphone B first because the metal is more rigid than air and sound is better propagated.*

Phase III: The inquiry-based experimental approach

To compare the speed of a sound pulse travelling in air and in solid, TTs performed the experiment suggested by the setting in Fig. 2. Each group was provided with: a PC with a RTL interface connected and relative data logger software; 2 sound sensors (microphones); a 3 meters long metallic (aluminium) rod; some vices and a small hammer (see Fig. 3).

Performing the experiment and using the data logger software utility, different groups of TTs obtained graphs of detected signals vs. time of the type reported in Fig. 4. From the analysis of these graphs it was evident that microphone B had detected a signal well before microphone A. So TTs could conclude that speed of sound in the metallic rod has to be higher than in air.

This experiment is very effective to verify the qualitative difference in speed of sound travelling in air and in metallic rod. Anyway, it is unable to provide a quantitative estimation of these speeds, because of the impossibility to trigger the instant in which the sound is produced with the starting of data collection by the RTL system. TTs were able to obtain quantitative estimations by slightly modifying the experimental setting (see "Move'in Science" for details).

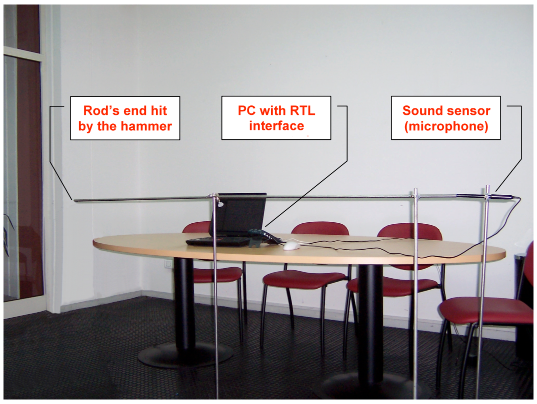

Figure 3: A typical RTL system configuration for sound speed measurements.

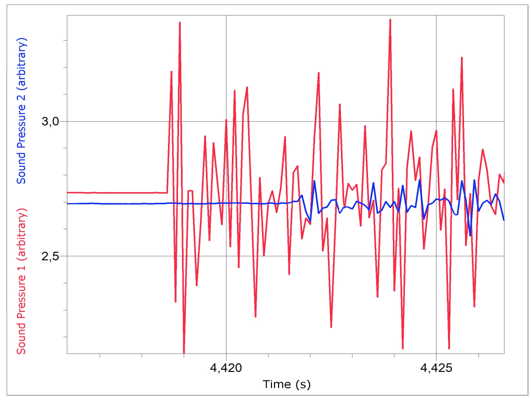

Figure 4: Graph of the signals detected by the microphones A and B vs. time.

Phase IV: The inquiry-based simulative approach

Experimental results gave qualitative and/or quantitative description of the phenomena. The next question to answer was why this happens as it does, that means to build a model able to explain the experimental evidence.

TTs were aware that, to understand how medium characteristics affect sound speed, its inertial and elastic distributed properties had to be taken into account. It was less clear what the actual role of these properties should have been. A meso-scopic model of a medium, thought as a linear chain of small spheres (inertial properties) interacting by means of springs (elastic properties), was implemented using the "Interactive Physics" simulation environment (see Fig. 5). The chain properties (mass value m and spring elastic constant K) are related to the medium ones (density ρ and Young modulus Y for metals or bulk modulus B for fluids). Mass value m and mean separation distance d determine medium density while spring stiffness K per unity length tell us how stiff a medium is. For solid materials the well known relations $K = Yd$ and $m = \rho d^3$ are valid (Ingard and Kraushar, 1964; Kittel, 1976), where d is the inter-atomic distance. The chain parameters reported in Fig. 5 refers to the case of aluminium and can be easily derived from the accepted values of ρ and Y (Fazio et al., 2006).

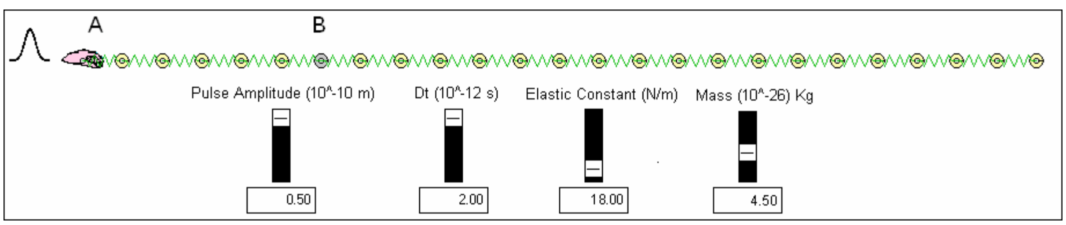

Figure 5: Interactive Physics simulation of an aluminium rod schematized as a mass-spring linear chain. The separation distance between masses is $d = 2.5 \cdot 10^{-10}$ m.

In the simulation, a pulse is applied to particle A and the longitudinal displacement of particle B is analyzed. From the evaluation of the delay time between the motion of particle B with respect to A (see Fig. 6) the pulse propagation speed in the chain can be calculated. In the case of aluminium TTs found sound speed values in accordance with their previous experimental measurement and accepted values.

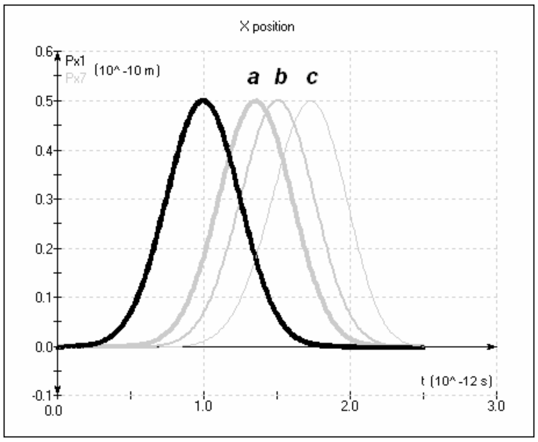

Figure 6: Displacement of particle A (black line) and of particle B (grey lines) vs. time for three different values of the chain particle mass and elastic constant. *a*: (K = 18 N/m - m = $4.5 \cdot 10^{-26}$ Kg); *b*: (K = 18 N/m - m = $9.0 \cdot 10^{-26}$ Kg); *c*: (K = 9 N/m - m = $9.0 \cdot 10^{-26}$ Kg).

Through the simulation TTs could study the pulse speed as a function of the chain properties, making and testing hypotheses and providing explanation about the different behaviour of media with respect to the speed of sound propagating in them. Figure 6 evidences a lower pulse speed in cases *b* and *c* with respect to *a*. To better understand how pulse speed depends on chain properties (and so on matter properties) TTs systematically investigated simulation outcomes in relation to the different adjustable parameters. Figure 7 shows that the squared pulse speed is proportional to the elastic constant and to the reciprocal of the mass, according to the relation $v \propto \sqrt{K/m}$.

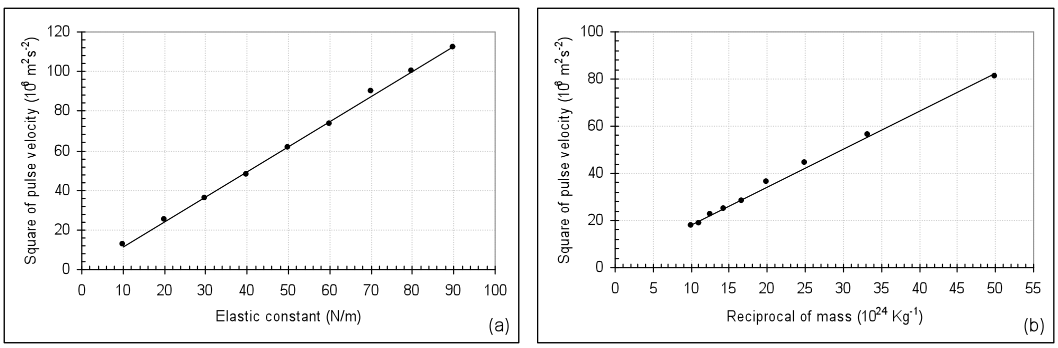

Figure 7: Square of the pulse speed vs. (a): chain spring elastic constant; (b): the reciprocal of the chain particle mass. Best fitting lines are also reported.

Phase V: Preparation of Learning Units to experiment in secondary school classes

In the last phase TTs were supposed to prepare a Learning Unit (LU) to present in secondary school classes in which they were performing their apprenticeship activities, by taking into account the specific school situations. Since the W pedagogical material was organised in an open structure to allow TTs to introduce change in accordance with their specific situation, many TTs were able to modify the proposed environments by maintaining the core of the rationale, objectives and methods of our design.

CONCLUSION

Our research faced many aspects involved in the design and experimentation of a teaching learning environment focusing on an Inquiry-Based approach to physics education. Details of the evaluation procedure can be found in “Move’in Science” where different aspects of our work are described.

Our approach allowed TTs to experience open learning environments based on context analysis and guide lines of inquiry activities that they were supposed to implement in their classrooms. This showed a twofold advantage: they could directly verify the pedagogical validity of these environments and, at the same time, make use of them to master the physics subject at the level of conceptual understanding that they needed to develop in their future pupils. In fact, some TTs showed a good knowledge of mechanical waves, but only a few were equipped with a deep knowledge of some significant factors which are considered relevant in influencing the study of modelling, such as encouraging accurate observations of phenomena, carefully planning experiments and searching for predictive explanations. Other TTs showed a knowledge of mathematical laws but were not able to provide coherent explanations for their observations and ideas about how the world works. Such a qualitative reasoning is relevant in understanding scientific ideas as well as in converting them into effective pedagogy, i.e. the resourceful knowledge of pedagogical implications for teaching a given topic. As a consequence, the search for explanations, deeply grounded on qualitative reasoning, has become the central point of the W.

By integrating lab section and simulation activities, TTs were able to design LUs, devoted to their future high school pupils, in which the role of the medium in determining the speed of sound was made clear. Their main objective was oriented to correctly address pupils cognitive resource and prevent possible misunderstandings they have experienced themselves during the above discussed activities.

As various research has shown, the activities performed using both laboratory work as well as computer modelling stimulated TTs to play an active role in the modelling process and to appreciate its role in developing ideas and explanations. Moreover, the LUs prepared by TTs showed us that the acquired abilities in the modelling procedures can be effectively transformed into the ability to transfer knowledge to pupils. According to our results, the familiarity with the pedagogical tools is related to good conceptualisation of the role of the physics models and to good ability in planning activities to transfer knowledge to pupils.

As the final W results show, we have gained insight into the ways physics teachers can transform their knowledge of mechanical wave propagation, not only to stimulate pupils' understanding of this topic but also to gain a better understanding of the topic. In fact, our study shows ways to provide TTs with a knowledge base which enables them to teach specific topics in a more effective and flexible way.

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Facilitating an authentic learning experience in introductory physics at the Limerick Institute of Technology

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In the last two decades there has been a paradigm shift within education research evidenced by a change in emphasis from research focussed on how instructors teach to research on how students learn (Hollingsworth & McLoughlin, 2000, Gerace & Beatty, 2005). Examining student backgrounds and learning styles at the outset of the academic year makes a valuable contribution to a lecturers understanding of their learner cohort and their strengths and weaknesses. This allows the lecturer to design and tailor their course delivery to optimise the learning experience of the student.

Research currently being undertaken at the Limerick Institute of Technology Centre of Expertise in Mathematics and Science Teaching and Learning is focussed on developing and delivering a set of pedagogical techniques designed specifically to meet the educational needs of our first year Science learners. These techniques include several active learning strategies and teaching interventions directed at addressing the deficiencies in learners' knowledge and understanding, developing their metacognitive skills and increasing their motivation and engagement. Our physics modules have been specifically designed with a strong emphasis on developing a holistic approach to student understanding of physics principles which are evident in everyday life and also relevant to the instrumentation and analytical techniques employed by biologists, environmental scientists, chemists and forensic scientists.

By placing an emphasis on active learning in introductory physics lectures, practicals & tutorials, developing metacognition and using group-work to solve context-rich physics problems an authentic learning experience is facilitated. Preliminary data suggests that multiple interventions are having a positive impact on learner performance.

BACKGROUND

Beginning in 2008, practitioner-led education research was commenced in introductory physics modules within the Department of Applied Science in the Limerick Institute of Technology. The focus of the research is to develop and deliver a set of pedagogical interventions designed specifically to meet the needs of our first year Science learners. These learners are registered on either level 8 ab-initio honours degree programmes (e.g. BSc in Pharmaceutical and Forensic Analysis) or 'add-on' programmes commencing with a level 6 National Certificate (e.g. Applied Biology, Environmental and Analytical Science). Level 6 National Certificate learners and level 8 ab-initio honours degree learners have separate physics modules.

In order to tailor interventions to meet the specific needs of our learners, it is necessary to compile a profile of learners. This is compiled at the outset of the academic year from several sources that are outlined in the section titled Data Collection Instruments.

For the academic year 2009/2010 these surveys reveal that 67% of science students are active learners, and are highly visual, sequential and sensing learners (O'Brien, 2009). The mean age for all first year students is 20±4. Mean CAO points range from 311±56 for the level 6 students to 401±29 for the level 8 students. In a recent study carried out in the Department of Applied Science it was revealed that students with CAO points lower than 300 are an 'at risk' group for attrition and failure in first year science, in particular level 6 learners. Results from mathematics diagnostic testing reveal that there are significant gaps in knowledge of algebra, trigonometry/geometry and numeracy/manipulation of formulae at both level 6 and level 8. The student background survey (*n*=77) reveals that the 53% of students attained a B or C grade in ordinary level mathematics at the Leaving Certificate. Biology was the most popular Leaving Certificate science subject with over 75% of students having studied it. Only 20% of students took Physics for the Leaving Certificate. Of those, two-thirds reported that they enjoyed it. 39% of all students surveyed stated they were 'somewhat prepared' to deal with the subject matter of physics, 30% stated they were either 'totally unprepared' or 'unprepared'. Further information from the background survey showed that over half of first year students were the first person in their family to attend a third level institution.

This profile reveals a number of challenges for both first year science students and their lecturers. Through the implementation of carefully selected interventions, outlined in the following section, it is anticipated that learners will be able to genuinely meet the learning outcomes of their physics modules, as engaged and motivated learners that can demonstrate a good degree of physics knowledge with some expertise in physics problem-solving and independent learning.

THEORETICAL FRAMEWORK AND METHODOLOGY

We are endeavouring to move from knowledge-transfer teaching model to a constructivist model where knowledge is scaffolded for the learner. In the words of von Glasersfeld (1989, p.10) "*'Telling' is not enough, because understanding is not a matter of passively receiving but of actively building up*". We identify with and align ourselves with a social constructivist educational philosophy as outlined by von Glasersfeld (1989, p. 11), which proposes that meaningful learning takes place though social interaction with peers and instructors.

What constitutes an authentic learning experience in introductory physics? We propose that an authentic learning experience is achieved when a learning culture is fostered whereby physics is presented, and perceived by the learner, as accessible, interesting, relevant, and with achievable goals. This culture should also stimulate a learner's intrinsic motivation (Bandura, 1994) and foster the development of independent learning, and transferrable problem-solving and critical thinking skills. In the particular instance of physics education, we propose that continuity should exist between disparate delivery modes of lecture, lab and tutorial, and that the relevance of physics to other first year science modules, such as chemistry and biology, should be evident. In short, we consider this to be a holistic approach to teaching introductory physics.

A reading of the literature surrounding physics education research exposes myriad ways in which to assist learners in moving from novice-like to more expert-like learning and performance in physics. Individual areas of research include how to engage students during lectures (Woods and Sheardown, 2009), measure and develop conceptual understanding of physics topics, uncover and address conceptual misunderstanding of physics topics (Chu, Treagust and Chandrasegaran 2007), probe student attitudes to physics (Redish, Saul and Steinberg, 1997), measure and develop metacognitive skills (Gourgey 2001), develop real-world problem-solving skills and use of collaborative learning environments for learning physics (Heller and Heller 1999, Gokhale, 1995).

A diverse set of research-based teaching and active learning interventions have been integrated into the traditional delivery modes of lectures, laboratory practicals and tutorials. This approach is supported by Pollock's research into multiple effective reforms for improving student performance (Pollock 2004). Based on the background and learning profile of learners in our science courses and the research surrounding physics education mentioned above, the following multiple interventions have been chosen to complement one another and optimise the learning experience in introductory physics.

Lectures use highly visual Powerpoint presentations with images, diagrams, graphs and animations to present physics theory, to suit the high proportion of visual learners. As advocated by Redish (2003, p. 127) partial lecture notes are supplied to learners at the start of the lecture to facilitate understanding the material rather than having to write constantly. In order to engage students in discussion of physics concepts and topics the ‘think-pair-share’, technique is employed at approximately fifteen minute intervals during a fifty-minute lecture. In addition, worked examples of conceptual and calculation questions, typifying those which appear in exams, are followed by a ‘Do It Yourself’ question session. It can be argued that blending conceptual tutorial and exam problems is effective in helping learners to understand the value of conceptual understanding. This approach is supported by Redish (2003, p. 152). Wherever possible, pieces of equipment like lenses, diffraction gratings and lasers are passed around the class for ‘hands-on’ demonstrations. Lecture content is heavily linked to real-world ‘every-day’ physics examples, and applications for biological and chemical analytical techniques e.g. spectrophotometry. Several times during the academic year specific time is given to class discussion on the meaning of metacognition and metacognitive skills. Finally, one physics mini-test given in the first term is used as a formative assessment tool and to help develop the learners’ own self-evaluation skills. The learners experience correcting their own script based on guidance and solutions provided in the lecture; a class discussion then follows.

Tutorials are one-hour sessions, on alternate weeks and are held in the physics laboratory. A collaborative learning model based on the work of Heller and Heller (1999), and Felder and Brent (2008) is employed. Groups of four students work on tutorial sheets that contain qualitative questions and quantitative questions based on current lecture and laboratory material. The questions are context-rich real-world scenarios (Heller and Heller, 1999) wherever possible and interaction with the instructor is through Socratic-style questioning, and formative feedback. Students have ready access to and make much use of resource material including textbooks, physics lab equipment, networked computers, and an interactive whiteboard. Physics problem-solving strategies are explored through discussion, worked examples and a ‘guideline’ document.

The laboratory practical is a two-hour session per week. The experiment circuit is synchronised to current lecture material. In order to promote deep learning, the learners are required to answer pre-lab questions relating to the physics concepts relevant to their assigned experiment. A combination of data-logging and traditional physics lab equipment is used not only in order to develop dexterity in handling equipment but also to experience multiple ways in which the data gathered can be represented e.g. graphs, digital displays, tables (Beichner, 1994). During the lab session emphasis is placed on the learner’s conceptual understanding of the physical principle(s) being investigated, as well as on results, calculations and interpretation of findings. A low ‘percentage error’ result is not the ultimate goal of any experiment; being able to describe and interpret what has happened on the bench in terms of physics principles and concepts is.

There are on average four group-work assignments and projects per academic year comprising an essay, a guest lecture, a photographic project called ‘Images of Physics’, and a Science Week hands-on physics experiment demonstration with accompanying poster. Each project has a reflective questioning component in order to heighten learners’ awareness of some aspect of their approach to research, attitudes to the physics principles encountered, or group work.

DATA COLLECTION INSTRUMENTS

A range of data collection instruments are being used to gauge the impact of our interventions on the performance and perceptions of our learners:

- Learners' backgrounds are characterised based on data from the following sources: Shannon Consortium Learning Styles Profile survey, a mathematics diagnostic test, and a learner background survey enquiring about CAO points, Leaving Certificate science subjects, employment and study time commitments.
- Learners' metacognitive skills are measured using a 31-item pre validated Likert-scale metacognitive ability survey based on the MCA-I developed by Cooper, Sandi-Urena and Stevens (2008). The pre-test is administered early in the academic year, and the post-test at Easter.
- Learners' attitudes to physics and their approaches to physics learning and problem-solving are measured using a Physics Background & Expectations Survey. This Likert-scale survey is based on the pre-validated Maryland Physics Expectations Survey (Redish *et al*, 1997). The pre-test is given during the very first physics lecture of the year, and the post-test given once the syllabus has been covered. Open-ended questions probe learners' opinions on aspects of group work, course structure and the relevance of the physics module to their chosen course of study.
- Student performance in physics is investigated through examinations administered at Christmas and Easter (which include one open-ended metacognition-related question), a terminal summer exam and a laboratory exam. Questions on all exams are categorised as either qualitative, quantitative, definitions, or explanation/interpretation of formulae. Continuous assessment is based on assignments and weekly lab reports.

PRELIMINARY RESULTS AND ANALYSIS

Learners background and expectations were surveyed at the start and end of the academic year. Using PASW version 17 the Wilcoxon Signed Ranks test was carried out on matched data to investigate whether or not there were statistically significant differences (α_2 = 0.05) from start to end of year in learner responses. Statistically significant differences were observed on a number of survey items e.g. '*The results of an exam don't give me any useful guidance to improve my understanding of the course material. All the learning associated with an exam is in the studying I do before it takes place*' showed a significant difference at ρ = 0.006. '*Physical laws have little relation to what I experience in the real world*' showed a significant difference at ρ = 0.046. '*When answering a physics calculation question I believe that understanding the underlying concept is important'* showed a significant difference at ρ = 0.049. '*In this module I do not expect to understand the equations in an intuitive sense; they must be just taken as givens*' showed a significant difference at ρ = 0.004.

The Wilcoxon Signed Ranks test was also carried out on matched data for the metacognitive skills survey in order to investigate whether or not there are statistically significant differences (α_2 = 0.05) in survey responses from start to end of year. Again, statistically significant differences were observed on a number of survey items e.g. '*I clearly identify the goal of a problem (the unknown variable to find or the concept to be defined) before attempting to solve the problem'* showed a significant difference at ρ = 0.001. *'Once a result is obtained I check to see that it agrees with what I expected*' showed a significant difference at ρ = 0.014. *'I make sure that my solution actually* *answers the question'* shows a significant difference at ρ = 0.024. *'If I don't understand what is being asked in a particular problem I seek clarification*' shows a significant difference at ρ = 0.033.

This preliminary exploration showed positive statistically significant differences in elements of both, the Physics Expectation and metacognition skills surveys. These findings are encouraging and will be further investigated to ascertain their validity and importance through triangulation with data gathered from other instruments.

The results of the open-ended questions that feature on the Physics Background and Expectations post-test survey were analysed using Excel pivot tables and charts. They reveal learner attitudes to various aspects of their physics modules: 80% of those who responded agreed that '*Overall this module has stimulated my interest in physics*' and 82% agree with the statement that '*This module has changed my attitude to physics'* in a positive sense. Learners report that their awareness of physics in everyday life has increased, their understanding of physics has increased and that physics is neither as boring nor as daunting as was expected. 80% agree that course assignments are interesting.

Regarding the relevance of physics, 90% agree that physics is a relevant subject for their chosen course of study, with many specifically reporting the links between chemistry (gas laws), mathematics and forensic science (fibre refractive index). Over 90% agree with the statement '*Having studied physics, mathematics and chemistry this year, the relationship and cross-over between each of these subjects is clearer to me*'. Teaching interventions within the classroom also get positive responses. 93% responded that '*The lecturer's use of technology in the classroom enhanced learning*', and 77% agreed that '*Interactive engagement techniques were of benefit to me in the classroom*'. A significant number of learners reported that they enjoyed being able to explore and share ideas and talk about physics among themselves. However, they also remarked that the degree of success of interactive engagement techniques depended somewhat on their neighbours in class. 87% of learners believe that '*Tutorial group-work was of benefit to me this year*' as problem solving seemed easier due to peer interaction. However, only two-thirds of students reported engaging in group-work/study outside class time. Reasons included difficulty in finding suitable times, and learners preferring solo study due to distractions within a group study scenario. The physics problem-solving skills taught in tutorials appear to be somewhat transferrable to other modules (specifically chemistry and mathematics) as reported by 85% of learners surveyed.

CONCLUSION

From a preliminary examination of the data gathered it appears that the multiple teaching and active learning interventions are having a positive impact on student attitudes to learning physics and self-reported metacognitive behaviours. Further analysis is required to investigate the effects of these interventions on student learning and on performance in examinations.

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Teachers' Voices: My Mathematics, My Teaching, My Experience of Project Maths

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Second level mathematics education in Ireland has undergone significant review in recent years, and this has led to the instigation of 'Project Maths.' A revised syllabus is being phased in; it has been piloted in 24 schools since 2008, and is being introduced nationwide from Autumn 2010. While some updating of curricular content is involved, the main focus is on trying to change predominant teaching and learning styles. Vigorous debate, reflecting teachers' views about mathematics education and the nature of mathematics itself, has accompanied the pilot phase. To capture the teachers' views, and to explore connections between their experiences of mathematics, their beliefs about pedagogy and their opinions of Project Maths, semi-structured interviews were held with prominent mathematics teachers who have been involved in various ways with the project. This paper will report on insights and themes that emerged.

INTRODUCTION

The study described in this paper aims to capture the views of some of the teachers who have been prominently involved in the debates about Project Maths, the mathematics curriculum project currently being introduced to second-level schools in Ireland. In particular, the paper seeks to present the teachers' stories and to examine relationships between their conceptions of mathematics, their views on teaching, and their experiences of Project Maths. Data collection began after the first Leaving Certificate examinations containing 'Project Maths' questions were held, and has yet to be completed; so the present version of the paper focuses on the background to the study, identifying Irish research that feeds into the work. Results will be presented at the conference.

BACKGROUND AND LITERATURE REVIEW

Mathematics curricula – Ireland in international context

International developments in mathematics curricula over the past fifty years can be described in terms of dominant trends roughly matched with ten-year periods. Thus, 'modern mathematics' characterised the 1960s; the 1970s were typified by the 'back to the basics' movement; the 1980s have been designated as 'the decade of problem solving'; and 'realistic mathematics education' (RME) and constructivist approaches to learning were flavours of the 1990s. RME and constructivism remained prominent in the decade 2000-2009, but more perspective may be needed in order to identify a dominant trend. A second categorisation focuses on the debate about the relative importance of 'process' and 'product.' The first two decades dealt mainly with content (hence, product); the second two were much more concerned with process. While such broad generalisations are necessarily imprecise and do scant justice to the early emergence or persistence of approaches in different countries, the simplified account provides a backdrop to the examination of curricula, in particular – for this paper – in Ireland.

In Ireland, the uptake of modern mathematics was notable, and the curricular reform introducing it reflected a major critique of existing practice. The emphasis remained strong in the more minor reviews of the 1970s, and obviated any undue swing towards 'basics.' Only in the 1980s and 1990s were comparatively 'basic' (though not entirely utilitarian) courses introduced, augmenting rather than replacing existing courses.

Overall, developments in these decades focused chiefly on *trying ensure that the amount and type of content, and the forms of assessment, were appropriate to the target groups taking the courses*, rather than on *emphasising the process of doing mathematics* (see Oldham (2007), which provides further references). This reflected, not only the greatest perceived needs addressed by the reviews taking place in the period, but also the long-standing tradition whereby the content of the syllabuses was the concern of the State Department of Education (later Education and Science), but process aspects were chiefly the province of the professionals implementing the syllabuses – that is, of the teachers. A better match of content (both extent and type) to student participants was intended to allow the teachers both time and scope to teach for *understanding*.

Perhaps expectations that such a move would happen on a large scale without more professional support were somewhat unrealistic. A finding of the Third International Mathematics Study (TIMSS) (Beaton, Mullis, Martin, Gonzales, Smith & Kelly, 1996), according to which Irish teachers appeared to give unusually high importance to 'product' aspects (content and routine skills) and unusually low importance to 'process' aspects, provided a wake-up call. The most recent decade in Ireland has seen a much stronger focus on teaching methodology. The professional development programme that supported the amended Junior Certificate courses introduced in 2000 was built on pooling and developing the expertise of good teachers and then sharing it with others around the country. Inevitably, however, the impact was limited, especially once the assessment of the amended course settled into a rather predictable pattern that did not obviate 'teaching to the test.' More was going to be needed in order to change prevailing practice; in particular, heed was going to have to be paid to teachers' conceptions of mathematics and their views on the nature of mathematics education.

Teachers' conceptions of mathematics – Irish research in international context

The importance of teachers' conceptions of mathematics, as a contributory factor in determining how they teach the subject, has been established for more than twenty years (see for example Philipp (2007), which provides further references; Philipp's distinctions between conceptions, beliefs, identity, and so forth, are outside the scope of this short paper). Thus, a teacher who views mathematics as a process is likely to teach differently from one whose focus is on the product. Moreover, for the latter viewpoint the type of product is important, with the teacher who sees mathematics as a meaningful system or set of relationships likely to teach differently from one who sees the subject as an arbitrary collection of rules. Work typically distinguishes three philosophical views, the first two of which are product oriented, while the third refers to mathematics as a process:

- Platonist – a body of knowledge, already existing and summarised in *true* theorems that can be discovered rather than created
- Instrumentalist – a bag of tools, not necessarily related in any meaningful way, but useful in obtaining answers to exercises and standard problems
- Problem-solving – a continuously expanding field of human creation, reflecting ongoing activity rather than a static product.

One relevant instrument that has been used in Ireland to capture respondents' views on the process-product dichotomy is the 'mathematics as a process' subscale that forms part of questionnaires employed in the Second International Mathematics Study (SIMS) (Robitaille & Garden, 1989). The scale consists of fifteen items, with responses ranging from 'strongly disagree' to 'strongly agree.' Examples include 'There are many ways to solve most mathematical problems' and 'Mathematics is a good field for creative people' (agreement pointing towards a process-oriented view) and 'There is always a rule to follow in solving a mathematics problem' (agreement pointing towards a product-oriented view). Carey (1990) used the instrument with Irish first-year school students in a follow-up study to SIMS, focusing in particular on gender; mean scores reflected overall neutral views, with no significant differences in scale scores between boys and girls. The present author has used the instrument with student-teachers, but to promote reflection and/or discussion rather than for research purposes.

With regard to the philosophical categorisation, the author designed a set of six statements intended to describe nuanced versions of the three philosophies. Examples include 'Mathematics is a body of important knowledge, encompassing eternal truths' (to encapsulate archetypal Platonism) and 'Mathematics is an activity involving the formulation and exploration of problems' (the Problem-solving view). Again, the instrument has been employed mainly in a teaching context. However, in a study with student-teachers taking a mathematics course that focused on problem solving, it was used to examine the change in preferred philosophy between the start and end of the course; a shift away from instrumentalist views was recorded (Oldham, 1997).

Other means for exploring teachers' philosophies of mathematics include narrative autobiography, reflective accounts, lesson observations and interviews. Eaton and O'Reilly (2010) focused on narrative and discussion in order to examine primary student-teachers' mathematical identities. The author has made use of autobiography and reflective structured essays, also with primary student-teachers (Oldham, 1997, 2005).

While there is no necessary connection between espoused philosophy of mathematics and beliefs about pedagogy, it is likely that process-oriented teachers would favour constructivist approaches to teaching. Recent Irish research on teaching mathematics tends to reflect the TIMSS findings reported above. Qualitative studies – by Lyons, Lynch, Close, Sheerin and Boland (2003) of ten classrooms, and by Brosnan (2008) in a longitudinal study of three teachers – reported traditional, product-oriented teaching. The large-scale Irish Calculator Study (Close, Oldham, Shiel, Dooley, Hackett & O'Leary, 2004) used an instrument due to Becker and Anderson (1998) and consisting of five pairs of statements; in each pair, one is intended to capture 'traditional' (perhaps behaviourist) approaches and the other to reflect 'progressive' views consistent with constructivism. An example of a pair is 'The content of the mathematics curriculum is the most important thing to teach' and 'The most important part of teaching is to encourage mathematical thinking among students; content is secondary.' For each pair, responding teachers have to place themselves on a five-point scale between the two extremes. Typically, Irish students were taught by teachers who reported using a rather traditional expository format albeit being concerned with promoting student interest and mathematical thinking.

PROJECT MATHS

Project Maths grew out of dissatisfaction with student performance in mathematics. The National Council for Curriculum and Assessment produced a discussion paper (NCCA, 2005) and instituted a consultation process about the future of second level mathematics education. More fundamental questions were posed than had been possible for the relatively limited curricular reviews in the 1980s and 1990s; in particular, issues with regard to teaching and learning and to the broader context of school life were addressed.

The curriculum innovation that resulted is unusual in many ways. Naturally, some updating of curricular content is involved at both Junior and Leaving Certificate level. However, implementation has focused on trying to change predominant teaching and learning styles: from behaviourist-type approaches based on exposition, rote learning and practice, to more constructivist approaches involving meaningful learning, 'hands on' activities, problem solving and applications. Introduction is phased; twenty-four pilot schools participated initially, with two out of five 'strands' being introduced at both Junior and Leaving Certificate in the first pilot year, two more in the second, and the fifth due in the third year. The national rollout is to follow similarly but with a two-year timelag, allowing the pilot schools to contribute to the development of the syllabus and of teaching and learning approaches that would implement it faithfully. Support is being provided by a group of teachers who form the Project Maths Development Team. Information about the project is available on its official website, www.projectmaths.ie.

As usual for times of curriculum change, the involvement of the mathematics teaching community in meetings and professional development sessions rose significantly during the period. Many discussions have taken place, in particular at meetings of the Irish Mathematics Teachers' Association and of its Dublin Branch; these have been vibrant and passionate, reflecting teachers' deeply held views. Altogether, it can be said that *the long overdue debate about mathematics as a process is now taking place in Ireland.*

THE STUDY TO DATE

As indicated above, this paper aims to capture the views of some of the teachers who have been prominently involved in the debates about Project Maths. In particular, it looks for relationships between the teachers' conceptions of mathematics, their views on teaching, and their experiences of Project Maths. For a paper that seeks to allow the teachers' individual voices to be heard, it was decided to choose a small number of teachers – all of them participants in the Dublin Branch discussions – and to conduct a semi-structured interview with each one. In order to obtain teachers' opinions after the first Leaving Certificate cycle involving Project Maths had been completed, data collection was planned for the period following the Leaving Certificate examinations, with additional comments to be sought after the results are announced. Where possible, instruments used in previous studies in Ireland would be adopted, so as to allow for placing the answers in a somewhat more general Irish context.

Six teachers – four men and two women – were selected for the study. Four of them teach in Project Maths pilot schools (two in one school and two in another); two do not, but have contributed substantially to the Dublin Branch discussions on the subject. Some were positive in general about Project Maths, while others had expressed reservations and had made statements that suggested to the author that the project ran counter to their own views on mathematics or mathematics education. Further details about the teachers are omitted in order to preserve their anonymity.

The interview schedule had to cover the three areas listed above: conceptions of mathematics, views on teaching, and experiences of Project Maths. Moreover, to provide an appropriate context for each interview, aspects of the teachers' mathematical and professional identity and their path to becoming mathematics teachers needed to be investigated. Following Eaton and O'Reilly (2010), an open question was placed first in the schedule, to elicit unstructured responses: '*Why did you choose to become a mathematics teacher?*' The rest of the schedule has six sections. Section A addresses the teachers' mathematical autobiographies; it draws largely on the essay question given by the author to generations of primary student teachers, modified to incorporate aspects of the work of Eaton and O'Reilly (2010). Section B focuses on the teachers' views with regard to the nature of mathematics as process or product, using the 'mathematics as a process' subscale from SIMS as a stimulus. Section C aims to address the teachers' philosophy of mathematics directly, by asking them to choose their favoured statements from the six written by the author to reflect particular views of mathematics. Respondents are asked to specify their first, second and third preferences (giving reasons). They are also asked to do the same for mathematics as they would expect to teach it to school students, and to account for any differences, thus providing a transition from addressing views of mathematics itself to considering mathematics pedagogy. The latter is addressed in Section D, using the instrument due to Becker and Anderson (1998). The final two sections ask about the teachers' experiences of Project Maths and about their suggestions for future support in the Project's implementation. No overt structure is provided in these sections, but it was intended that a 'prompt' would be offered with regard to the innovative nature of the Project in allowing the teachers in the pilot schools to contribute to syllabus formation, if the point did not occur spontaneously.

The schedule was piloted with two of the author's colleagues – both, therefore, people with expertise in research methods. One is also a philosopher of education with a background in mathematics teaching; he was particularly well equipped to critique the statements in section C, checking that they are likely to reflect the philosophies intended. No changes were made as a result of the pilots.

All six teachers accepted the invitation to be interviewed, and five of the six interviews have taken place; the final one is scheduled for mid-August. Interviews – typically of about an hour's duration – were held in the author's office in Trinity College, and were recorded. The five interviews have been transcribed. The transcripts will be analysed by means of multiple readings, some focusing specifically on addressing the relationships between conceptions of mathematics, views on teaching, and experiences of Project Maths, and others seeking other themes or individual views of interest. The author looks forward to letting the teachers' voices be heard.

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Facilitating inquiry based learning in mathematics teacher education

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A driving question in teacher education centers on how to help prospective teachers become expert teachers. The absence of a shared professional curriculum to prepare teachers to teach mathematics combined with the difficulty translating traditional research knowledge into forms that teachers can use in their practice have motivated this study. This paper reports on the combined efforts of teacher educators, teachers, and preservice teachers to engage in inquiry-based teaching of primary mathematics. What is innovative is the use of the classroom lesson as the unit of analysis combined with engagement in cycles of inquiry to produce exemplar mathematics lessons. Lesson Study was the primary method used to support a focus on examining teaching through the design and implementation of 'study lessons'. Insights into preservice teachers' reflections on inquiry-based teaching are presented in addition to a discussion of the benefits of efforts such as this which translate traditional research knowledge into forms preservice and practising teachers can use to improve their practice.

INQUIRY-BASED LEARNING

Inquiry based learning is often used as an approach to restructure aspects of teacher education and maximise the potential of learners. An inquiry-based approach to learning involves restructuring the manner in which the content is taught. Advocates of inquiry-based learning argue that this restructuring will provide students with more authentic experiences into the practices of mathematics and science and will increase motivation and interest in science and mathematics. The move to inquiry based approaches requires a move from didactic teaching practices toward practices that engage students in observation, experimentation, planning and culminating in the construction of knowledge and understandings of the discipline. In this study, inquiry based learning is manifested in the activities that preservice teachers engage in while planning for and teaching mathematics lessons. What emerges is a model of preservice teachers working with content (mathematics and mathematics pedagogy) in ways that encourage them to seek resolutions to questions and issues that arise when teaching.

LESSON STUDY AS A TOOL TO PROMOTE INQUIRY BASED LEARNING

Lesson Study is the vehicle used to promote an inquiry-based approach to the teaching and learning of mathematics. Lesson Study is a Japanese form of professional development involving the design and observation of live lessons, called research lessons, by a group of classroom teachers. Lesson Study is becoming an increasingly popular process for improving classroom practice (Lewis & Tsuchida, 1998; Stigler & Hiebert, 1999, chapter 7) and its use with Irish preservice primary teachers to support the development of mathematical understanding has been documented in a number of studies (Leavy, 2009; 2010). The central activity in Lesson Study is for teachers to work collaboratively on the design and implementation of a *study lesson* with the shared purpose of improving teaching. The lesson is designed by the teachers, one of whom agrees to teach the lesson while the others observe and collect data on learning and teaching as it unfolds during the lesson. The research lesson and data detailing observations are shared at a post-lesson colloquium. A significant feature of Lesson Study is the cycle of inquiry within which the primary activity is located. While Lesson Study can be described in a number of ways, broadly speaking the cycle of inquiry consists of three phases with a number of activities occurring within each phase. Phase 1 is *Research and Preparation of the Study Lesson*, Phase 2 is the *Implementation Phase,* and Phase 3 is *Reflection and Improvement.*

PARTICIPANTS

The 20 participants were final year preservice primary teachers. Six were male and two were International Erasmus students. All participants had elected to enrol in a curriculum specialization in mathematics education; however the degree of confidence in teaching mathematics varied across participants. While many were confident in teaching primary level mathematics, a similar proportion lacked confidence in teaching mathematics and wished to improve their understandings of mathematics education.

METHOD AND DATA COLLECTION

Algebra was the mathematics content area developed over the course of the lesson study. Four areas were identified: growing/repeating patterns, functions, equality, and variables. Participants were divided into four groups; each group focused on one topic.

During phase 1, *the research and preparation of a study lesson,* groups were observed as they worked collaboratively to design their lesson. Groups were provided with a number of reading materials relating to the algebraic topic of study. Groups met regularly to design their lesson, and met with the researcher, who acted as a mentor to the group, on at least three occasions. Artefacts arising from the collaborative planning were collected, for example the questions arising from these meetings and resources used to plan lessons. The detailed lesson plan arising from this phase was presented to the researchers and feedback on the lesson plan was provided prior to moving into phase 2.

During phase 2, *the implementation phase,* the researchers observed the teaching of the research lesson in a local primary school. One member of each group taught the lesson and other members were responsible for observing how particular aspects of the lesson played out. Attention was focused on children's understanding of the algebraic concepts; responses to questions, activities and tasks presented; assessment issues and (any) difficulties that emerged during the lesson. In phase 3, *reflection and improvement*, researchers met with the group immediately after the lesson was taught and provided feedback to the group on the outcomes of the lesson. The group then revised the lesson in accordance with observations. Finally, the newly revised lesson was examined by the researchers prior to the lesson being taught the second time.

The revised lesson was taught in a second primary school. This second enactment of the lesson constituted the *second implementation* stage of the study. On this occasion the lesson was videotaped by a professional video crew team and observed again by the researchers. Each group then provided a written report on the process of Lesson Study and made an in-class presentation to the entire class. During the in-class presentation, group members shared reflections about new versions of the lesson and the development of their algebraic and pedagogical understandings of lesson study.

Case 1 – Equality

This group focused on 'equality' as a foundation for algebra. An overarching purpose was to support children in moving from thinking of the equals sign as a request to 'do something' to thinking of the equals sign as expressing the relationship 'is the same as'. Based on readings of literature pertaining to children's misconceptions of equals sign, the group identified a number of approaches used to support children in thinking about equality more broadly by developing balance and equivalence notions of the equals sign.

The lesson started by examining 4th class children's current conceptions of the symbol '='. A number of problem situations (*e.g.* money) were used to emphasize that expressions on each side of the equals sign may look very different yet have the same value. A piece of children's literature was introduced (*Equal Shmequal* by Virginis Kroll) to help extend the concept of equals meaning the 'same value as'. In the story a seesaw is used to model the concept of 'balance'. Parallel to reading the story, children were encouraged to simulate a balance scales/seesaw and demonstrate equality in the story scenarios by adjusting the balance of their hands. Children were then encouraged to make the connection between the equals sign and their seesaws through the introduction of a pan-balance scales. Working with the pan-balance (see image 1) offered children a concrete experience of equality and an opportunity to engage physically with number sentences. Number sentences and simple linear equations were initially investigated using concrete objects on the pan-balance. Additional activities that reinforced the concepts of balance and equivalence were missing-addend problems and open-number sentences. Children worked in small groups to examine number sentences and reported back to the whole class on the outcomes of their work (see image 2).

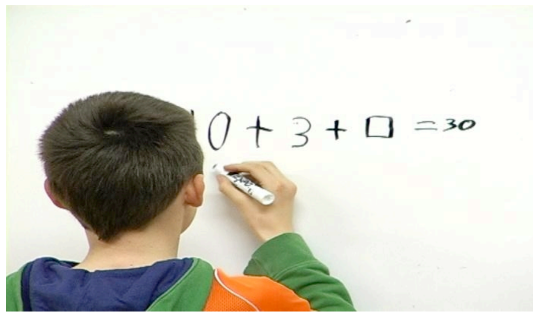

Image 1: Using pan balances for equality

Image 2: Completing number sentences

Through teaching, observing and reflecting upon the first enactment of the lesson a number of changes were made to improve upon the initial lesson design. The primary issues pertained to the lack of challenge in the initial lesson – although the contexts were fruitful in developing notions of equality, the quantities presented under-challenged the children in terms of numerical reasoning. Also the operations used (primarily addition and subtraction) did not extend children's reasoning. Other pedagogical considerations were examined and revised in relation to the nature and use of specific mathematical equipment and materials fundamental to developing notions of equality.

Case 2 – Functions

The second group were given the task of introducing the concept of 'function' (rule) to 4th class pupils. On reading the relevant literature and becoming aware of the various methodologies which could be used to introduce the concept e.g. growing patterns, literature, the student teachers in this group decided to use a 'physical' function machine. The context they chose was that of a 'broken' oven (see image 3), where each button resulted in the 'input' being transformed according to a specific rule/functions e.g. doubled, increased by 15 etc. Functions (rules) were introduced developmentally from 1 step rules (e.g. $\times 9$) to 2-step rules (e.g. $\times 2+1$) by means of guided discovery. While in the initial example images of food were used, subsequently interlocking cubes were used to represent both input and output. Pupils were involved in the process of placing the input into the oven and analysing the number of items in the output. Both the teacher and pupils recorded the relevant data (see image 4). In each case, pupils were encouraged to predict the rule and to check their prediction by checking additional inputs provided.

Pupils were provided with the challenge of predicting the 'input' if aware of both the 'output' and 'rule'. Subsequently pupils themselves had the opportunity to work in groups, with each member having an opportunity to act as 'rule generator'. A number of groups shared one of their rules with the class.

Image 3: The Function Machine 'rule'

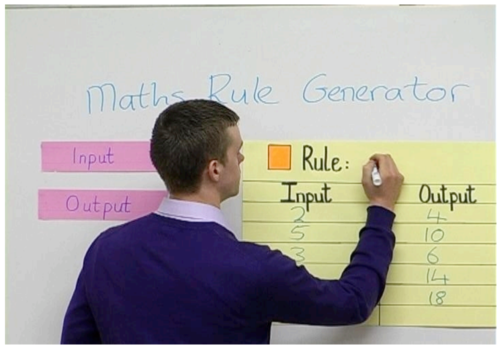

Image 4: Identifying the 'rule'

On initially implementing the lesson in the first school context, various issues arose. Firstly the need became apparent to the student teachers for the 'function machine' work to be streamlined, i.e. to have materials (both inputs and outputs) prepared in advance. It was also decided that base ten blocks (Dienes blocks) would prove less cumbersome and more efficient in terms of counting. It was also believed that there was more potential for pupil challenge within the lesson through the provision of more time to address 2-step functions. In terms of organisation of group feedback, it was also decided that the student teachers should work with the groups during the selection and presentation of each group's rule. In the second teaching of the lesson, pupils independently came up with both 1 and 2 step functions when acting as 'rule generators' and were eager to challenge the class to predict the rule.

Case 3 – Variables

The third group prepared a lesson on teaching 'variables' to 4th class. Variables are symbols, *e.g.* letters, that take the place of numbers or ranges of numbers. According to the Primary School Mathematics Curriculum (PSMC) (1999) children should be enabled to "explore the concept of a variable in the context of simple patterns, tables and simple formulae and substitute values for variables" (Government of Ireland, 1999, p.96). Taking this into consideration the group decided to introduce the concept of a variable through the use of a variable wheel (see image 5). The variable wheel allowed children to explore the idea of a variable as a letter that can stand for any member of a set of numbers and also allowed children to substitute numbers for variables. The key focus in this aspect of the lesson was that children came to realise that a letter could stand for any number depending on the problem. In the initial lesson, on completing the above task, pupils demonstrated a misconception that a letter always held the same constant value, e.g. a=1, e=5.

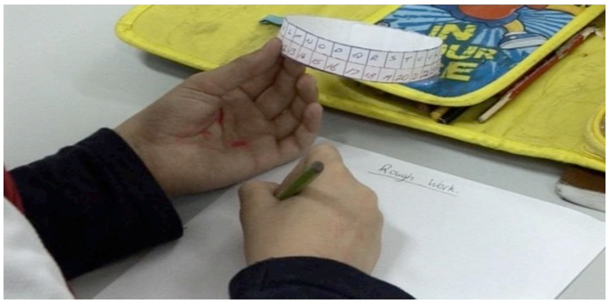

Image 5: The variable wheel used in the variable lesson

Following this the group used story problems that required a variable to solve them. In each problem there was an unknown value to be found. Children were allowed to pick any letter to represent the unknown. A simple table of what was known was drawn up. A number sentence was then written and solved. After considering the pupil misconception outlined above, in the second teaching of the lesson the student teachers reinforced the fact that a letter may hold different values depending on the context. This was achieved through the presentation of two problems in which the same letter was used to represent the unknown (Problem 1: F (France) = 36; Problem 2: F (France) = 45). Following this children were provided with an opportunity to create their own word problems that required a variable to solve them (see image 6).

SUMMARY AND CONCLUSIONS

As part of the assessment of the module, student teachers were requested to reflect on their learning over the course of the Lesson Study process. This was presented by means of group presentation and individual reflections. On analysis the students' learning fell into a number of broad categories. A sample of the reported learning will now be presented, providing the reader with a 'taste' of the nature of this learning.

Algebraic concepts

In some cases, student teachers reported that prior to the project they possessed limited knowledge of the relevant concepts, e.g. "My understanding of the concept was lacking" (Equality group: Eva). Many testified that through the process of partaking in the Lesson Study project they had learned 'algebra' themselves, i.e. they had developed their own subject matter knowledge:

> …I had a limited understanding of what the equals sign means…I understood the equals sign …as 'is' (as in 3+5 'is' 8) not as 'is the same as' or the 'same value as', so I learnt something very important myself (Equality group: Mia);

> As a result of trial and error that I undertook in the lesson plan my own understanding of algebra and how to write equations improved (Variables group: Rosemary).

Beliefs and perceptions about algebra and its teaching

There was evidence of improved attitudes towards the topic of algebra:

> I have grown to like algebra over the last few weeks and I feel this will be reflected in my future lessons…I no longer see it as a boring topic. It was just as interesting and perhaps fun as other strand units like data (Equality group: Valerie).

Reference was also made to changing beliefs regarding the nature of algebra:

> Algebra is not as abstract as we originally thought, once it is presented in context (Variable group presentation).

Teaching mathematics

While some comments were quite general:

> I feel the Lesson Study's greatest benefit was improving my understanding of teaching maths as a whole (Functions group: James),

others referred to their increased awareness of the benefits of specific strategies:

> It offered me insight into how effective group work is. I saw…that pupils teach each other and learn from others… (Equality group: Valerie);

> From the Lesson Study I have realised that if it is a new concept or topic for the class…the most important thing to do is to break the concept down into its most basic form and start from there (Variables group: Peter);

> In all areas of maths teaching it is so important to explain the language of maths (Variables group: Rosemary).

Teaching Algebra

Some of the student teachers reported having gained knowledge specific to the teaching of the strand of algebra:

> The Lesson Study has taught me that live number lines/equations can be used right up through the school in different classes and also in different strands of the curriculum (Equality group: Valerie);

> In teaching algebra as in other areas of maths the best way to explain an abstract task to the pupils is to model exactly how it is done with the children contributing (Variables group: Rosemary).

Increased awareness of pupil responses/misconceptions

A number of student teachers acknowledged that the Lesson Study highlighted the benefits of predicting and responding appropriately to pupil ideas:

> The most vital section of the Lesson Study was that of the expected students' reactions. This ultimately was a method of assessing the children's understanding of the lesson and required deep reflection on the way children think and learn (Functions group: James);

> The Lesson Study has taught me to be open to what the children have to say. The teacher can learn how to teach from the pupil as well as the pupil learning from the teacher (Equality group: Valerie).

The role of algebra in the curriculum

Many student teachers reported having gained increased insight into the potential for algebraic reasoning as well as opportunities for linkage within the strand of algebra and with other mathematics strands and curriculum subjects:

> I now realise that children who understand equality are well on their way to understanding relationships expressed by number sentences/equations (Equality group: Mia);

> The Lesson Study has allowed me to see that variables can be used…across all strands of the curriculum once it is introduced (Variables group: Rosemary).

Overall perspectives of Lesson Study

Students found that working together on Lesson Study had huge benefits in terms of working collaboratively and drawing on a variety of perspectives and ideas The group work aspect of Lesson Study had challenges for the students as "it was very time consuming" (Variable group: Ella) and as a result it was difficult "to meet the needs of the group" (Functions group: Peter). However, the overall sentiment from students about Lesson Study was that it was a worthwhile experience, e.g. "I had a wonderful experience and cannot stress how beneficial the Lesson Study was" (Equality group: Marie).

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Diagnosis and individual facilitation in science teacher education

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This contribution will give an insight into a project which is running at Dortmund University of Technology and which focuses on “diagnosing and individual facilitation” in science teacher education. The project (www.dortmint.de), which won a competition for excellence in science teacher education in Germany, therefore combines three content-oriented and two structural activities. First, teacher students shall be diagnosed themselves in order to provide them individual support to have a greater success in their own learning of chemistry. It is aimed that those students experience the power of diagnosing and individual facilitation in their own learning and because of this will be more ready to use such methods being a teacher themselves. The second content-oriented activity therefore asks them to design instruments for diagnosing and individual facilitation which will be used in the third content-oriented activity by other students when teaching in class. Those content-oriented activities are supported by two structural activities which link the subjects (mathematics, physics, chemistry, biology and technology) involved and care for a professional recruiting of students interested in teaching especially challenging pupils.

This contribution will focus on the first content-oriented activity and will show, how the first semester for chemistry teacher students has been changed, which instruments for diagnosing and individual facilitation have been used and which effects could be observed.

Mathematical Representations as a Means towards Inquiry-based Teaching and Learning

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The significant role representations play in mathematics teaching and learning as part of inquiry – based education has been acknowledged by research (Kaput, 1998, Goldin and Shteingold, 2001, Ma, 1999, Pyke, 2003, Mason, 2005, and Boaler, 2009). This baseline study was conducted at the Lesotho College of Education with 112 first year student teachers who were registered for the Diploma in Education Primary (DEP) programme in 2009. The study reported in this paper was intended to explore participants' recognition of mathematical representations as resources for solving mathematics tasks. Participants were given questionnaire to answer at the beginning of the Diploma Program. The questionnaire consisted of eight mathematics tasks. About ten months later after taking two mathematics courses, 10 purposively chosen participants were invited to participate in clinical interviews where they were asked to talk about their responses to the Survey Instrument. Our talk at the conference will focus on some participants' responses to tasks and transcripts. Data were analyzed qualitatively and quantitatively. Results reveal that whilst students recognize other forms of representations, they strongly hold on to symbolic representations and use of algorithms to perform operations. We conclude that participants did not use representations flexibly and effectively that accompanied some tasks. We argue that in lectures, students need to spend time working on problem solving and developing mathematical reasoning through the use of external mathematical representations.

Cross-Disciplinary, Authentic Student Research Projects

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In the Dutch secondary education system, students must carry out at the end of their school career a rather large research or design project to demonstrate their ability to apply acquired knowledge and skills while pursuing a research question or design goal in some depth. They are encouraged to choose the topic themselves and they are to some extent free in setting up their work. Ideally, the students do not only see it as a compulsory subject but also enjoy the stimulating aspects of doing their own research or design. Challenging and authentic projects, which are representative for actual research and design work done by professionals, seem effective in this respect. The focus of this paper is on how the use of ICT for data acquisition, video-analysis, modelling, and data analysis can contribute to the realisation of such projects in mathematics and science education and on how it can give students opportunities to take the nature and level of their work close to the characteristics of work of experts in the field. We present two examples of students' inquiry work, in the context of bungee jumping and human gait, and we discuss the ICT usage, the authenticity and resemblance with an expert's approach.

INTRODUCTION

We concur with Hodson (2009) and other educational researchers (e.g., Roth, van Eijck, Reis & Hsu, 2008) that there are at least three major goals of mathematics, science and technology (MST) education: (1) learning MST, by which we mean the familiarity and understanding of ideas and concepts inherent in these fields; (2) learning about MST, which adopts a much broader view of MST, focusing on the philosophy, history and methodology of these fields; and (3) learning to do MST, by which we mean that the learner gains the ability to engage in and develop expertise in scientific inquiry and problem solving. The cited authors distinguish a fourth purpose of MST education, viz., engagement in sociopolitical action, but it hardly plays a role in our work. Our focus is on providing students with opportunities to experience how science is enacted, i.e., with authentic science, and in particular on providing students with ICT tools that allow them to act as 'real' scientists.

The intention to approach MST education as a study of scientific practice is more easily stated than implemented in a nationwide MST curriculum. The Dutch curriculum reforms of the last two decades in upper level secondary education, introducing new concepts like the 'study house' as a place for students to learn to learn and the so-called 'study profiles' consisting of fixed combinations of subjects, can be looked upon as necessary steps in this direction. Students must build up a portfolio consisting of small practical investigation tasks (4-10 hrs) and one rather large (80 hrs) cross-disciplinary research or design experiment in order to record the progress in their learning of doing science. The main instructional purposes of the small investigation tasks are to give students opportunities to (1) build up general competencies such as research skills, ICT skills, communication skills, and so on; (2) deepen or enlarge existing mathematical and scientific knowledge; and (3) become more proficient in applying knowledge and skills in practice. In the final project students must demonstrate their achieved level of knowledge, skills, and attitude in the form of a report and/or presentation of independent work on a topic of their own choice. For example, in a research project students must demonstrate their research abilities, ranging from choosing a manageable problem, formulating a good research question and structuring their work to drawing conclusions and presenting the results. Notwithstanding that the final project is part of the examination programme and a sufficient mark is needed for obtaining a secondary school diploma, many curriculum developers and teachers see it as a chance to expose students to the real world of research and design, and as an opportunity to let students enjoy doing research and development on a subject they personally relate to. In this paper, we explicate our meanings of the adjectives 'cross-disciplinary' and 'authentic' in the context of secondary school students' inquiry work. We illustrate this with two examples, one about bungee jumping and the other about gait analysis. We briefly discuss the authentic nature of these projects and the role of technology. More detailed accounts of the projects can be found elsewhere (Heck & van Dongen, 2008; Heck, Ellermeijer & Kędzierska, 2010; Heck, Uylings & Kędzierska, 2010).

WHAT DO WE MEAN BY CROSS-DISCIPLINARY, AUTHENTIC INQUIRY BY STUDENTS?

We deliberately refer in the title of this section to our meaning of cross-disciplinary, authentic student inquiry because there is no general consensus amongst researchers of mathematics and science education. They use terms like authentic science, authentic learning, authentic inquiry, authentic modelling, and so on, in various meanings (see, for example, Hodson, 2009; Roth *et al*, 2008; Woolnough, 2000).

We refer to an 'authentic student research project' as a student's investigation having the following characteristics:

1. Students work on a self-chosen, challenging, ill-defined, open-ended problem that is rooted in a real life situation instead of a more abstract or ideal situation;
2. Students do not follow some standard recipes, but they examine their problem from different perspectives, using a variety of resources and high-order skills.
3. A broad range of competencies is required to make the project a success. Think of making good use of ICT for information gathering, data acquisition, data processing and analysis, problem-solving, and reporting;
4. Students' work is open-ended in the sense that there exist multiple methods or approaches to obtain many possible or even competing results. The student researchers actually decide if the investigation is finished for whatever reason;
5. It offers students the opportunity to be in contact with contemporary, cross-disciplinary research and to learn about the nature of mathematics and science;
6. Students disclose their own understanding through a portfolio and/or a more or less polished product like a report, paper, or presentation.

A project is called 'cross-disciplinary' when more than one discipline contributes in an essential way to the process of coming to an understanding of the problem situation. The student research projects presented in this paper are mainly rooted in applied mathematics, biology and physics. The term 'cross-disciplinary' is used, and not a term like 'inter-disciplinary,' to emphasise that all disciplines are required to get satisfactory results: the whole is more than the sum of the parts. In both projects discussed in this paper, mathematical modelling meets scientific experimentation.

UNDERSTANDING PHYSICS OF BUNGEE JUMPING

We discuss the first phase of bungee jumping, when the bungee jumper falls down, but the bungee rope is still slack. In instructional material this phase is often considered a free-fall, but when the mass of the bungee rope is taken into account, the bungee jumper reaches acceleration greater than g. This result is contrary to the usual experience with free falling objects. In 2003, two Dutch secondary school students read about this in the paper of Menz (1993) on the website www.bungee.com and were intrigued. They teamed up to investigate the physics of bungee jumping and, like ‘real’ scientists, they searched for more background information; at a later stage of their investigation they even contacted David Kagan, who is one of the authors of a paper on the subject (Kagan & Kott, 1996). The students formulated the following research question: “How large is the acceleration at a bungee jump and to what extent is this acceleration influenced by the relative mass of the rope and the jumper?” Using the analogy of the motion of a bullwhip, they hypothesized that the acceleration would be greater than g and that this effect would be more dramatic in case the rope is relatively heavier compared to the jumper.

In order to find quantitative support for their hypothesis the students designed an experiment in which they could collect position-time data through video measurements on a dropped scale model and on dropped wooden blocks of various weight attached to ropes of various stiffness. Figure 1a is a sketch of the experimental setting. The students realised that working with a scale model or wooden blocks is not the same as investigating real bungee jumping, but that it would provide them with enough information on what might happen in reality and probably lead to a good understanding. This indicates a research design in which procedures to address the problem are determined, relevant variables are identified and controlled, and measurements are planned.

Note that not the measured position is the variable of interest, but a derived quantity, *viz.*, acceleration. In previous practical investigations based on video analysis with the Coach learning and authoring environment (Heck, Kędzierska & Ellermeijer, 2009), the students had learned that adequate numerical derivatives could be obtained from measured position data. Soon they realized that the mass ratio between rope and objects was too low to see an outstanding result and they repeated the experiment with objects of larger mass ratio. This is another aspect of authentic inquiry: researchers are responsible for detecting flaws in their experimental set-up and must decide how to adjust their original plans. In this case, the students also decided to concentrate on the moment when the object has fallen a distance equal to the rest length of the elastic (because they had observed that the acceleration is greatest at this point of the motion). The graph of the acceleration at the moment that the block has fallen a distance equal to the rest length of the elastic as a function of the mass ratio of elastic and block is shown in Figure 1b, together with the graph of the following theoretical result taken by the students from (Kagan & Kott, 1996):

$$a = g(1 + \mu(4 + \mu)/8)$$

where μ is the mass ratio of the elastic and the wooden block. The students noted that these graphs were alike, with the theoretical values just a bit higher. They attributed the difference mainly to the development of heat during the motion. Again, this indicates a behaviour of the students that resembles the attitude of researchers: comparing their own results with work of others and trying to explain differences by scientific reasoning.

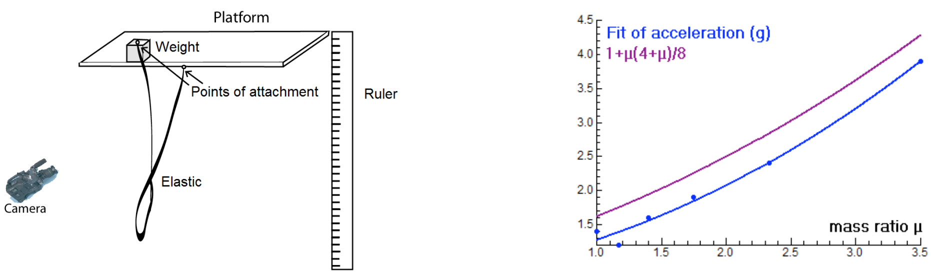

Figure 1: (a) Sketch of the experimental setting. (b) experimental and computed values.

The students published about their work in the journal of the Dutch Physics Society (Dubbelaar & Brantjes, 2003). It triggered quite a number of reactions in the journal and for almost a year on Internet. It seemed that part of the Dutch physics community, at all levels of education, was suddenly playing with chains, elastics, etc. There were complaints about the quality of physics teaching in the Netherlands, arguing that obviously(!) $a \leq g$ and that the students' work proved that the level of physics education in the Netherlands had decreased in the last decades. The editorial commentary was subtle, but to the point: "The students who wrote the paper may consider it a compliment that scepticism overcame professional physicists and physics teachers. That's how (or maybe it is just the point that) experienced intuition can be wrong." Physics intuition is easily fooled, as everyone is taught the Galilean paradigm of the motion of constant masses, according to which every acceleration must be produced by a force. A launched rocket and a falling chain or slinky are counterexamples to this line of thought. In these examples one does not deal with a rigid body, but instead with an object of changing mass. Therefore, the traditional form of Newton's 2nd law, $F = m \cdot a$, does not apply. The interested reader is referred to (Heck, Uylings & Kędzierska, 2010) for a detailed mathematical model that can be used in a quantitative approach with a modelling and simulation tool.

GAIT ANALYSIS

In this project, a high school student collected and analysed gait data in much the same way movement scientists do, namely, via recording and measurement of motions with a video tool and via electromyography, i.e., measurement of muscle activity. The authenticity of the student project was rooted in: (1) the use of inexpensive tools (a web cam, a simple EMG/ECG set and Coach software), which are on the one hand fit for educational practice and on the other hand in essence close to the techniques used by biomechanists; and (2) the student's use of the theoretical framework, nomenclature, and research methods of practitioners. That is to say, the student conducted many aspects of motion analysis herself: she formulated research questions about a self-selected gait pattern, searched and studied background information (amongst which articles and fragments of gait analysis books), designed and carried out experiments, processed, analysed and interpreted collected data, and finally wrote a paper (Heck & van Dongen, 2008).

The main research question in this project was: "What is the course of human gait?" It was specialized as follows:

1. "Which phases are distinguished in the gait cycle?"
2. "What muscle activity happens during gait?"
3. "How do bones and joints make gait possible?"

The first and third sub-questions were addressed by video measurement with a web cam of the planar motion of the leg around the hip and knee joint during normal walk on a motorised treadmill in a sports centre. The recorded data were analysed in a hip angle versus knee angle diagram and the periodic leg motion was modelled as a force-driven harmonic oscillator. The angular motion curve of the knee joint is described in this model by a sum of two sine functions, in which one frequency is nearly twice as large as the other one. These frequencies can be found by sinusoidal regression. Muscle activity is typically studied using dynamic electromyography (EMG). In case of measurement of activity of superficial muscles, surface electrodes are placed on the skin surface to detect the electric activity responsible for contraction of muscles (Perry & Burnfield, 2010). EMG recording is rather difficult because correct placement of electrodes is critical. Processing and interpreting an EMG for a muscle is also not easy. It is extremely useful in the experiment that Coach allows simultaneous measurement with sensors and video capture. The video clip and the measured data are synchronized: this means that pointing with the mouse at a point on the graph or at a table entry automatically shows the corresponding video frame and that selecting a particular frame highlights the corresponding points in diagrams, when scanning mode is on. Then, scrubbing reveals that extrema in the clearly periodic EMG signals are consistently linked to certain gait events.

This research project offered the student the opportunity to personally experience the challenges faced in gait analysis. Although she found it difficult to process and interpret the recorded EMG data, she managed to read off from the EMG signal when muscle activity was on and off in various gait patterns. She also managed (Figure 2) to interpret the processed signal in terms of phases and events in the gait cycle, simply by reasoning about what muscle groups are involved in producing a particular body part movement.

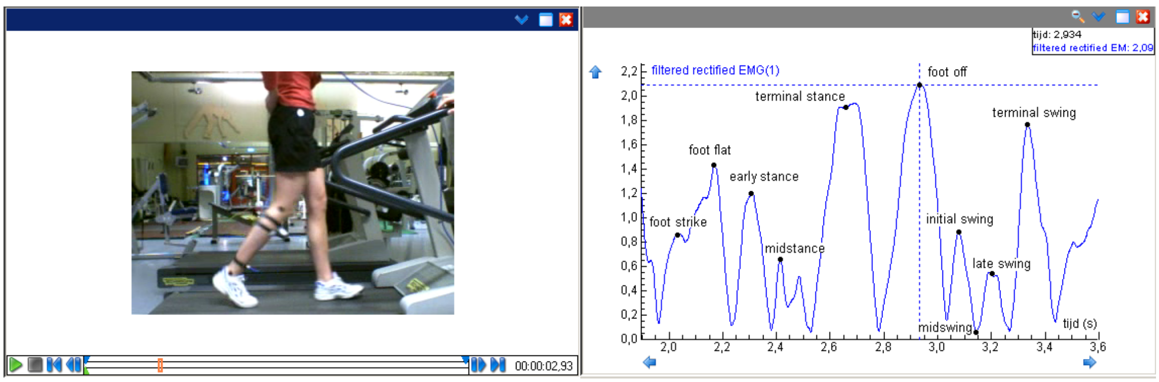

Figure 2: Processed EMG signal of the gastrocnemius for normal walking at low speed.

CONCLUSION

The educational issue in the students' investigative work that was described in this paper is the ICT-supported interaction between experimental work and mathematical model ling, in which the interpretation of results is based on methods from mathematics and science. The role of ICT in investigative work is to allow students to collect real-time data of good quality, to construct and use computer models of dynamic systems in much the same way as professionals do, and to compare results from experiments, models, and theory. Furthermore, students can develop and practise through the activities their research abilities, and be in con-tact with experts in the field of study. The fact that they must apply their knowledge of mathematics and science in a meaningful way in a concrete context leads at the same time to deepening and consolidation of this knowledge. Through this kind of practical investigation students practise the following important research abilities:

- formulate good research questions that guide the work;
- design and implement an experiment for collection of relevant data;
- apply mathematical knowledge and techniques, and science concepts in new situations;
- construct, test, evaluate, and improve computer models, and have insight in their role in science;
- interpret and theoretically underpin results;
- collaborate with others in an investigation task and reflect on the work.

ICT plays an important role in enabling students to carry out investigations at a high level of quality. It also brings the real world into mathematics and science education in an attractive way. We consider the student-driven experimental design, the modelling process, the underlying thinking processes, and the discussions with peers during the research as more important in the students' work than the obtained results. All the same, it is joyful when experiment, model, and theory are in agreement, as was the case in the project of understanding the physics of bungee jumping and in the human gait study.

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Primary student teachers' conceptions about good science teaching: Towards dialogic inquiry-based learning

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Inquiry-based learning has become standardised approach in science teaching. However, every inquiry- based educational ambition is not implemented in practice at the level they are suggested to. In order to improve our student teachers' abilities to use inquiry teaching we redesigned our science methods course. In the present paper we describe how the science method course changed student teachers' conceptions about teaching science. Results revealed that inquiry-based learning is not sufficiently present in primary student teachers' understanding. The problem-based approach was the major lack when thinking about the standards for inquiry-based learning. Also, classroom communication was not explicitly considered in students' pre-conceptions. Learning profiles of six student teachers revealed that except of two cases there was a progress in conceptions concerning inquiry-based learning and dialogic teaching. In the end four of the student teachers reached the standards for inquiry-based learning.

Systemic Education Transformation for Innovation and Economic Growth in the 21st Century

Martina Roth

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Most countries' education systems haven't kept pace with the dramatic **changes in the global economy** and the skill sets that are required for students to succeed today and throughout the 21st Century. These skills include: the ability to think critically and solve problems, the ability to think creatively and drive innovation, the ability to work cooperatively and a familiarity with the IT technologies in common use in the business world. This problem is bigger than any one government, corporation, academia or organization could solve on its own.

A **Systemic Education Transformation** is needed, in collaboration with all stakeholders: government, NGO, academia, industry. The approach must be holistic and should include **Policy** to support systemic and sustainable change, **Curriculum standards and Assessment** focused on helping student achieve the skills needed to today's global economy, **Professional Development** to help teachers integrate technology into the classroom effectively, Information and Communications Technology (**ICT**) to enable access to information, facilitate collaboration and encourage communication and creation, **Research and Evaluation** to ensure continuous improvement. Intel is committed to support the systemic education transformation on a global and local level with its Intel® Education Initiative.

ςMƎ⊆ 2010

Thursday Afternoon Session,
16th September 2010

Centre for the Advancement of Science Teaching and Learning

CASTeL

ESTABLISH – European Science and Technology in Action: Building Links with Industry, Schools and Home

Workshop Facilitators: Eilish McLoughlin[1], Odilla Finlayson[1], Ton Ellermeijer[2], Margareta Ekborg[3]

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[3] Malmö University, Sweden

ESTABLISH (European Science and Technology in Action: Building Links with Industry, Schools and Home, 2010) is a new science education project funded under the EU Seventh Framework Programme. The aim of ESTABLISH is to facilitate and implement an inquiry based approach in the teaching and learning of science and technology across Europe with second level students (age 12-18 years). To facilitate the adoption of an Inquiry Based Science Education (IBSE) methodology in the classroom, ESTABLISH will develop and provide appropriate teaching and learning IBSE units (informed by scientific and industrial communities), together with appropriate supports for both in-service and pre-service teachers. The rationale for these units lies in creating authentic learning environments for science by bringing together and involving all stakeholders that make change possible, particularly the scientific and industrial communities, policy makers, parents, science education researchers and teachers. During the ESTABLISH workshop at SMEC2010, participants will get an overview of the ESTABLISH project and its framework for developing IBSE units and will participate in discussions on the development of IBSE units.

INTRODUCTION

ESTABLISH brings together a consortium of over 60 partners from 11 European countries to encourage and promote the more widespread use of Inquiry-Based Science Education (IBSE) in second level schools. Innovation in classroom practice will be achieved through the involvement of stakeholders for the development and provision of:

- Appropriate teaching and learning IBSE units (informed by scientific and industrial communities)
- Appropriate supports for both in-service and pre-service teachers to implement IBSE
- Sharing with and informing stakeholders (teachers, parents, policy makers, scientific and industrial communities).

FRAMEWORK FOR IBSE TEACHING AND LEARNING UNITS

The criteria for each ESTABLISH Inquiry-Based Science Unit are that they conform to the ESTABLISH definition of Inquiry Based Science Education (IBSE) and that they encourage and facilitate students to be active learners. Each ESTABLISH teaching and learning Unit is built around an agreed framework, addressing selected science themes. The units are designed to inspire teachers to generate their own IBSE materials and link to real world/industrial applications and also give specific attention to gender issues and cultural adaptations. Each ESTABLISH unit is constructed to present the following information for teachers: science topic, IBSE character, Pedagogical Content Knowledge, Industrial Content Knowledge, Learning path(s), Assessment and Student Learning Activities. The number of activities per unit can vary unit as these can be used in different teaching situations and teachers as authors are flexible to make their own selection.

In terms of defining IBSE and scientific inquiry the ESTABLISH definition is based on the definition of inquiry (Linn, Davis and Bell, 2004)

> "Inquiry is the intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments."

While each IBSE activity contains the basic elements of inquiry, it is instructive to illustrate a hierarchy of such activities with respect to student participation or locus of control (Wenning, 2005), i.e. interactive demonstration/guided discovery/guided inquiry/bounded inquiry/open inquiry. These IBSE activities will be structured in the BSCS 5E Instructional Model (2010) of the Learning Cycle for ESTABLISH units. The term Industrial Content Knowledge was devised to discuss the relevance of this unit of/to industry and provide details on the type on industrial links that will be involved.

During the course of this four year project, the ESTABLISH consortium will use their IBSE framework to identify and develop 15 teaching and learning units to be implemented across their eleven participating countries. These units will include topics from across physics, chemistry, biology integrated science and technology and will be trialled and tested, in collaboration with second level teachers and students in each country, to enable these units to be adapted for each country/curriculum.

Three of ESTABLISH units (from topics in Physics, Chemistry, Biology) will be presented at this workshop, and participants will get an opportunity to discuss Unit development and structure and contribute to the development of new units in these disciplines.

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PROJECT MATHS: Learning and Teaching for the 21st Century Assessment

Workshop Facilitator: Rachel Linney

National Council for Curriculum and Assessment (NCCA), Dublin 2, Ireland.

September 2010 marks the beginning of the phased introduction of curriculum change in mathematics in all schools in Ireland and represents the most radical reform of mathematics education in post-primary schools since the formation of the state.

Informed by the experience of teachers and students in an initial group of 24 schools the draft syllabus strands written in terms of learning outcomes promote a shift away from rote learning procedures and facts towards a more student centred approach of inquiry and investigation. One of the main messages being that mathematics should be taught in contexts that allow learners to make connections within mathematics, between mathematics and other subjects and between mathematics and its applications in the real world. The aim of this workshop is to allow participants to experience how concepts are approached in a mathematics classroom.

INTRODUCTION

Project Maths is a curriculum and assessment project in post-primary mathematics that began in 2008 in Ireland, arising from the National Council for Curriculum and Assessment (NCCA) Review of Mathematics. Project Maths involves the introduction of revised syllabuses for both Junior and Leaving Certificate Mathematics in Ireland. An initial group of 24 schools introduced the first two revised syllabus strands in September 2008, and these have been refined in light of this experience. The five strands are 1. Statistics and Probability, 2. Geometry and Trigonometry, 3. Number, 4. Algebra, 5. Functions. In September 2010, these schools take the final step with the introduction of the fifth strand of the revised syllabuses. National roll-out of the changes begins in September 2010, with the introduction of strands 1 and 2 in all schools. The changes will continue in September 2011 and 2012, until all five strands have been introduced in all schools.

WHAT'S IN IT FOR STUDENTS?

According as the revised strands are introduced, students will experience mathematics in a new way, using examples and applications that are meaningful for them. These will also allow students to appreciate how mathematics relates to daily life and to the world of work. Students will develop skills in analysing, interpreting and presenting mathematical information; in logical reasoning and argument, and in applying their mathematical knowledge and skills to solve familiar and unfamiliar problems. In the recent 2010 Leaving Certificate Examinations the impact of Project Maths has shown that 18.5% of candidates from the 24 schools took the higher level paper, compared to the 16% of the candidates nationally who did so. Almost 80% of the Project Maths candidates achieved an A, B, or C grade at higher level – slightly better than the overall national performance. A greater percentage of candidates from the 24 schools also achieved A, B and C grades at Ordinary level and Foundation level than the overall national performance.

JUNIOR CERTIFICATE MATHEMATICS

In the junior cycle, a more investigative approach will be used which will build on and extend students' experience of mathematics in the primary school. To provide better continuity with primary school mathematics, a bridging framework is being developed that links the various strands of mathematics in the primary school to topics in the Junior Certificate mathematics syllabuses. A common introductory course in mathematics at the start of the junior cycle will make it possible for students to delay their choice of syllabus level until a later stage. Two revised syllabus levels will be implemented at Junior Certificate, Ordinary level and Higher level, with a targeted uptake of 60% of the student cohort for Higher-level mathematics. This is expected to facilitate increased uptake of Leaving Certificate Higher-level mathematics. Initially, a Foundation level examination, based on the revised Ordinary level syllabus, will also be provided. As the revised syllabuses and the targeted uptake become established, the necessity for the Foundation level examination will be kept under review.

LEAVING CERTIFICATE MATHEMATICS

In the senior cycle, students' experience of mathematics will enable them to develop the knowledge and skills necessary for their future lives as well as for further study in areas that rely on mathematics. Leaving Certificate Mathematics will be provided at three syllabus levels, Foundation, Ordinary and Higher, with corresponding levels of examination papers. An uptake of 30% at Higher level is targeted. The issue of the status of the Foundation level course and the examination grades achieved by candidates in terms of acceptability for some courses at third level will be explored. As the revised syllabus strands are introduced, there will be incremental changes to the examination papers.

The focus of this workshop is to allow participants to experience the approach taken by students for investigating data, which is currently being rolled out to all schools in Ireland in Statistics and Probability stand of Project Maths.

Seeking an Inquiry Culture in Mathematics Teaching

Barbara Jaworski

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In recent years my research has been focused on the use of inquiry to develop mathematics teaching (at all levels), largely in an inquiry community of mathematics educators and mathematics teachers. Most recently I am focusing on mathematics teaching at university level, particularly in a community including mathematicians and mathematics educators.

Community may be conceptualised in Wenger's terms of 'community of practice' in relation to 'mutual engagement', 'joint enterprise' and 'shared repertoire'; further, 'belonging' to a community of practice involves 'engagement', 'imagination' and 'alignment'. Along with colleagues in recent research, I have extended Wenger's theoretical constructions to include an inquiry way of being within a community of practice: thus constituting a 'community of inquiry' and encouraging an inquiry culture in mathematics learning and teaching. An essential part of such a community of inquiry is the construct of 'critical alignment' in which we look critically into what we are doing as we align with its norms and expectations.

I shall address the design of teaching, and concomitant research, that seeks to promote mathematical learning within a range of contexts in which teachers align with norms and expectations within a well-established community of practice (school or university). I will discuss forms of pedagogy to encourage the use of inquiry as a learning tool and a way of being leading to development of an inquiry culture supporting mathematical learning and understanding.

I will point to current research that is exploring teaching at a range of levels and focus particularly on research in which teachers design mathematical activity for students, using collaborative inquiry and explore the developmental outcomes of design implementation. Here the design of teaching and the design of research go hand in hand, and the dynamic process of learning about teaching goes on alongside a critical scrutiny of students' development of understanding in mathematics and analysis of data emerging from survey, interview and observation.

ςΜƎ⊆ 2010

Thursday Poster Session, 16th September 2010

CASTeL
Centre for the Advancement of Science Teaching and Learning

Lab experiments as a tool of an everyday assessment

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This poster gives an insight into a research project investigating in which ways pupils' practical activities can be used as a tool for diagnosis and assessment. Looking at the development of school chemistry education one can see that the way of teaching has changed and the variability of teaching methods has increased. In spite of these changes assessment tools used at school remain mostly the same as before: paper and pencil tests which often focus on encyclopaedic chemical knowledge. Thus, currently we have to complain a gap between the quality of teaching and the ways of testing of what have been taught. It seems therefore feasible to develop new assessment tools that focus on diagnosis. Practical activities can be expected to be useful as a suitable assessment instrument: They offer possibilities for learning in many important fields of competence and have a great importance in school chemistry teaching. To realize an assessment by the pupil's lab work instruments were developed and tested which can be produced by the teachers themselves and which are suitable for everyday chemistry lessons. Some of the instruments used in the project will be presented, the experiences that were made using them will be reported and selected results about the attitudes of pupils and teachers towards experimenting before and after participating in the project will be presented to give an idea of the effects of using pupils' lab work as a tool for diagnosis and assessment.

How the South-Eastern Mediterranean Environmental Project (SEMEP) can help implement the new 2010 Curriculum of Cyprus

Constantinos Phanis

Ministry of Education and Culture, Cyprus.

The South-Eastern Mediterranean Environmental Project (SEMEP) is an UNESCO program. The 15th annual meeting of the National Coordinators has taken place in Paris from the 17th to the 19th of May at UNESCO Headquarters. This interdisciplinary environmental education project aims to foster knowledge, awareness and understanding of the common historical, social, cultural, ecological and ethical heritage in order to promote a culture of peace and tolerance through science among countries. There are twelve SEMEP schools in Cyprus. SEMEP schools maintain a geographic balance (rural / urban areas – all districts of Cyprus) and students are encouraged to work on topics that relate / affect their lives and their local community.

A plan of how science can be integrated with an environmental awareness of sustainability is promoted through the 2009-2010 Cyprus SEMEP which supports the implementation of the new 2010 national curriculum. As part of the new science curriculum guidelines the students will be expected to collect and record data, analyse their data and draw conclusions. The Cyprus SEMEP has underlined the importance of the student projects to fulfill the above requirements. The project allows a team of students, teachers and science academics to apply the newly developed (2010) national curriculum which will be implemented from 2011. Students representing SEMEP schools communicated and published their results in a seminar that took place in an environmental centre. At the seminar the students' projects were evaluated by the teacher instructors and science academics through a round table discussion. At the environmental centre the students additionally carried out a study on the ecology of a habitat. The methodology of the investigation was discussed and the students collected data which they presented in the form of tables and graphs. The students themselves evaluated the methodology and suggested further investigations to solve the problem. The students were encouraged to search valid sources and to use technical language using visual aids to communicate information and ideas. A new pedagogic approach is promoted involving pupils and teachers more actively, engaging them with experiments which allow integration of science and developing skills necessary for scientific research.

BACKGROUND

In 2009 the 14th annual meeting of SEMEP national coordinators took place in Slovenia. The SEMEP national coordinators presented their student projects and agreed the theme for 2009-2010: "Bridging cultures, biodiversity, ecology, history through science education". The role and aims of SEMEP is summarized in Table 1.

Table 1: The role and aims of SEMEP.

1	**SEMEP** is a **UNESCO** environmental education project focusing primarily on the South Eastern Mediterranean sea region, involving students at the upper primary and secondary levels in both formal and non formal sectors. Member countries include: Greece, Cyprus, Turkey, Italy, Slovenia, Croatia, Bulgaria, Romania, Israel, Palestinian Authority, Egypt, Malta and Jordan. It is intended to create an educational, environmental and cultural network for contact and cooperation among students and teachers in the region that reaches beyond the school to the community.
2	**SEMEP** learns on **UNESCO** experiences in other environmental projects.
3	**SEMEP** provides an opportunity to consider environmental issues that are of common concern to countries in the region. More than just another curriculum initiative it addresses the need to promote this consciousness in school going children and the community.
4	**SEMEP** thus aims at interrelating education, geared to both the natural and social environment, with cultural values. Such values are of particular importance in this part of the world where the development of an extremely rich civilisation involved a continuous interchange of social, philosophical and cultural values.
5	**SEMEP** encourages a holistic approach to education within the framework of existing school curricula. It is based on problem identification, problem solving, determining decision making parameters, actual experiencing and skills in a wide range of communication techniques.
6	**SEMEP** is interdisciplinary in character. In Cyprus twelve secondary schools participate in the SEMEP project with the involvement of teachers and students, notably of the natural and social sciences such as biology, physics, chemistry, geography, economics, civics and history as well as arts and languages.
7	**SEMEP** is formulated to encourage collaboration at both Governmental and non-Governmental (NGO) levels.

Knowledge of environmental issues is interrelated with many of the political and moral dilemmas posed by contemporary society that can only be investigated through a well-defined scientific methodology. The PISA 2006 Science competencies for tomorrow's world indicate that on average across OECD (Organization for Economic Co-operation and Economic Development) countries, **only** 1.3% of 15-year-olds reached Level 6 of the PISA 2006 science scale, the highest proficiency level. It is thus obvious that a new approach is required to increase the number of students who could consistently identify, explain and apply scientific knowledge, and knowledge about science, in a variety of complex life situations. The SEMEP 2009-2010 Cyprus project has developed a novel good practice, a new paradigm for science and environmental education in an attempt to integrate science and environmental awareness of sustainability as part of education for all and as part of civic education.

METHODOLOGY

A new innovative working template calendar was developed in Cyprus to provide guidance and to improve monitoring, data collection, evaluation and reporting.

1. October 2009: Teacher training seminar took place at the Pedoulas Centre of Environmental Education.
2. December 2009: Research topic and methodology of each SEMEP school was approved.
3. March 2010: The first Pancyprian two day student seminar took place at Pedoulas Centre of Environmental Education.
4. May 2010: Student presentations were published on the internet (Ref: **www.unesco.org.cy**
5. April 2010: SEMEP partner school visit.
6. An international summer school is planned for 2011.

The SEMEP seminars allow a team of teachers and academics to discuss the scientific methodology of the students' project including the following parameters:

- Observe / Identify a Social and Ethical dilemma
- Plan Research
- Record/ Measure evidence - Collect data
- Interpret/ Analyse data - Draw conclusions
- Evaluate
- Communicate - Report/Writing/ Publishing - Results

The rationale is to develop scientific literacy and to advocate for an integrated science. The SEMEP schools' activities included interviews, photography,nature walks, research through the web/internet, visits to universities, zoos, wineries, sand dunes, wild life parks, hospitals, dairy industries, fish farms, research Institutes and Environmental Centres in order to investigate a social /ethical dilemma so as to acquire new knowledge through a designed scientific methodology. The role of the teachers during the project was to facilitate the work of students. At all times during the project, from initial planning to writing up, the students were encouraged to discuss their ideas with the teacher and their team. The writing of the report was entirely the students' work. At least five students of mixed ability collaborated on the same topic, which in most cases was an issue of particular concern to the school's local community. The report was word processed and presented as a power point presentation. Project Presentations included:

- Ethnobotany
- Sand Dunes
- Biodiversity of Scented Herbs of Cyprus
- Trees in Our Lives
- Solar and Bioclimate Designs
- Charcoal Production and the Environment
- The Role of Women in Cyprus.

The student presentations took place in March 2010 during the first Pancyprian two-day student seminar at Pedoulas Centre of Environmental Education. The students also participated in a designed experiment which linked scientific research with awareness and understanding of the common historical, social, cultural, ecological and ethical heritage of the Mediterranean region. The students performed an experiment to investigate habituation of a giant Mediterranean snail to a stimulus (Methodology Edexcel 2010 curriculum, 2010)

The presentation also included:

- History of snails: http://news.bbc.co.uk/2/hi/science/nature/7572553.stm
- Evolution of snails: http://news.bbc.co.uk/2/hi/7971200.stm
- Reproduction and distribution of snails using scientific methodology
- Economy of a snail farm
- Cooking of snails (French - Escargots a La Bourguignonne (Snails with Garlic Butter)
- Personal experience

The students were asked to answer the following questions:

Q1 Write a ***hypothesis*** which this experiment will test.

Q2 Using your ***graph***, state whether you think there is a positive, negative or no correlation between the number of stimulations and the time for eye stalk withdrawal.

Q3 ***Explain any patterns*** or trends in your data, supporting your ideas with evidence from the data and your biological knowledge of habituation. Relate your findings to your hypothesis.

Q4 ***Suggest*** a reason why snails may become habituated to a prodding stimulus in the wild.

Q5 ***Evaluate the procedure*** used for this experiment.

Q6 Develop a hypothesis regarding snail adaptations and ***design a method to investigate*** how an abiotic factor affects snail distribution in an ecosystem.

EDUCATIONAL IMPLICATIONS

It is imperative for schools to teach more effectively in order to foster scientific literacy, rather than cover more content. 'Science for all' is based on the conviction that a scientifically literate person is one who is cognizant that science, mathematics, and technology are human enterprises dependent upon one another. Project 2061: (Science for All Americans) (Rutherford & Ahlgren, 1990).

The idea of SEMEP is to connect subject areas because in the real world, people's lives are not separated into separate subjects; therefore, it seems only logical that subject areas should not be separated in schools. The Cypriot national reform effort (2009-2010) is currently stressing the need to integrate or make connections among the curriculum. The Cypriot SEMEP project is designed to promote science, mathematics, and technology and gives emphasis to the 7E learning cycle (Eisenkraft 2003). "What do you think?" questions *elicit* the students' prior conceptions. The ecosystem *engages* and motivates students by arousing their interest. The students *explore* the environment under investigation and make predictions, design experiments, collect and analyze data, draw conclusions, and develop hypotheses. Various degrees of teacher and student ownership and control are possible. New concepts are introduced and new terms are *explained*. This authentic format allows students to e*laborate* by practicing the near transfer of learning. Substantial evidence exists to indicate that fieldwork, properly-conceived, adequately-planned, well-taught and effectively followed up, offers learners opportunities to develop their knowledge and skills in ways that add value to their everyday experiences in the classroom (Rickinson *et al* 2004).

The SEMEP Cyprus 2009-2010 project has produced innovative practices and the SEMEP network shows ways to develop regional and international understanding (Minutes of the 15th Meeting of SEMEP National Coordinators, UNESCO, Paris, 2010).

The 16th annual meeting of national coordinators will take place during the month of May 2011 in Nicosia, Cyprus, in collaboration with the Cyprus Ministry of Education and Culture and the Cyprus National Commission for UNESCO and a future project which includes an assessment which will *evaluate* student performance in designing experiments, interpreting data and evaluating methodology will be proposed.

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Exploring the Use of Inquiry-Based Leaning in Second Level Science Education

Joanne Broggy and George McClelland

National Centre for Excellence in Mathematics and Science Teaching and Learning (NCE-MSTL)

The introduction of the new Junior Certificate Science syllabus in 2003 saw an increased emphasis on scientific investigation skills and the application of science process skills in student activities. To complement this change a new assessment structure was devised and implemented, providing practical assessment components; Coursework A and Coursework B. However, since the introduction of the Coursework B assignment significant problems have been highlighted by the science teachers; including the workload involved, poor ability of the students to carry out the investigations, lack of resources and the effect the increased workload is having on teaching time required to finish the syllabus (Higgins, 2009).

This paper reports on a collaborative research study between the National Centre for Excellence for Mathematics and Science Teaching and Learning (NCE-MSTL) and the Kerry Education Service (KES) to develop the investigation skills of junior cycle science students in an effort to tackle the negative issues arising from Coursework B. The project aims to utilise Inquiry Based Learning (IBL) as a teaching approach that will encourage students to develop and improve their ability in carrying out scientific investigations using Coursework A as a framework to prepare them for Coursework B in the third year of the Junior Certificate Science syllabus. Particulars of the inquiry based classes together with the structure of the project will be discussed.

INTRODUCTION

With the introduction of the revised Junior Certificate (JC) science syllabus, practical work and problem solving have become the forefront of the science classroom through the incorporation of scientific investigations both within coursework A and B. A recent article (Higgins, 2009) in *Science* magazine reports the findings of a questionnaire administered by the ISTA (Irish Science Teachers Association) which asked science teachers' opinions of the new syllabus. Science teachers around Ireland reported that since the introduction of the revised syllabus their workload increased as the majority of them (91.4%) are giving a considerable to very considerable amount of time to help their students with coursework B (Higgins, 2009). The impact of coursework B on teachers' satisfaction of the syllabus is also reported in a study carried out for the Department of Education and Science (Eivers, Shiel and Cheevers, 2006). The report states that 41.2% of science teachers are dissatisfied or very dissatisfied with the Coursework B element of the syllabus (Eivers *et al*, 2006, p. 15). One possible reason for this dissatisfaction may be that teachers are required to spend a large amount of time helping their students complete their work because the students are unable to carry out the investigations themselves due to poor problem solving skills and lack of experience using investigative practical approaches. The Junior Certificate syllabus purports that the experience gained through the completion of Coursework A is sufficient to prepare the junior cycle students to complete the Coursework B component. However, this is not the case as the students do not get the opportunity to develop their skills in planning and conducting investigations when completing the Coursework A experiments as these are often taught using a 'recipe-style' approach and the students simply complete the task without thought or reflection. In an attempt to rectify this problem and shift the focus from students simply following the 'recipe' when carrying out experiments and passively receiving information from the teacher, this research study aims to provide a framework which will guide, both the teachers and students alike, through the investigative science process. This is turn will advance and improve the students' ability in problem solving and consequently prepare them for Coursework B in the third year of their junior cycle.

THE RESEARCH PROJECT

The research project is a collaborative project with the National Centre for Excellence in Mathematics and Science Teaching and Learning (NCE-MSTL) and the Kerry Education Service (KES) which will commence at the onset of the academic school year 2010/2011. The action research project involves the eight vocational schools within the KES and is aimed at developing Junior Certificate science students' scientific process skills. The three specific aims of the project are:

1. To develop the students' investigative skills through inquiry based lessons plans using Coursework A as the framework.
2. To provide Continual Professional Development (CPD) training to teachers in scientific process skills necessary for Coursework A and Coursework B.
3. To develop a valuable teaching resource incorporating a number of investigative approaches that can be used by both the teacher and students when carrying out scientific investigations.

In order to successfully satisfy these three aims the principal researcher (Joanne Broggy) has planned a three year research project so as to record and report the progress of a group of junior cycle students as they advance from year one to year three in junior cycle science. The planning for this project commenced in February 2010 and since then a 'lead' teacher from each of the schools involved has been identified. The participating teachers each received information on the project outlining the structure and the level of involvement required from them. At the onset of this project in September 2010 the teachers involved will attend a full day training session on IBL. This training session will outline the particulars of IBL including the process involved in lesson planning for inquiry lessons. The teachers will also observe an exemplar lesson that incorporates IBL.

A key output of this research project is evaluated continual professional development (CPD) training. Within the first year of the project the eight teachers involved will receive CPD training on elements that are applicable to the teaching and learning of science and also on the use of IBL in science classrooms. Topics covered in these training sessions include scientific language, the teacher as a facilitator of learning, reflective practice and cooperative learning, amongst others. These CPD training sessions will run during school time in the KES and will be two hours in duration. The initial year of the project is divided into two phases – autumn and spring. During both phases the teachers will receive two CPD training sessions each. The eight participating schools involved will work from the same scheme of work which will allow the teachers to support each other during the project.

The use of the Coursework A investigations is fundamental in this research project as it is through these experiments that the students will practice and develop their scientific process skills. The data collected from this project will be in the form of teacher reflections. Participating teachers will be asked to comment on their experience using IBL when completing the Coursework A experiments. It is aimed that the Coursework A experiments outlined in the syllabus will be conducted in an investigative manner where students will guide their own discovery. The following diagram (Figure 1) represents the predicted structure of year one of the project.

February 2010 – May 2010

- Planning project
- Identifying 'lead' teachers
- Finalise Scheme of work

September 2010 – December 2010 (Autumn)

- Intensive training session
- CPD training
- Coursework A investigation
- CPD training

January 2011 – April 2011 (Spring)

- CPD training
- Coursework A investigation
- CPD training
- Coursework A investigation

Figure 1: Planned structure for year 1 of the research project.

THE USE OF INQUIRY BASED LEARNING

In order to develop junior cycle students' scientific process skills change is required in the teaching and learning of science. For this project the most significant change is the introduction of inquiry based learning. In the past teachers have expressed negative views on the use of inquiry based learning, however often their understanding of inquiry based learning is fragmented and unclear. It is often perceived as simply asking the students questions at the beginning of a lesson and carrying out group work, however in order for the lesson to facilitate an inquiry based approach several keys stages must be addressed. These have being identified as the five E's in the past; engagement, exploration, explanation, elaboration and evaluation. The integration of these five stages will allow the students to take responsibility for their own learning, in addition to allowing them to "make meaning and develop deep science conceptual and procedural understanding from classroom experiences" (Klentschy and Thompson, 2008, p.2). The key characteristics of each stage are outlined below.

Engagement

In the first stage the students encounter the instructional task which makes connections between their past and present learning experiences. The engagement phase is used to motivate and engage the students and there are several ways to do this which include the use of interesting questions, video clips demonstrating a surprising event and the use of intriguing photos. This stage of the lesson is extremely important as it builds curiosity and provides direction for the remainder of the lesson.

Exploration

This stage imitates guided discovery. The students use concrete experiences to make observations, collect data and test predictions. During this stage the teacher provides scaffolding by observing, questioning and guiding.

Explanation

The third stage, explanation, is the stage where students begin communicating their abstract experiences. The students share their experiences and discoveries with both their peers and their teacher. It is during this phase that new scientific language is introduced and related to the students' experiences. Together, the students and teachers utilise the concepts and the experiences to describe and explain the phenomenon and answer the initial question.

Elaboration

In the elaboration stage the students expand on the concepts they have learned, make connections to other related concepts and apply their new understandings to the world around them and real life applications. The application of this new knowledge provides the students with an opportunity to move beyond memorization to deeper understanding of what they have learned.

Evaluation

The final stage of the inquiry process provides the teachers with an opportunity to assess the students' knowledge and provide feedback on performance. This can be carried out through the use of several assessment tools including the use of essay style questions, multiple-choice and concept mapping.

SUMMARY

This poster represents the planning and structure involved in a large collaborative project with the NCE-MSTL and the KES which will commence at the beginning of the academic school year 2010/2011. Elements of the 5 E's together with the constructivist framework will be intertwined to develop lesson plans that will encourage the use of IBL in junior cycle science classrooms. The project is extremely timely and important as it aims to improve junior cycle science students' scientific process skills at a time when they are struggling to complete individual investigations outlined in the JC syllabus.

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Using mathematical identity to gain insight into how students prefer to learn mathematics

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In early 2009 the authors carried out research into pre-service teachers' mathematical identity both in Belfast and Dublin. Mathematical identity is considered as the multi-faceted relationship that an individual has with mathematics, including knowledge and experiences, perceptions of oneself and others. One of the issues discussed in focus groups was how students preferred to learn. In particular they mentioned the value of situating mathematics in a practical or 'real-life' context, figuring things out on their own, discussing ideas and finding a breakthrough. This paper will focus on the discussion amongst students in Dublin and, in particular, their criticisms of their experience with mathematics teaching at second level. The evidence will be situated in the context of 'Project Maths', the programme of incremental curricular reform in mathematics in post-primary schools in (the Republic of) Ireland, now in the early stages of implementation. Evidence suggests that the exercise of uncovering and exploring the mathematical identity of pre-service teachers is very useful for raising awareness of approaches to teaching which are likely to result in authentic learning of mathematics.

Identifying the chemical misconceptions of pre-service science teachers

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It has been well documented that students of science hold many misconceptions in their subject area (Yeziersky & Birk, 2006; Kerr & Waltz, 2007; Taber, 2009). These misconceptions are typically deep rooted and difficult to change, embedded in the students' long term memory. An issue of particular concern is the chemical misconceptions of science teachers as they can often be the source of student misconceptions as they are imparted through the teaching of the subject. (Kind, 2004; Kind, 2009)

This study examines pre-service science teachers' misconceptions in areas of general chemistry. This was carried out by implementing a pre and post chemistry concept test during a 3rd year chemistry pedagogy module. Initial results show that pre-service teachers do indeed hold deep misconceptions in certain areas of their subject. This is also reflected in their level of confidence in teaching chemistry, with 47.8% of students stating that they have very low confidence or no confidence in their ability to teach chemistry when they commence their next teaching practice. Interestingly, students' lack of confidence and misconceptions does not lead to a negative attitude towards their subject, with 54.8% of students feeling either very positive or positive towards chemistry. It is now intended to run this study on a greater scale, across all four years of pre-service science teachers training, in order to examine whether misconceptions change or develop as the student's progress through their course.

INTRODUCTION

Chemistry is a difficult and complex subject; this is not a novel idea (Childs & Sheehan, 2009). The difficulty of the subject is, in the main, due to its abstract nature. This leads to student misconceptions, which are often held quite deeply and are difficult to change (Reddish, 1994; Johnstone, 2006). This is of considerable concern for pre-service science teachers, as they may leave their third level education without having ever had their own chemical misconceptions being addressed. This may lead not only to a poor subject knowledge and understanding, but also to a teacher's own misconceptions being passed onto their students, thus creating a vicious cycle.

Johnstone's (1997) model (Figure 1), on the following page, discusses how these alternative conceptions are formed based on the effect of the students' previous knowledge and their perception of new information, as the abstract and complex nature of chemistry can lead to an information complexity when students are trying to digest new topics, in other words, an information overload. It has been documented that even when results derived from an experimental situation do not fit with the students own conception, students may actually perceive the results to fit, when they do not. (Driver cited by Taber, 2002)

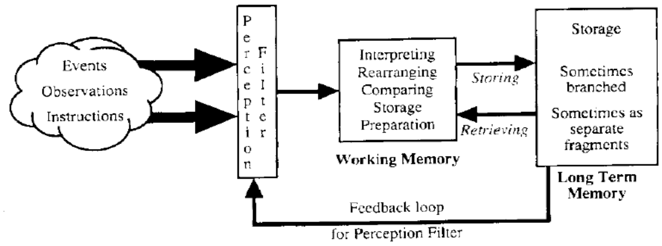

Figure 1: How learners construct knowledge (Johnstone, 1997).

Taking this information processing model into account, the science teacher must be prepared to address their own misconceptions and to be aware and able to adequately tackle their students' ones, in order for deep change to take place. Studies have shown that when student misconceptions are specifically addressed in an appropriate manner the student can change, otherwise they will remain quite stable and deep rooted. (Holt-Reynolds cited by Waldron, Pike, Varley, Murphy and Greenwood 2007; Hayes & Childs, 2009)

METHODOLOGY

This study is a pilot study, which will lead onto a larger project guided by the findings of this study. The initial research questions which have been used to guide this study are: What misconceptions do pre-service teachers hold, is there a link between misconceptions and gender, what effect do misconceptions have on students' feelings of confidence and preparedness in teaching chemistry?

In order to examine the misconceptions of the pre-service science teachers a chemical misconception test was developed. The test consisted of 17 questions which encompassed the conceptual areas described in Table 1.

Table 1: Structure of the pre-service science teacher chemical misconceptions test and source of questions.

Concept Area	Questions	Sources of questions
Particulate nature of matter	Q2, Q5, Q6	Mulford and Robinson (2002); Sheehan (2010); Yezierski and Birk (2006)
Equilibrium	Q4	National Institute for Science Education (2008)
Concentration of solutions	Q14 (a – g), Q17 (a, b)	National Institute for Science Education (2008)
Atomic structure	Q13, Q16 (a, b)	Mulford and Robinson (2002); National Institute for Science Education (2008)
Chemical reactions	Q1, Q11 (a, b), Q12 (a, b)	Mulford and Robinson (2002); Sheehan (2010); Developed by author
Reacting masses and stiochiometry	Q15	Developed by author
Phase changes	Q3 (a – e)	National Institute for Science Education (2008)
Organic chemistry	Q7, Q8, Q9, Q10 (a - c)	Childs, O'Dwyer & Hanley (2010)

It was impossible to test the students for misconceptions in all areas of the Leaving Certificate chemistry syllabus due to time constraints. It was therefore decided to test areas that studies had shown to be problematic and that the authors knew from their own experience with the students to be areas of difficulty (Peterson and Tregust, 1989;

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Mulford and Robinson, 2002; Yezierksi and Birk, 2006; Tan and Taber, 2009; Sheehan, 2010).

Students were given the test instrument during a 3rd year chemistry pedagogy lecture session (N = 55) and there was a response rate of 80% (n = 44) for the pre-test and 53% (n = 29) for the post-test and 26 students completed both the pre-and the post-test. Students were also given a questionnaire examining their confidence for their upcoming 4th year teaching practice experience. Responses were coded and analysed using SPSS.

RESULTS

The key areas that students have misconceptions in are summarised in Table 2 below.

Table 2: Results of pre- and post-concept tests by concept area

Concept Area	**Pre - test average % (n = 26)**	**Post - test average % (n = 26)**	**Overall Average % (n = 26)**	**Significant difference (p < 0.05)**
Particulate nature of matter (Q2, Q5, Q6)	48.7	48.7	48.7	No
Equilibrium (Q4)	76.9	84.6	80.8	No
Concentration of solutions (Q14, Q17)	63.7	58.6	61.2	No
Atomic structure (Q13, Q16)	34.6	26.9	30.8	Yes (negative – question 13 – energy levels)
Chemical reactions (Q1, Q11, Q12)	55.2	59.2	57.2	No
Reacting masses and stiochiometry (Q15)	19.2	15.4	17.3	No
Phase changes (Q3)	50.0	66.2	58.1	Yes (positive)
Organic chemistry (Q,7, Q8, Q9, Q10)	56.9	50.8	53.9	Yes (negative – question 10c – skeletal structure)

For the most part students did not improve in their chemical conceptions in individual areas, other than in phase changes. When examining the results of the whole cohort in both the pre- and the post-test, a significant difference was noted between the two scores. Overall students scored significantly higher in the post test, indicating that there was a slight improvement in their conceptual understanding of chemistry topics between the pre- (M = 52.4, SE = 2.54) and post-test (M = 57.0, SE = 2.91, $t(25) = -2.459$, $p = 0.021$, $r = 0.44$). The misconceptions exhibited by students in the pre-test were not specifically addressed during the course of the module.

Course area also appeared to have a part to play in the student scores in both the pre-and the post-test. Students who were in the course area of the physical sciences (65.1%) scored significantly better ($p < 0.05$) than those in either the biological sciences (49.7%) with chemistry or in physical education with chemistry (45.5%).

Other factors involved in students' concept test results were gender. Similarly to other studies (Sheehan 2010), it was found that the students' gender was significant ($p < 0.05$) in their scores in the misconceptions test. Male students (60.8%) scored better than female students (49.4%), in this sample. While pre-service teachers may not be aware of their own chemical misconceptions it does have an effect of their confidence, students with higher scores in the pre-misconceptions test were more confident in their ability to teach chemistry at leaving certificate level, yet 54.8% of students were positive or very positive about the subject. There was a strong correlation between the students' confidence in their ability to teach chemistry and their pre-test results ($p < 0.01$).

CONCLUSION

The overall performance of the pre-service science teachers in the concept tests was poor. The cohort tested was in their third year of study, and it would be hoped that at this stage of their third level education there would be less chemical misconceptions. Some areas examined, such as reacting masses and stiochiometry, atomic structure and particulate nature of matter, and chemical reactions were particularly weak. This is to be expected, as if chemical misconceptions are not specifically targeted and addressed correctly this will not change. Gender and course area appear to be significant factors in this study, while this does link to other studies with similar findings (Sheehan 2010) it may also be due to the small size of the classes within the cohort. It can be clearly seen in these findings, and in what other studies have taught us, that just teaching and learning more chemistry content is not enough. It does not remove the issue of chemical misconceptions, and we are left with pre-service science teachers whose results indicate, have an inadequate understanding of their subject.

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The use of Classroom Response Systems and Multimedia Presentations to enhance Teaching and Learning in First Year Physics

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The purpose of this study is to investigate the use of technologies including classroom response systems and multimedia presentations to enhance teaching and learning in first year physics. Draper & Brown claimed appropriate use of the response pad systems can increase interactivity by provoking students to think, making them feel secure enough to answer questions anonymously, and increase their confidence in their own learning capacity. A related aim is to systematically integrate the contrasting delivery modes of lectures, and laboratory practical for physics in order to develop students' conceptual understanding of physics in relation to physics laboratory experiments. To do this, a range of learning objects and instructional aides will be developed to help students to explore physics concepts and to develop their understanding of these concepts.

A mixed methods design format will be used for this research project. A combination of qualitative and quantitative analyses will be carried out using the following testing instruments: surveys, questionnaires and pre- and post-testing. This approach requires that the qualitative and quantitative data gathering will take place over the same testing time. The results should indicate if using technologies will enhance teaching and learning in first year physics and whether the contrasting delivery modes of lectures, tutorials and laboratory practical for physics can be better integrated in order to develop students' conceptual understanding of physics. Preliminary survey data was collected during a piloted use of response pads systems in two first year physics lectures with encouraging results.

CAN RESPONSE PAD SYSTEMS AND MULTIMEDIA INCORPORATE THE CONSTRUCTIVIST MODEL OF LEARNING INTO THIRD LEVEL PHYSICS?

New technologies have the potential to enhance teaching and learning in first year physics and to integrate the contrasting delivery modes of lectures, tutorials and laboratory practical in order to develop students' conceptual understanding of physics. Verbal questions in lecture halls can only assess a few students learning and students are typically not very forthcoming with answers. Written work examines all the students but the lecturer is unable to give instantaneous analysis of the student's answer. The lecturer is unable to provide timely response to clarify misconceptions. Response pad systems (RPS) act as an alternative to verbal and written questioning (Mun, Hew and Cheung, 2009). The RPS can be used for asking real time multiple choice questions for immediate concept checking, quizzes, interactive demonstrations, data gathering and to take attendance. The RPS allows an educator to create course appropriate questions, and allows the facility to track each student's performance data generated during lesson or team activities. A receiver instantaneously produces a histogram of student responses and can also record information about individual responses. The RPS allows all the students to answer questions individually with the touch of a button. Immediate correction by the system takes place and the score results are displayed to the lecturer. Lecturers can then adjust their lesson to the needs of the pupils to tackle their misinterpretation in the lesson (Hennessy *et al*, 2007). The constructivist learning model suggests that learners' engagement is central in learning (Siau, Sheng and Nah, 2006) by allowing whole class class student teacher interactivity. When students interact with instructors, they are more actively engaged in learning. When interactivity is present in the classroom, students are more motivated to learn, but also more attentive, more participative, and more likely to exchange ideas with instructors and fellow students (Hennessy *et al*, 2007).

Multimedia applications can provide students with experience of concepts via graphics, audio and animations. Multimedia applications offer idealised visual depictions of physical phenomena which may not be possible in a lecture hall (Hennessy *et al*, 2007). This can increase student experience of various laboratory concepts by introducing them into lectures. Instructional videos of laboratory experiments also allow the students to preview experiments before they perform it in the laboratory and revise the experiment after they have preformed it. This could enable pupils to focus on significant processes and outcomes of the experiment. Java Applets are mini applications that provide total interactivity, combined with full multimedia and graphics that allow students to easily visualise difficult concepts. Java Applets can offer students opportunities to interpret and challenge their knowledge of concepts by manipulating components of the Applet. Investigative questions may be examined by the student and accurate data may be obtained (Hennessy *et al*, 2007). They also have the advantage of allowing students to have a personalized learning experience (Sethi, & Antcliffe, 2002). Moshell and Hughes (2002) suggest constructivist learning occurs through the exploration of multimedia applications and through the modification or manipulation of these applications. Finally all multimedia applications allow the student the option of repeatable interaction, providing more opportunities for the student to experience and construct their physics ideas.

METHODOLOGY

This research involves two related approaches. First, a set of interactive applications will be compiled based on practical physics experiments and associated concepts and these will be integrated into the physics lectures and made available to students online. Second, a set of multiple choice questions will be developed to aid in the development of conceptual knowledge in physics. Associated surveys, questionnaires pre- and post-tests, will be compiled that will examine conceptual physics understanding. A mixed methods design format will be used to test the effectiveness of these methods. A combination of qualitative and quantitative analyses will be carried out using the following testing instruments: surveys, questionnaires and pre- and post-testing. The pre and post-tests for conceptual understanding can be administered in both the lecture as part of the interactive engagement technique and the laboratory practical using the response pad systems. The questionnaires can be administered either in the lecture hall or online.

PRELIMINARY DATA

Preliminary work has been completed on developing the multimedia presentations. These incorporate live video of lab procedures combined with onscreen annotation and references to theoretical models. In some cases, java applications have also been identified to support interactive manipulation of data. It is hoped that these objects will help bridge a perceived gap between lectures and lab work, where students have difficulty integrating their learning from the two contrasting modes of delivery. These objects will be piloted and evaluated in the current academic year.

Response pad systems have been piloted in two lectures for two physics classes. In total 65 students were surveyed. The use of classroom response systems in lectures provided some very positive data. Figure 1 and Figure 2 yielded similar results. More than half of the students rate the RPS as effective at helping them to discover their strengths and weaknesses with the minority rating the RPS as ineffective. An analysis of the students

RPS question scores with regard to their exam scores may suggest a correlation between the effectiveness of the RPS questions at discovering areas of weakness and strengths in physics topics. Figure 3 and Figure 4 show a high proportion of the students in rating the RPS as effective at improving their physics knowledge and engaging them in class.

How effective are the response pad systems at helping you discover your strengths in physics?

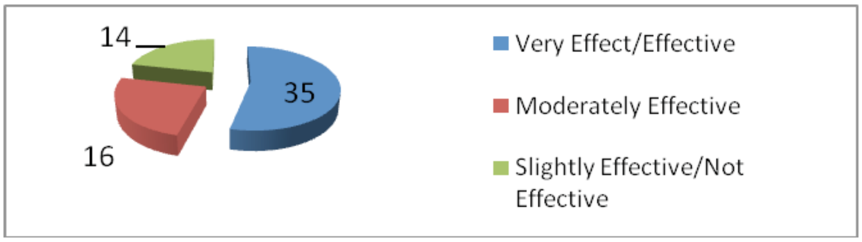

Figure 1: Effectiveness of response pad systems at revealing strengths in physics.

How effective are the response pad systems at helping you discover your weaker areas in physics?

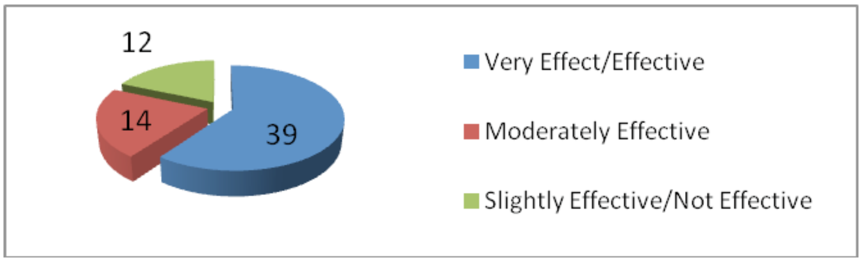

Figure 2: Effectiveness of response pad systems at revealing week areas in physics.

How effective are the response pad systems at improving your knowledge of physics concepts?

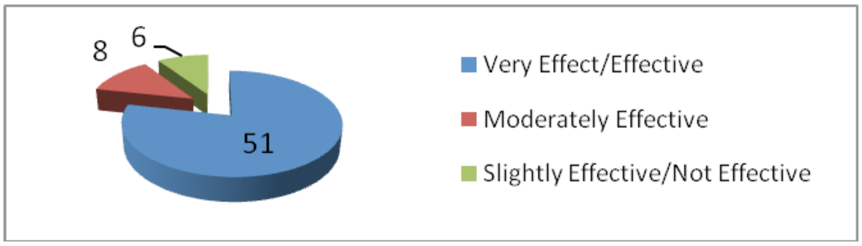

Figure 3: Effectiveness of response pad systems at improving knowledge in physics.

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How effective are the response pad systems at engaging you in physics class?

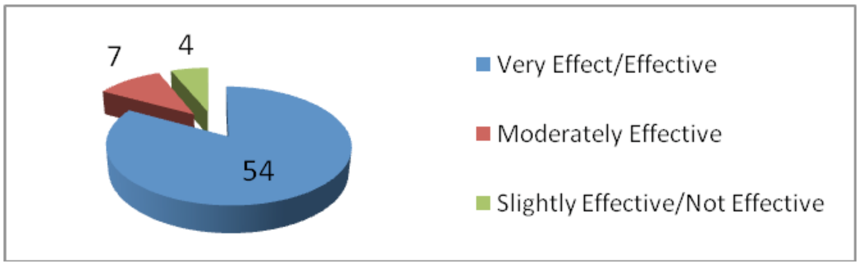

Figure 4: Effectiveness of response pad systems at improving engagement in physics.

CONCLUSION

New technologies can support teaching and learning in first year physics. The introduction of classroom response systems show positive student feedback and hence encouraging results for their implementation in future lectures. When combined with the multimedia objects described here, it is hoped to better engage students and to enhance their conceptual understanding of physics concepts.

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Maximising engagement and knowledge transfer in large classes

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Limerick Institute of Technology, in conjunction with the National Centre for Excellence in Mathematics and Science Teaching and Learning (NCE-MSTL) is seeking to undertake an evidence based research project into innovative uses of technology for the enhancement of teaching and learning of mathematics for first year engineering students.

Most first year students of engineering and science in the Institute of Technologies in Shannon region have met grade C and B in ordinary level leaving certificate mathematics (Bradley, 2008). These students often find the mathematics component of their course challenging. Evidence from diagnostic testing at LIT (Bradley, 2008) has shown that they often are ill-equipped to independently deal with the level of mathematics required for the first year of their course. Frequently coupled to this lack of mathematical skills is a dislike, fear or lack of understanding of the subject resulting in lack of participation in class. This project aims to create an active learning environment by incorporation of formative assessment and feedback and using 'Classroom Response System' to engage students; increase their participation in discussions; promote problem solving skills and maximise the knowledge transfer in large classes.

INTRODUCTION

The issues surrounding first year students' mathematical incompetency and issues in higher education have become a growing concern. This so-called 'Mathematics Problem' was reported in Ireland (O'Donoghue, 1999) and in the UK (Hunt and Lawson, 1996) and many other countries including US (Evensky et al., 1997) and Australia (Barry& Davis, 1999). The 'Mathematics Problem' was originally characterised in the UK report, *Tackling the Mathematics Problem* (LMS, 1995). First year students were found to have (LMS, 1995:4):

1. "A serious lack of ability to undertake numerical and algebraic calculations with fluency and accuracy".
2. "A marked declined in analytical powers when faced with simple problems requiring more than one step."
3. "A changed perception of what mathematics is - in particular of the essential place within it of precision and proof."

According to O'Donoghue (1999) in Ireland the lack of mathematical preparedness of Irish students studying first year subjects has led to increasing students' subject failure and attrition. In 1997 the University of Limerick introduced diagnostic testing to address the increasing concerns by mathematics lectures in regards to students' mathematical ability. Since then as the result of diagnostic testing in an attempt to care for 'at risk students' and to help mathematically underprepared students entering courses with mathematics as a component, support services and mathematics learning centres have been established (Gill, 2006). One of the biggest challenges we face in first year of these courses is that students taking maths courses cover a wide range of knowledge background, ability and motivation. Problems are more recognizable when we deal with large and more diverse groups of students like universities and college lectures with large number of students from different educational backgrounds like international students, mature students and students who have just left the secondary school. According to a survey (Bradley, 2000) in Limerick Institute of Technology, 52.2% of first year students found lectures difficult to understand; 63% found understanding certain subjects difficult; 45% like practicals. At the same time students had little time to study outside class because a large number of them travel home every weekend (58% live away from home); they work part-time (58% work part-time) and they spend time on other social activities. 77.6% of first year students expect a full time course to be no more than 9.00-5.00 Monday to Friday.

THEORETICAL FRAMEWORK

According to Constructivism (Piaget, 1971) students need feedback in order to improve their understanding and identify misconceptions; at the same time teachers who have a good understanding of where their students are from their pre-existing knowledge point of view are the best positioned to help their students to learn (Formative Assessment). Hattie and Timperley (2007) showed that feedback was actually the most important factor and had more impact on learning quality than any other single factor**.** Directed teaching, focusing on 'what happens next' through feedback and monitoring in classroom, informs the teacher about the success or failure of his teaching, making learning for both teacher and student visible (Hattie, 2008). This teaching paradigm enables us to give students feedback on their performance and gives us feedback of students' understanding in order to improve that understanding.

Sadler (1989) analysed feedback to show that for learning to take place the following need to be known: the goal, students' present position and how to close the gap.

RESEARCH METHODOLOGY

In our research, questions that have to be addressed are:

1. How to engage students in critical thinking; improve their problem solving skills in mathematics and promote higher order thinking by formative assessment and effective feedbacks?
2. How the use of Classroom Response System can affect the process of formative assessment and feedback in teaching and learning mathematics?
3. How the use of Classroom Response System can influence the students' motivation and participation in mathematics lectures?

The majority of students in Limerick Institute of Technology are considered to be active learners (O'Brien, 2009); so incorporation of formative assessment and feedback could be a suitable approach to increase engagement and motivation in students.

Questions are an essential part of the process of producing knowledge and without them we cannot talk about feedback and formative teaching, but how questions are asked and answered has broader implications that go beyond a simple and precise means of measuring students' performance. Mattuck (2009) states that questions can be fundamental building blocks that shape the content and structure of the class and help manage the way the material is assimilated. The concept 'Good-Questions' has been introduced by Mazur (1997) for teaching physics. There are several types of questions (Quick Check, Probing, Deep, etc.) (GoodQuestions Project 2003) that could be designed for use in a class depending on the purpose and intended outcome.

At present we are carrying out research into the use of Classroom Response Systems (clickers) to increase students' participation in discussion and concurrently to help students to develop a more effective and efficient process of obtaining knowledge by using well-constructed "good questions". Clickers are the obvious choice of technology for this research. They allow for two-way communication between an instructor and students and enable us to get all students involved and receive instant feedback from the whole class instead of relying on responses of few who are willing to speak out, regardless of the size of a class. The designed multiple choice questions on chosen topics (Algebra, Calculus, Trigonometric) aim to raise the visibility of the key concepts, common misconceptions and to promote a more active learning environment.

To measure the effectiveness of above intervention multiple sources of evidence (online assessments, midterm and end of semester exam results) and a mixed methods approach will be employed; using a combination of qualitative and quantitative analyses. The research strategy employed is based on John Creswell's (2003) concurrent triangulation approach. This approach requires that the qualitative and quantitative data gathering will take place over the same testing cycle. The results of the testing will be 'mixed' at the analysis and interpretation stage of the project. The benefits of this research strategy include confirmation and cross-validation of results in a single testing cycle, short-term study. The questionnaires will be administered either in the lecture hall or online. Random samples of students will be selected for structured interviews. The pre and post tests for conceptual understanding can be administered in both the lecture as part of the interactive engagement technique and in the laboratory practical. Statistical analysis will be carried out on the quantitative data. The qualitative data will be assessed through case studies.

Results of pilot tests (n=80) are encouraging and interventions are now being designed to implement in the coming academic year. I am working closely with one of mathematics lectures in Department of Engineering who will be using the designed applications and clickers in a first year service mathematics course in one session for 10 sequential weeks starting from the beginning of the coming academic year (2010-11). Throughout the design, implementation and evaluation phases I will be liaising and collaborating with the subject lecturer and use his feedback to constantly improve the applications. A suite of online applications based on mathematical topics, methods and techniques covered in lectures is currently under development to be used as backup exercises and practical assessments during the academic year.

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Investigating Levels of Knowledge among Senior Cycle Mathematics Teachers: Is it Enough to Facilitate Inquiry Based Learning?

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Mathematics in Ireland is currently seeking to overcome numerous issues including poor uptake of higher level mathematics, negative attitudes towards mathematics and deficient attainment levels (English et al., 1991; Chief Examiners Report, 2000; NCCA, 2005). However research has found that inquiry based learning (IBL) can enhance students' experiences, their levels of satisfaction and retention rates in a given subject (Kahn & O'Rourke, 2005). Hence, IBL may offer a solution to many of the aforementioned problems. Prior to this occurring, however, we must ensure that teachers are prepared and capable of facilitating IBL. Towers (2010) claims that teachers need an extensive knowledge base in order to incorporate IBL into their mathematics classroom. This paper investigates the current levels of knowledge among practising mathematics teachers and aims to see whether or not Irish teachers have the knowledge required to facilitate authentic learning experiences in mathematics. In an attempt to analyse levels of teacher knowledge the authors designed an investigation tool which was piloted among 22 Senior Cycle mathematics teachers. Focus groups were also conducted in order to gather qualitative data in relation to teachers levels of knowledge. Teachers' own perceptions of their level of knowledge were also investigated in an attempt to establish whether or not they are confident in different knowledge domains. Despite students playing a leading role in inquiry based activities (Kahn & O'Rourke, 2005) it is of paramount importance for teachers to develop this confidence so that they can believe in their own ability to facilitate IBL tasks effectively.

INTRODUCTION

According to Flick (1997) those involved in the field of science education have, for many years now, advocated the promotion of Inquiry Based Learning (IBL) in primary level science classes. The authors firmly believe that IBL must also be promoted in mathematics classes at both primary and secondary level due to the numerous benefits it offers. For example Healey (2005) found that student learning is optimised when taught using this method while Kahn & O'Rourke (2005) believe that students' levels of satisfaction and retention rates can be enhanced as a result of adopting this approach to teaching. Furthermore strong links have also been identified between this approach to teaching and an improvement in students' ability to deal with problem solving and mathematical applications, an integral area of the new Project Maths curriculum (Department of Education and Skills, 2010). Due to the importance attributed to IBL, Towers (2010) believes that during their tertiary education teachers now develop an understanding of the critical need for IBL in the mathematics classroom. Despite this deep rooted understanding however she also found that teachers are simply unable to apply such methods when they enter the mathematics classroom and she suggests that they may know how to 'talk the talk before they can walk the walk' (Towers, 2010, p. 243). It is critical therefore that in addition to teachers developing an understanding of the importance of IBL they must also develop the knowledge required to incorporate it into their mathematics classrooms.

POSTER SESSION

THE IMPORTANCE OF AN EXTENSIVE KNOWLEDGE BASE FOR THE PURPOSE OF MATHEMATICS TEACHING

"To be a teacher requires extensive and highly organised bodies of knowledge" (Shulman, 1985, p. 447). Over the past three decades researchers such as Shulman (1985), Fennema & Franke (1992) and Rowland (2007) have come to accept the fact that a knowledge of mathematics alone does not necessarily guarantee good teaching. Instead, they claim, it is imperative that teachers develop a package of knowledge that will serve to enhance their teaching and allow them to incorporate inductive teaching methods such as IBL in the mathematics classroom. In addition to this, Towers (2010) also found that a teacher's knowledge base must evolve in order to incorporate IBL in their practice. Instead of teachers depending on knowledge of routines and procedures, as has been the case in the past at both primary and secondary level in regions such as the United States and Spain (Ma, 1999; Blanco, 2003), Towers (2010) believes that teachers must now concentrate on connecting numerous different types of knowledge and utilising different types of knowledge in the classroom depending on the mathematical content and activity.

Prior to the turn of the century the area of teacher knowledge was one which was largely under-researched (Shulman, 1985). However recent years have witnessed research eliciting the types of knowledge deemed necessary for effective teaching including the knowledge that is critical for teachers in order to allow them to incorporate IBL into their mathematics classrooms. Such knowledge types include a strong knowledge and understanding of how students learn, a knowledge of alternative approaches to teaching i.e. pedagogical knowledge, a knowledge of connections and a deep understanding of mathematical content as well as its relevance and applicability (Lampert & Ball, 1998; Puntambeker et al., 2007; Towers, 2010). Only when teachers have developed these different types of knowledge will they be capable of incorporating guided inquiry in their mathematics classroom and hence the development of such knowledge domains will also enable teachers to engage students in the learning process and to stimulate their interest in the subject of mathematics.

METHODOLOGY

The purpose of this study was to quantify the current levels of knowledge among practising Senior Cycle mathematics teachers and to determine whether or not they had the sufficient knowledge required to integrate IBL into their classrooms. The authors previously outlined the different types of knowledge required for the purpose of IBL and in order to measure teachers' levels of knowledge in each of these domains a mixed method approach was used. The authors investigated the issue qualitatively through the use of focus groups and quantitatively through a pilot study which required teachers to complete a questionnaire that assessed their knowledge in a number of different domains.

In total 35 teachers were involved in the study, 13 teachers (6 male and 7 female) participated in the focus groups while 22 teachers (7 male, 13 female, 2 ID's withheld) were involved in the pilot study. The subjects involved were teaching at Senior Cycle level in schools throughout the Republic of Ireland and teaching experience ranged from 3 years to 39 years.

FINDINGS AND CONCLUSIONS

The authors will now highlight a select number of findings from this study and will outline the impact of such findings on the implementation of IBL in Irish mathematics classrooms:

Over 30% of teachers believe pedagogical knowledge to be the least important knowledge for the purpose of mathematics teaching. If teachers do not deem this type of knowledge important it is highly unlikely that they will strive to develop and enhance their levels of knowledge in this domain. This is extremely worrying as research has clearly shown that teachers need proficiency in this type of knowledge in order to become aware of alternative approaches to teaching and to allow them to facilitate IBL in their classroom.

Throughout both the focus groups and the pilot study teachers constantly refer to their poor levels of knowledge. Teachers appear to have little confidence in their own levels of knowledge and without this confidence it will be very hard for such teachers to implement IBL in the mathematics classroom.

82% of teachers in this study do not believe it possible to involve students in the mathematics classroom. As a result these teachers will find it impossible to incorporate IBL into their classroom as such teaching methods rely heavily on students being involved in the learning process.

Knowledge of connections was also deemed necessary in order to help students form links between topics previously studied and those currently being investigated. Throughout both the qualitative and quantitative phases of this study teachers struggle to connect the topic of calculus to other topics on the Leaving Certificate while the only connections they make between calculus and real life situations were trivial and very similar to those found in all Senior Cycle textbooks.

A major obstacle facing IBL in classrooms to date is the procedural approach which many teachers appear to adopt. This study showed that while 50% of teachers were able to correctly answer questions using rules and procedures only 13.73% were able to correctly apply such procedures to solve everyday problems. Therefore it is evident that teachers involved in this study do not have the knowledge required for problem solving activities and so it is highly unlikely that their students will acquire such knowledge, hence making IBL a near impossibility

In conclusion the levels of knowledge demonstrated by teachers in this study present an extremely bleak image of the current levels of knowledge among Senior Cycle mathematics teachers in Ireland. Furthermore these findings would suggest that Senior Cycle mathematics teachers are not currently in a position to incorporate IBL into their classrooms and they need to develop numerous different knowledge domains before they have the knowledge base which researchers such as Lampert & Ball (1998), Puntambeker *et al* (2007) and Towers (2010) believe necessary for effective IBL to occur.

POSTER SESSION

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The Role of Talk in Relation to Mathematical Thinking and Problem Solving

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This PhD project aims to explore the role of talk in relation to mathematical thinking and problem solving. The basic theory on which the project is grounded is that mathematical discourse and activities of high cognitive demand can facilitate mathematical attainment of a deep conceptual nature. Traditional forms of mathematics teaching revolving around computation and algorithms do not provide an authentic experience of the discipline to students of mathematics. In theory, teaching in a manner which does provide authentic experiences involves using inquiry based methods and cognitively demanding problem solving tasks. However this can be very difficult to implement successfully in practice. For this reason, the project aims to broach both theoretical and practical aspects by employing a design research methodology. There are two distinct phases to the research. The initial phase involves the collection of audio-recordings of primary level mathematics lessons on number strand topics which will be analysed paying particular attention to the issues of discourse and the nature of the mathematical tasks. The second phase involves a multi-tiered teaching experiment, where the researcher will aim to create a mathematical discourse community that engages in authentic mathematical inquiry in her own classroom. The intention is that in this manner discourse at classroom level will mirror patterns of discourse at discipline level.

MATHEMATICS AS A DISCIPLINE, IN EVERYDAY LIFE AND SCHOOL MATHEMATICS - IS THERE A DIFFERENCE?

It seems worthwhile to begin by exploring what an authentic experience of mathematics may be and by examining whether students currently learn in an authentic manner. Mathematics can be considered on three broad levels – as a discipline, in everyday life and as it is experienced in school. When considering mathematics as a discipline, I am referring to the types of mathematical activities that are carried out by professional mathematicians or those who study mathematics at university level. Unlike the main cohort of primary school teachers, I was lucky enough to study mathematics to Masters Level in NUl, Galway before finding my way into primary teaching. Though much of the specific course content that I learned in my mathematics courses is forgotten now, the mathematical ways of working are not. These included peer discussion as well as lecturer- led whole class discussion. It also involved long periods of solitary struggle, intense concentration, and persistence. It involved, almost exclusively, tasks that were highly cognitively demanding. These tasks and methods of working actively supported creativity and flexibility in mathematical thinking and reasoning. Persistence, creativity, motivation and even joy would seem to be common themes that emerge when mathematicians speak about their work (Boaler, 2009; Hersh, 2005; P6lya, 1945/1990).

Mathematics in everyday life can be more complicated to pin down. There are some situations where the mathematics in everyday practice is obvious. The mathematics inherent in other situations is less obvious and often involves some kind of estimation or a problem in context. In our everyday lives, problem solving is highly situated and the context of a problem can both form the problem itself and suggest a solution method (Lave, 1988). In fact this is a similar situation to mathematics as it is experienced by many professionals such as architects, scientists or engineers who use mathematics and mathematical models to solve problems that are often highly situated. This contrasts with mathematical problem solving as it is experienced by many students. Indeed there is evidence to suggest that mathematics as it is carried out in everyday life is very different to classroom mathematics and also that the procedures used to solve problems in real life vary immensely from the procedures used to solve problems in the classroom (Brown, Collins & Duguid, 1989; Lave, 1988).

Features of working mathematically, such as those outlined in the first paragraph, as well as patterns of dialogue involving making conjectures and examining and justifying ones own mathematical thinking and the mathematical thinking of others, seem central to the mathematical activities of those working with mathematics as a discipline (Lampert, 1990; P6lya, 1945/1990). This is supported by the view of mathematics put forward by Lakatos (1976), where mathematical understanding emerges when the learner follows a zig-zag path between proof and refutation. The work of Lakatos is a dialogue between teacher and students discussing various historically significant mathematical proofs. Lakatos implies that this process of refuting and refining mathematical ideas, occurs both across mathematics as a domain and at an individual level. Does this dialectical process occur in school mathematical discourse? The evidence would suggest that in the majority of cases it does not. School mathematics often consists of traditional style lessons where the teacher models a procedure or strategy and then children practise examples of this type of task (often from a textbook). This structure supports the teacher or textbook as mathematical authority and does not facilitate the forms of mathematical discourse described above. Boaler states:

> In many maths classrooms a very narrow subject is taught to children, that is nothing like the maths of the world or the maths that mathematicians use. This narrow subject involves copying methods that teachers demonstrate and reproducing them accurately again and again. (2009, p. 2)

TRADITIONAL TEACHING VS. AUTHENTIC EXPERIENCES OF LEARNING MATHEMATICS

Exactly how many mathematics classes in Ireland are carried out according to the traditional template is hard to judge. However 95% of the children in the fourth classes studied in the 2004 National Assessment of Mathematics Achievement (NAMA) are in classes where the teacher says the text book is used everyday (Shiel, Surgenor, Close and Millar, 2006). This raises questions about the nature of lessons in Irish primary classrooms and the types of activities students engage in. Evidence from studies carried out at secondary level in Ireland suggests that the traditional approach of teacher exposition followed by pupil practice is still common (Lyons, Lynch, Close, Sheeran & Boland,2003). However there has been movement both nationally and internationally toward providing more authentic experiences in the learning of mathematics.

Realistic Mathematics Education (RME), the Dutch approach to mathematics education, grew from the work of Freudenthal (1973). It involves the use of context problems, which are problems where the context is experientially real for the student. The idea is that learners mathematise the context problem by describing it in mathematical terms. Then in reflecting on this process, learners should be encouraged to mathematise their own mathematical activity (Freudenthal, 1973). The RME movement has influenced the Programme for International Student Assessment (PISA) (Shiel, Perkins, Close & Oldham, 2007) and can be seen to have influenced the revised curriculum for second level which values problem¬solving (www.projectmaths.ie). Prominence was also given to problem solving at primary level with the introduction of the revised curriculum in 1999. However the transition from traditional teaching to more progressive forms which provide students with a more authentic experience of leaning mathematics can be can be difficult to implement successfully in practice. My research aims to explore some of these issues.

Method: Phase 1- Audio Recordings

There are two distinct phases to the research. The initial phase involves the collection of audio-recordings of primary level mathematics lessons on number strand topics from third to sixth class. These will be collected from up to 15 different classes, selected on a volunteer basis after the researcher makes an initial invitation for participation to the whole staff of various schools, some of which I have a personal or professional connection with. I will not be present during recording due to the constraints of my own teaching position but all recordings and invitations to participate will be carried out according to the ethical guidelines laid down by St. Patrick's College. The aim of this phase of the research is to develop understanding of the nature of discourse and mathematical discourse in some primary school classes. Also the nature of the mathematical tasks and the relationship between the task and the resultant discourse will be examined. It is envisaged that results from phase 1 will inform the design of the teaching experiment in phase 2.

Method: Phase 2 - Teaching Experiment

The second phase involves a multi-tiered teaching experiment, employing a design research methodology. The researcher will conduct a teaching experiment in her own classroom, the aim of which is to facilitate a classroom discourse community that regularly engages in cognitively demanding tasks. Here a discourse community is understood to be one in which the classroom norms around social interaction support students in the making of mathematical conjectures. In this way discussion, justification, refutation and negotiation of mathematical definitions and mathematical 'truths' can be facilitated. The mathematical tasks will be designed according the RME approach and will consist of context problems that explore number concepts and linkage between these and other mathematical content domains. It is hoped that the RME style tasks combined with the discourse focussed teaching methodology may facilitate student participation in authentic mathematical inquiry. Teaching colleagues will be invited to collaborate through formal and informal planning and evaluation of the lesson resources, as well in reviews of audio or video recordings of lessons. It is intended that recordings will be collected in short phases across the whole school year so as to document the planned evolution of discourse within the classroom community. Initial student orientations toward mathematics and samples of students' mathematical reasoning will be gauged in the form of a start-of-year questionnaire and simple mathematics test where students are encouraged to write about their reasoning. A daily teaching journal will be kept and students will be invited to keep their own journals and reflect on a regular basis on the mathematics tasks they have engaged in. Audio recordings will be made of the lessons that involve context problems tasks and these will include records of whole-class as well as group or pair discussion. There will be four to five recordings a month. At the end of the year, students will sit the Drumcondra Primary Mathematics Test at their level and will also sit a researcher designed test that encourages them to show their mathematical reasoning. This will be compared with the test results from those carried out at the start of the year. Pupils will also be given a questionnaire that explores their attitude toward mathematics in general and the content of the realistic mathematics lessons in particular.

The instructional materials that are developed for the teaching experiment may be adapted as a result of reflecting on their implementation in my own class. Following necessary adaptations and with suitable explanations and supports, they may then be offered to a wider audience, either to adapt and implement in their own classes or for general feedback. This is envisaged to occur on at least two levels, through informal invitations to colleagues and on a more formal level through public invitations to other teachers via the 'InTouch' magazine or other media outlets.

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Baseline study of learning style preferences of 13 and 14 year olds and subsequent comparison with teacher learning styles

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Using the Physical Modality Preferences as outlined in Dunn & Dunn's model of learning styles, a group of pupils (*n*=83) participated in this survey. It attempted to elucidate through a questionnaire if a person preferred Visual, Auditory or Kinaesthetic learning styles. There were 24 questions, 8 questions describing each learning style. The same questionnaire was completed by teachers (*n*=54). The pupils were divided into 3 groups.

Group (1) (*n*=23) were well behaved and of good ability, Group (2) (*n*=21) well-behaved and weak ability and group (3) (*n*=27) were mixed ability and less disciplined.

Results: In Group (1) twice as many preferred Auditory to either Visual or Kinaesthetic learning. Group (2) displayed the greatest variability in learning preferences that included many dual preferences. Visual learning was the preferred method in this group. Group (3) (mixed ability and less disciplined) expressed a preference for Visual and Auditory learning in equal numbers. Over half the teachers preferred Visual learning, but only 5% preferred Kinaesthetic learning, where 17 to 19% of pupils expressed a preference for this type of learning.

Conclusions: This study is a brief snapshot of a small number of pupils. Nearly 20% of each group preferred Kinaesthetic learning (only found in the disruptive group in Dunn and Dunn (1990). The skewed nature of the teachers' result may be due either to the individuals process of career selection resulting from their learning style or simply that learning style may change in adulthood (Gremli, 2003).

INTRODUCTION

The key theme of the Atlantic Conference 2010 in Tullamore was "how can educators inspire students to engage with science, technology, engineering and maths (STEM)?" Many of the multinational companies in Ireland have voiced their concern recently about the quality of Irish graduates. To improve the number and quality of scientists in the workforce, Ireland needs to build its own body of knowledge of the learning styles and preferences of it's students to improve teaching strategies. There are many learning styles that can be grouped together: constitutional, cognitive, personality type and learning preferences (Coffield *et al*, 2004). To achieve the goal of empowering students as they leave school, it is important to recognize their different learning preferences and incorporate this into a strategy to motivate them to seek information to improve their understanding and ability in science.

To date there is very little research on learning styles of students in second level education in Ireland. Dwyer (2008) studied a group of students at Dublin Institute of Technology. It is not possible to use these students as a comparison. The subjects of that study were first year engineering students and so this was likely to skew the learning preferences. Cook and Leckey (2009) also studied a group of first year university students at University of Ulster, Jordanstown, and found that school learning habits persisted into first year.

The current study is an attempt to set a baseline for learning preferences with a cohort of second year students in a mixed Community College and to compare this with the learning preferences of teachers.

METHODS

Using the Physical Modality Preferences as outlined in Dunn & Dunn's model of learning styles, a group of pupils (*n*=83) participated in this survey. There were 24 questions, 8 questions describing each learning style. For each question, the student was asked how "often, sometimes or seldom" they performed certain tasks while learning. One mark was given to a "seldom" answer, 3 marks were given to a "sometimes" answer and 5 marks to an "often" answer. In any category: Visual, Auditory or Kinaesthetic, this meant that a person could get as little as 8 (8×1) or as many as 40 (5×8) points.

The same questionnaire was completed by teachers (*n*=54). The pupils were divided into 3 groups. Group (1) (*n*=23) were well behaved and of good ability, Group (2) (*n*=21) well behaved and weak ability and group (3) (*n*=27) were mixed ability and less disciplined. The questionnaires were given at registration or during pastoral care class. They were administered by Transition Year students. A teacher was also present in the room. As the exercise was perceived as a student-to-student questionnaire and names were not required in the survey, there was no fear or threat of reprisal after completion.

RESULTS

In Group (1) twice as many preferred Auditory to either Visual or Kinaesthetic learning. Group (2) displayed the greatest variability in learning preferences that included many dual preferences. Visual learning was the preferred method in this group. Group (3) (mixed ability and less disciplined) expressed a preference for Visual and Auditory learning in equal numbers. Over half the teachers preferred Visual learning, but only 5% preferred Kinaesthetic learning, where 17 to 19% of pupils expressed a preference for this type of learning. In Table 1, the results were calculated as follows: each group was analysed separately but in the same manner. Each subject was assigned a learning preference based on their highest score. If their highest score was for visual learning, then they were categorised as visual learners. If they had equal scores they were put into a combined category. Table 1 shows the data associated with Figure 1.

Table 1: Learning Preference of Teachers and Students.

	Visual	Auditory	Kinaestheti c	A/V	V/K	A/K	AVK
Teachers % total	51.9	27.8	5.6	9.3	3.7	1.9	0
(1) Good behavior, Good ability % total	21.7	43.5	17.4	13.0	4.3	0	0
(2) Good behavior, weak ability% total	42.9	9.5	19.0	19.0	4.8	0	4.8
(3) Mixed behavior and ability % total	37.9	34.5	17.2	0	6.9	3.4	0

As explained above, a respondent was allocated a group based on their highest score. Figure 2 describes the raw data that is, the numeric results. Some people showed a low preference for any learning style, while others showed a high preference for all learning styles. In Figure 2, Group 1 are students who have good behavior, good ability, Group 2 are students who have good behavior, weak ability, Group 3 are students who have mixed behavior and ability and Group 4 are teachers. The only group to fall below 20 points in learning preference is teachers. The average of all other preference scores is between 20 and 25.

DISCUSSION

Teachers are far more visual that any student group. Firstly, it is possible that career choice has skewed this result and that visual learners are attracted to this profession. Secondly, learning preferences has been found to change with age (Kolb, 1984).

The “better” more disciplined students (Group 1) preferred auditory learning, perhaps they have been taught in a way that suits their learning preference. If this is so, they would be more engaged and behave better (Lennington and Stein, 1997).

Group (2) consisted of pupils who were well behaved but of weak ability. Although a high percentage of this group were visual learners, there was a greater variety of learning styles within this group, If this is compared to the numeric average preference scores, Group 2 had less interest in all learning methods. This difference in overall level of interest in learning may contribute to their weaker academic results.

Similar to Group (2), Group (3) (less well disciplined, lower academic ability) had less interest in any type of learning, which means that in general they are probably disengaged from any attempts to educate them. This is the group that received much attention at the Atlantic Conference in Tullamore this year. They were described as the students who according to their teachers had no attention span, but these were the same teenagers who could sit and play complex games on PlayStation and X-Box for hours, thus displaying a remarkable ability to concentrate. Many of these students have “moved on” from current teaching methodologies.

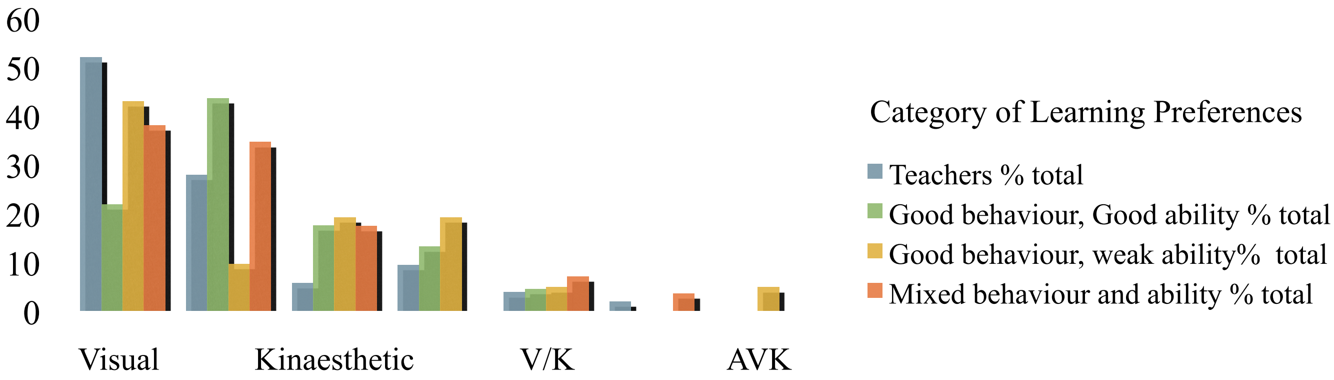

Figure 1: Comparison of Learning Preferences among Teachers and Three Groups of Second Year Students.

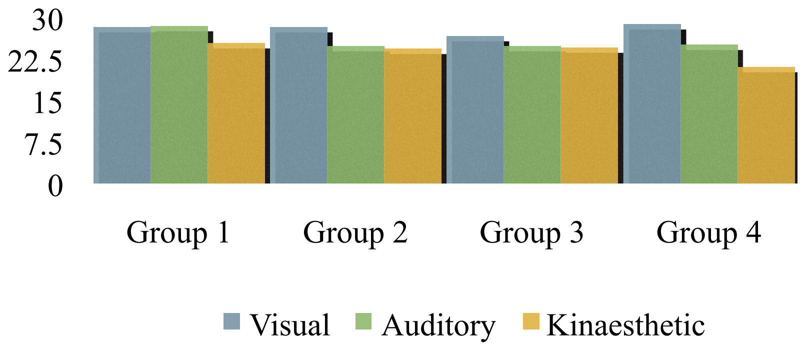

Figure 2: Average preference scores for each type of learning.

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CONCLUSION

All teachers know the strengths and weaknesses of the classes they teach. The purpose of this exercise was as much to enhance the learning experience of this group of students as it was to shed light on the necessity of improving teaching methodologies to inspire student (as electronic games do) along a path of lifelong learning through self motivation and inquiry.

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Embedding Inquiry Based Learning into Programming

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Changes within our approach to teaching can make some students feel uncomfortable. To overcome this, inquiry based learning, which is strongly supported by research in the areas of intellectual development and approaches to learning (Prince and Felder, 2006), can be used. Inquiry based approaches should be introduced in combination with existing teaching styles in order to address the needs of all students. The key aspects of inquiry based learning from the students point of view are that the students: are involved in the process of learning; engage in an exploration process; raise questions, propose explanations, and use observations; plan and carry out learning activities; communicate with staff and peers. Pair programming enhances the communication among peers and encourages students to ask questions of each other and be more ambitious in their computer programming practicals. The students subsequently gain confidence from one another to try different approaches to solving programming problems; this enhances deeper learning. Additionally, working in pairs provides some students with the courage to ask questions of the teacher while in their pair, which they may not do alone. The overall aim is to use pair programming to encourage inquiry based learning within programming modules, to improve attendance and practical assessment results.

INTRODUCTION

Much research has been carried out and published on the benefits of both inquiry based learning and working in small groups. Inquiry based learning is an approach to increasing retention through the use of a teaching approach that allows student-constructed learning rather than teacher transmitted information (Sparks Foundation 2010). It has many benefits including increasing student involvement, encouraging collaboration among students and developing a deeper knowledge due to the students thinking through the processes themselves (Prince & Felder 2006, Prince & Felder 2007). The use of small groups in higher education closely matches what many remember as our early learning experiences in primary school. Small groups are typically considered to be groups of 10 or less students; in this paper we will discuss the use of paired groups: two students per group. Research indicates that small group learning promotes active learning, self-motivation, deep learning, transferable skills etc and it is widely used in fields such as medical education (Crosby 1996).

The concept of pair programming has recently been introduced in the United States, both in companies and universities. Within an industrial setting, software developers spend 50% of their time working with one other person and this is due to the fact that working in teams of two or more improves productivity (Cockburn & Williams 2001). Although it typically takes 15% more development time, pair programming improves many aspects of programming including design quality, reducing defects, enhancing technical skills and improving team communications; these are all skills that we also require in our students. Therefore we introduced the concept of pair programming in first year Algorithmic Programming modules as a means of encouraging inquiry based learning. In this paper, we present the approach used to embedding pair programming in teaching practice and some of the results obtained.

METHODOLOGY

With respect to carrying out practicals and practical assessments, the students were put into pairs. The students were allowed to choose their own partners, as randomly selecting partners can lead to many problems during the course of the module.

In their pairs, the students completed the practicals and were assessed. However, assessment was still conducted on an individual basis in the following manner:

a) both students had to be present at assessment in order to obtain their individual mark;
b) both students were asked individual questions about the practical, hence both students had to demonstrate their own understanding.

By conducting the assessment in this way, no individual student received credit for their partner's work.

After the exam component of the module was completed, additional statistical analysis was carried out to ascertain if the overall exam performance improved in comparison to the previous year, thus providing evidence that pair programming leads to deeper learning and understanding. However, this will also have to be cross correlated with other module marks to determine if an overall improvement is unique only to the Algorithmic Programming module, or if indeed the student cohort is academically superior to the previous year. The cross-correlation analysis is presented below.

PUTTING IT INTO PRACTICE

The ideas presented in this project were implemented in semester 2 of the academic year 2009-10, in the Algorithmic Programming II module. At the beginning of the term, the concept of pair programming was introduced to the students. They were informed that they could select their own partners and the academic should be informed of the partners by email within one week. At the beginning this appeared to work well as the pairs were established. However, some issues arose in this in that firstly some students did not appear in the module until week 2 or 3 and also hadn't read their email. By week 4 or 5 some students had already dropped out of the course and their partners were left to find a new partner. However, in general these issues were resolved, although it was a little unsettling for the students concerned but it is also a real life issue that they need to be able to adapt to.

The assessment was quite straightforward. Each pair was assessed but each student assessed individually. The pair was asked to select which PC they were using. Then each student was requested to conduct a number of tasks and answer questions to establish their level of understanding of the practical and in particular ensure that both students had participated in the practical. This worked well and there were no major issues.

Overall, the idea of pair programming worked well, although it did not provide all the answers to encouraging our students to engage.

RESULTS

In (Coleman & Nicholl 2010), we presented results showing an improvement in practical assessments and attendance in comparison to the Algorithmic Programming II module in the previous year (AY0809). Here we summarise the results of cross-correlating with the same cohort's attendance and performance in the Mathematics module in semester 1 of the same academic year (AY0910). By using the same student cohort, we aim to determine if the pair programming has had a positive impact on the student attendance and performance by determining the expectation from the Mathematics module. The results given in Table 1 are computed in the following way:

Change in Maths module = (Math0910-Math0809) / math0809

APII Expectation0910 = APII_0809 + (APII_0809 * Change in Maths module)

% change = ((APII_0910-APII Expectation0910) / APII Expectation0910) * 100

Table 1: Summary of cross correlation with the mathematics module

	% change
Practical attendance – all students	+20.6%
Practical attendance – females	+21.8%
Lecture attendance – all students	+19.9%
Lecture attendance – females	+15.7%
Assessment marks – all students	+53.5%
Assessment marks – females	+61.0%

DISCUSSION

The idea behind this project was to introduce a practice in the Algorithmic Programming II module that would encourage the students to engage and participate in the module and ultimately improve first year retention. Now we need to consider: did we achieve this? Did we go some way towards achieving this?

Within the UK and Ireland, the issue of student retention is prominent. However, throughout the academic year we can often determine which students are likely to fail first year based on their attendance and amount of engagement in the degree programme. This is particularly prevalent in computer science related disciplines as students often learn ICT in schools and think this is computer science. Therefore when entering the degree programme many discover it is not what they first thought.

The main reason for introducing pair programming into the programming module was to get students to engage with each other and the module, improving attendance, performance and overall retention. The attendance at practical improved in comparison to the attendance in AY08/09. Did this then improve the practical assessment marks significantly? As illustrated in Table 1, the practical assessment marks increased on average by almost 54% compared with the expectation. Table 1 also illustrated improved performance among the females in the class which is also an expectation of pair programming.

The next major aim of this project was that by encouraging students to attend their practicals and practical assessments, learning would be enhanced and the students would understand programming better than in previous years. The improvement in learning would be determined by improved class test and examination marks. Unfortunately this was not the case. The average class test mark dropped by 2% and the overall examination marks were similar to previous years. However, this was primarily due to approximately 8 students who never engaged in the module and didn't sit the exam. Clearly, this is still a relevant point as the aim of the project with to improve engagement and attendance. But what can we do with these students? How can we make these students that don't want to learn, learn? There is no easy answer to this problem, and it is a problem that we all face. As previously stated, we aim to try to improve this by introducing pair programming in the Semester 1 programming module to see if we can encourage increased engagement from week 1 with the aim of seeing some improvements overall in programming modules and retention.

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Reflection in Mathematics – The Search for an Appropriate Resource for Adult Learners of Mathematics in Higher Education

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POSTER SESSION

Having its genesis in research realised in 2007 enquiring into the relationship between mathematical confidence and competency in the context of mature students' self-efficacy, we began to investigate more specifically mature students' objections to reflective practice as an aid to learning mathematics on a tertiary preparatory course – the WIT Certificate in Foundation Studies. Anecdotal evidence indicated a reluctance to engage with the mathematics learning journal manifesting as inability to journal and lack of awareness of accrued personal benefits. Therefore, we began to review this phenomenon with purpose. Ultimately, the realisation of this research has arrived in the form of a type of student handbook (25 x A4 pages), addressing the issues/objections/reluctance of mature students in this context. It illustrates explicitly the process of reflecting on one's learning and the inherent personal benefits.

Feedback specifically from practitioner-experts in the field of Maths Learning Centres (MLCs) revealed students prefer concise materials/resources – with traditional students a maximum of 2 × A4 pages; or 4 × A4 pages in the case of matures. This next phase of our research has thus involved the transformation from a larger resource (25 × A4 pages) into a more palatable, user-friendly, and practical form whilst ensuring it retains the essences of reflexivity as a practice and skill.

The class of 2011 will be the first cohort to be presented with the resource immediately in Semester 1 and so, our research will monitor this group over the academic year. We see this project as a longitudinal study and would hope to have up to 5 years of data collated ultimately before concluding conclusively on its effectiveness as a tool for mathematics education.

Collaborating on this project is Fiona McKenzie-Brown, a past student – formerly a most vehement antagonist regarding reflexivity in general and mathematics in particular. Cooperation provided us both with a balanced perspective in terms of the instructor-student interface, whilst helping us to maintain reliability and rigour.

Originally our goal for the handbook was for it to be used with WIT Cert. in Foundation Studies students. Ultimately our resource was piloted at the beginning of Semester 2 with the class of 2010, and feedback will be gathered subsequently on the effectiveness and usefulness of the resource to adult learners of mathematics. Moreover, currently there exists an opportunity to research its effectiveness whilst working with non-confident, perhaps mathephobic learners within the Institute's Maths Learning Centre and the wider MLC community.

Teaching the calculation of electric flux in an intermediate electromagnetism course

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The ability to calculate electric flux is an important skill to learn in the development of a person's comprehension of Gauss' Law. As a result, due emphasis and attention must be given to students' understanding in this area. Here, we give a progress report on our investigations of some difficulties students have with the topic and outline our approach to address the issues identified.

POSTER SESSION

INTRODUCTION

A good deal of research exists regarding the teaching and learning of electrostatics. Normally this research is focused on the identification of student difficulties surrounding Gauss's law and the development of teaching materials and teaching sequences that will help to eradicate these (Guisasola, Michelini, Mossenta & Viola, 2007; Guisasola, Almudi, Salinas, Zuza, & Ceberio, 2008; Saarelainen & Hirvonen, 2009; Singh, 2006). Chabay and Sherwood (2006) recognise that flux is a difficult concept especially when students have not dealt with surface integrals or multivariable calculus before. Singh (2006) highlighted misconceptions students have in relation to electric flux including the inability of students to differentiate between electric field and electric flux, the idea that flux is a vector because it involves a cos θ, and the belief that $\Phi = EA$ is always true.

While it is believed that understanding the concept electric flux is a highly important step in the build-up to Gauss' law and is vital in making the mathematical representation of Gauss' law meaningful (Saarelainen & Hirvonen 2009), there are few recommendations on how student learning in this area can be improved. We feel that being able to calculate electric flux is also a requirement for eventual complete understanding of all forms of Gauss's law.

In this paper, we will describe our approach to the teaching of calculating electric flux, providing analysis of pre and post-test data and a discussion on how this data will allow us to make changes to the existing material.

OVERVIEW

Our intermediate Electromagnetism course is taught to physics and engineering students and pre-service science teachers (approx. 45) and is given over 36 hours. This is broken into 12 lectures (one per week) and 24 tutorials (two per week). The lectures are there to provide students with the relevant definitions and introduce new vocabulary. Tutorials adapted from *Tutorials in Introductory Physics* (McDermott & Shaffer, 2002), which are completed in groups of typically 4 or 5 students, are used to develop the physics concepts introduced in lectures. We have developed follow-on tutorials that are more mathematics-based (calculating electric flux being one of these). Prior to starting the *Calculating Electric Flux* tutorial, a conceptual tutorial on electric flux has been completed by students. The latter introduces the area vector, allows students to discover the cosine dependence of flux, and shows that the flux through a cube face due to a point charge at the centre of the cube is not constant.

PRETEST

The pretest questions mirror the tutorial described below. In the first pretest question students were told that a square sheet of sides a is placed parallel to the x,y-plane in a uniform electric field given by $\vec{E} = 4E_0\hat{y} + 3E_0\hat{z}$ and they were asked what the value of $\vec{E}\cdot\hat{n}$ would be if the normal pointed upwards. We note that we did not provide a diagram, nor did we specify that by "upwards" we meant "in the positive z-direction"; this will be rectified in future versions of the pretest.

Five students out of 34 respondents gave the answer we considered correct, *i.e.*, $3E_0$. Of these, four gave a correct explanation stating that the normal is in the z-direction; the other did not give an explanation.

Three students answered $4E_0$. One guessed; one said the y-direction denotes the normal plane, and thus gave a correct answer; the last student took the normal to be the z-axis, concluded that the dot product is the z-component, yet chose the wrong answer.

Six students chose the answer $5E_0$. Four of these explained that this was the result of the addition of the two vectors; one said it was a guess, and the other said that he was unable to explain vector calculus).

Eight students (25%) stated that $\vec{E}\cdot\hat{n}$ would be zero, with four reasoning that the electric field and the area vector are perpendicular. Depending on their interpretation of what the x,y-plane is, these answers may or may not be correct.

A further 25% gave an incorrect answer of $7E_0$, with half of them reasoning that because the electric field and area vector are perpendicular, the dot product is 1 and so you can just add the magnitudes of the two vectors.

In the second question, students were asked whether the statement "*the flux through the sheet is given by the magnitude of the electric field, E, times the area of the sheet, A"* is true, false or whether you would need more information. Eighteen students (55%) answered correctly that the statement is true. However, no student gave an explanation for why they thought this, with only answers like "flux is equal to field times area" being given.

The last question told students that the original electric field is removed and that a point charge is now placed under one of the corners of the sheet. They were then given the same statement from the second question and again are asked if it is true, false or if they would need more information. Eleven students (30%) believe that this statement still holds in this new situation. Ten believe that the statement is false but only three of these provide an explanation that shows that they understand why it is not true, *e.g.*, the electric field decreases with increasing distance so the flux will be different everywhere on the sheet.

TUTORIAL AND HOMEWORK

Generally our tutorials consist of two parts. The first part contains a lot of scaffolding in a simple setting; the second part builds on the concepts and techniques developed in the first part. Thus, students are asked to apply their newly acquired knowledge straight away.

In part I of the *Calculating Electric Flux* tutorial, students are given an electric field $\vec{E} = 2E_0\hat{y} + 3E_0\hat{z}$. They are asked to sketch field vectors and field lines in two different boxes that have scale-less y and z-axes drawn in, and to state whether the field is constant or not. We note that many students appear to mentally omit the caret from the unit vectors; they state that the electric field is not constant. This may stem from a coping strategy adopted in one-dimensional vector problems, where omission of the arrows above a variable often turns a vector equation into a correct scalar equation.

Next, students are required to explain why the electric field can be taken outside the integral sign in the electric flux formula. They are then asked to give the value of $\vec{E}\cdot\hat{n}$ given the equation of the electric field and the direction of the normal. They are then given the dimensions of the sheet (a by a) and are asked to evaluate the electric flux.

In part II, the original electric field is removed and a charge q is now placed a distance below one of the corners of the sheet, as shown below in Figure 1.

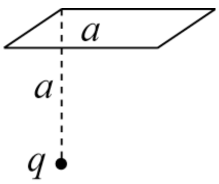

Figure 1: A point charge below a square sheet.

Students are asked to consider a small segment of length dx and width dy on the sheet centred at a point (x,y), and then justify the expression for the electric flux Φ_E through the segment, $\mathrm{d}\Phi_E = \left(\vec{E}\cdot\hat{n}\right)\mathrm{d}x\mathrm{d}y$. They are then guided stepwise towards finding the total electric flux through the sheet, by replacing $\vec{E}\cdot\hat{n}$ by a scalar expression in x and y, and integrating with respect to both variables.

A similar procedure is practiced again in the homework question where student must calculate the flux through a sheet due to a uniform linear charge distribution.

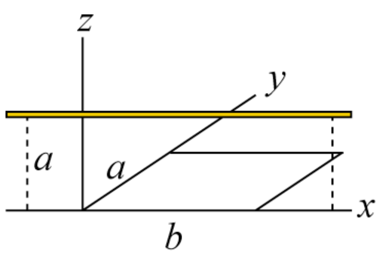

Figure 2: Linear charge distribution a distance a above the sheet.

POST-TEST

As a post-test students were told to consider the electric flux through a circular disk due to a point charge a distance z_0 above the centre of the disk. The situation is shown in Figure 3.

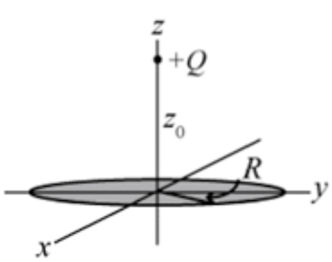

Figure 3: A point charge $+Q$ a distance z_0 above a circular disk of radius R.

In the first part of this question students were asked to explain that for very small values of R the electric flux is approximated by $\Phi_E = QR^2/4\varepsilon_0 z_0^2$. Twelve out of the 45 students (25%) who took the test answered this part correctly with a full explanation, reasoning that when R is small the electric field through the disk can be considered constant and so you can multiply the electric field and the area to get the above equation. A further 25% answered correctly but did not give a complete explanation, for example, neglecting to explain that we do not have to integrate because the electric field is constant. 35% answered incorrectly and 15% did not provide and answer.

In the second part students were asked to explain that for very large values of R the electric flux is approximated by $\Phi_E = Q/2\varepsilon_0$. Only 10% of students answered correctly. Thirty students gave an incorrect answer with eight of this thirty reasoning that now r is approximately equal to R (instead of z_0 in the first part) and got an answer that is out by a factor of two.

Mirroring the tutorial, in the third part students were given the equation for the flux through a small segment and are asked to show how you would get this equation. One third were able to explain how to obtain the equation, but nearly half of the students (19) answered incorrectly. Of these only one had used the equation $\Phi_E = EA\cos\theta$; the others applied incorrect mathematics in order to fit the equation given in the question.

The last part asked students to calculate the flux through the entire disk. This required them to integrate the equation they were given in the third part with the correct limits. Twenty students (45%) did not give an answer. 30% answered correctly (20% completely and 10% with gaps).

POSTER SESSION

CONCLUSION

From the analysis and comparison of the pre and post-test data, it is noticed that there is some improvement in the quality of students' answers after instruction. However, the magnitude of student error in the post test and the lack of response to the integration section of the question are still worrying. Different pretest questions will be used to probe students understanding further to find where the real difficulties lie. From this, we will be able to develop the tutorial in order to try to resolve the current problems in the area.

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In at the deep end – open design for first year Engineering students

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To simulate the open design process in the workplace first year students are assigned an open design project as one of their end of term Physics lab sessions. For the purpose of this exercise the problem posed was to "set up an experiment to verify the equation for limiting friction". In preparation for this exercise, most of the relevant knowledge was covered earlier in the semester in both mechanics and physics. Several specialist classes were given in the preceding week. These classes revised the knowledge required and covered additional necessary background; it also gave an opportunity to introduce the problem in detail. The students were given a two-page handout with the background theory, and a list of functional requirements and outputs. They were told that an excel spreadsheet is to be set up to evaluate the frictional force for different materials across various experimental setups. Students must explain their choices and final recommendations. The exercise is open ended and students are given the freedom to go into as much detail as they wish within the time provided. The exercise proved challenging for many students, more used to well-defined laboratory work. The good students rose well to the challenge, producing a wide variety of interesting and satisfactory designs that met the brief. The students completed an online anonymous survey giving feedback on the process. The results of this feedback were mixed with the stronger students enjoying the challenge and many of the weaker students struggling to get to grips with the open ended approach required

INTRODUCTION

It is axiomatic that the aim of an engineering course is to produce good engineers. A key element of being a good engineer is the ability to solve problems in an effective and creative way. Working against this goal is the formation of students at second level, where many of the subjects are taught in a rigid manner, and students are trained to answer predictable questions. This almost eliminates the element of creative thinking from the students. Unfortunately, much of the work done at third level reinforces this problem, with much of the teaching of theory and practice following rigid and predetermined paths. Students are given problems in Physics and Mathematics that have one and only one answer. Students learn to recognise particular types of problem, and learn the method for solving that problem. Laboratory sessions that are designed to reinforce theoretical elements end up with students blindly following a list of instructions, without considering why.

Whereas design projects have long been seen as the capstone to engineering courses, there is a growing recognition that design must also be the cornerstone of engineering courses, and appear in some form in all years of the course (Sheppard, 1999).

Dekker (1996) in his paper on *The Difference Between "Open-Ended Projects" and "Design Projects"* says that 'The practice of engineering is essentially solving open-ended, poorly-defined problems or challenges." An education that only presents students with clear, highly-structured, single-answer problems, is failing to prepare them for the real world of engineering.' This is particularly true for the 21st Century engineer, facing a multiplicity of challenges in building a sustainable infrastructure that society can rely on.

Sheppard and Jennison (1997) quote the Accreditation Board for Engineering and Technology (ABET) definition of engineering design as "a decision-making process (often iterative), in which the basic sciences and mathematics and engineering sciences are applied to convert resources optimally to meet a stated objective." They add that “The problems that engineering design responds to are typically open-ended and underdefined, by which we mean that, respectively: " (1) There are usually many acceptable solutions to a design problem (so uniqueness does not apply); and (2) solutions for design problems cannot normally be found by routinely applying a mathematical formula in a structured way" (Dekker, 1996). Bordogna adds, "In essence, engineering is the process of integrating knowledge to some purpose. It is a societal activity focused on connecting pieces of knowledge and technology to synthesize new products, systems, and sciences of high quality with respect to environmental fragility." (quoted in Sheppard and Jennison, 1997)

Bailey (1979) in his book on engineering creativity, defines six steps in the problem solving process: (1) Problem Inquiry, (2) Specifying Goals, (3) Determining Means, (4) Solution Optimization, (5) Construction and Verification, and (6) Convince Others. The usual problems given to students, especially in first-year, all but eliminate steps 1 to 4, asking of students only to construct and verify that which has been specified and determined by their lecturer.

The aim of this project is to introduce more of this type of exercise into the early years of our courses. This innovation came about during Louis Bucciarelli’s time as Visiting Professor at DIT, during the second semester of 2009. Professor Bucciarelli of MIT is an acknowledged expert in this area (Bucciarelli, 1994).

GROUP BACKGROUND

The current project undertaken with first-year level 7 students of Mechanical Engineering in DIT is an attempt to rectify that deficiency. The first-year Mechanical students are above average for a level 7 programme, with typical Leaving Certificate points of 350. The class numbers are usually between 60 and 70, though in the Academic year 2009-10, the number was 83. The students study a range of modules: Mathematics, Physics (Integrated Principles of Technology and Heat and Energy), Mechanics and Materials, Instrumentation, Professional Development, Workshop Processes, Drawing and Computation. One of the aims of this project, in addition to the open design element, was to try and integrate material from a number of the modules, so that students would see the material from the different modules as forming an integrated whole, rather than isolated pieces of information.

OPEN DESIGN PROJECT DETAILS

The background to the exercise was introduced in a class lecture, with the key theoretical elements, such as the properties of elastic solids, stress, strain, the elastic properties, the concepts of equilibrium and compatibility of deformation - as all of these are ingredients of the design exercise. The relationship between the hoop stress and the pressure at the interface of the bushing and the shaft was derived in a general manner, avoiding the use of integration.

In the lab sessions, the students were broken into four groups of around 16 – 18, and the exercise was done four times with each group for two two-hour sessions. The students were divided into teams of 3 or 4 and given a two-page outline of the exercise, and the submission requirements. The students were then left to tackle the problem, with the lecturers available to answer questions.

At the end of the second session, the teams were given one week to write up the report and submit it, along with the excel spreadsheet that they had designed.

The open design exercise was deliberately presented to students in an unstructured way, in contrast to their normal work assignments which are very 'recipe' orientated. The students were told that the overall aim of the exercise was to verify the law of friction at impending motion for different materials. It also was made clear to the students that they had to design a spreadsheet to verify the law, but the design details were entirely at their discretion.

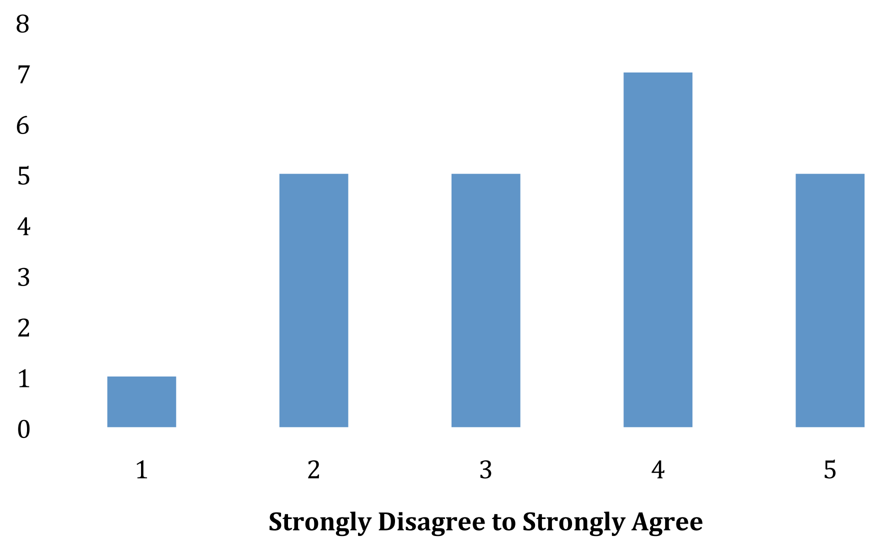
GENERAL OBSERVATIONS ON THE EXERCISE

1. The exercise did require the students to utilize a wide variety of knowledge from their different modules.
2. The open-ended nature of the exercise sets a research-like context. Students are encouraged to search the web for relevant information, to explore possible "solutions", to critique the proposal in the first place, even to offer alternatives.
3. Students are active; furthermore, the openness gives the more advanced students the opportunity to go ahead while, at the same time, those less prepared are challenged at their level. The class does not proceed "lock-step".
4. Monitoring the students work while responding to their questions in process reveals lacunae in their understanding without passing judgement.
5. Students learn something about engineering design process, its iterative nature, how theory underpins building a product, the necessity of tradeoffs.

SURVEY RESULTS

An anonymous online survey was taken, with 23 students responding. The questionnaire was a standard five level Likert, ranging from 1, strongly disagree to 5, strongly agree.

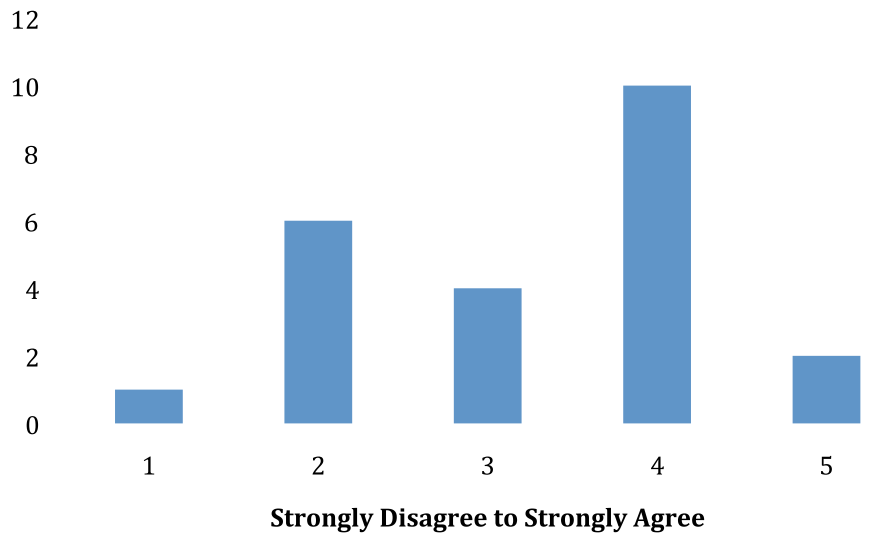
The first question was: 'I found the open design exercise an interesting challenge.'



Graph 1: 'An Interesting Challenge'

A total of 52.1% agreed.

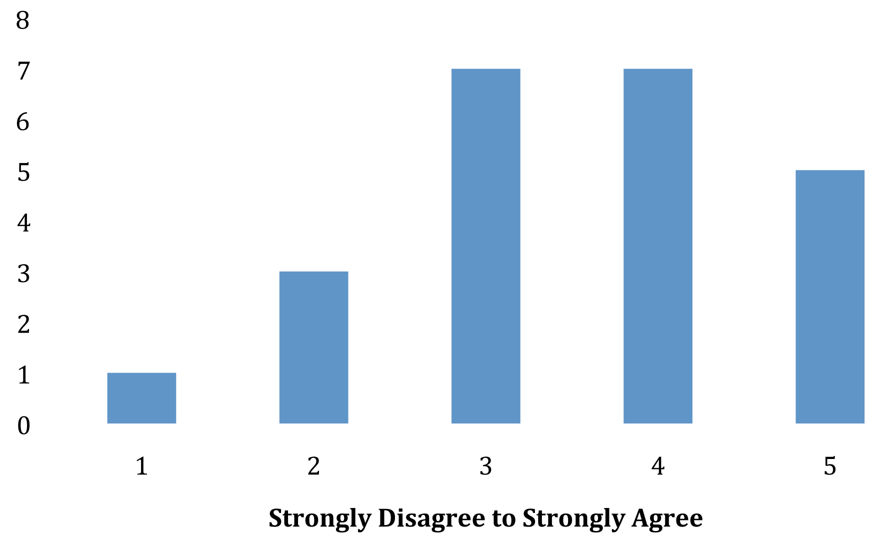
The second question was: 'I enjoyed the design exercise.'



Graph 2: ‘Enjoyed the Exercise’

A total of 52.2% agreed.

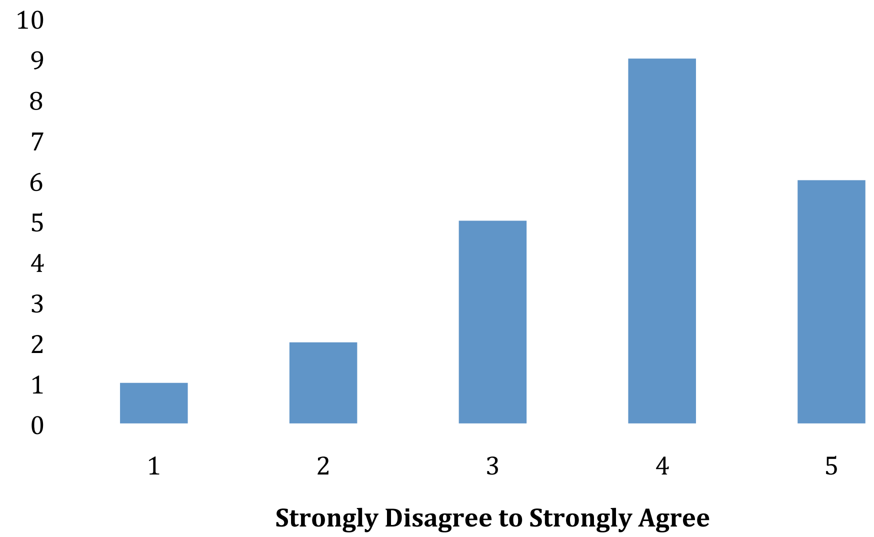
The third question was: ‘I learned about using a spreadsheet in engineering design.’



Graph 3: ‘Learnt about Spreadsheets’

A total of 52.1% agreed.

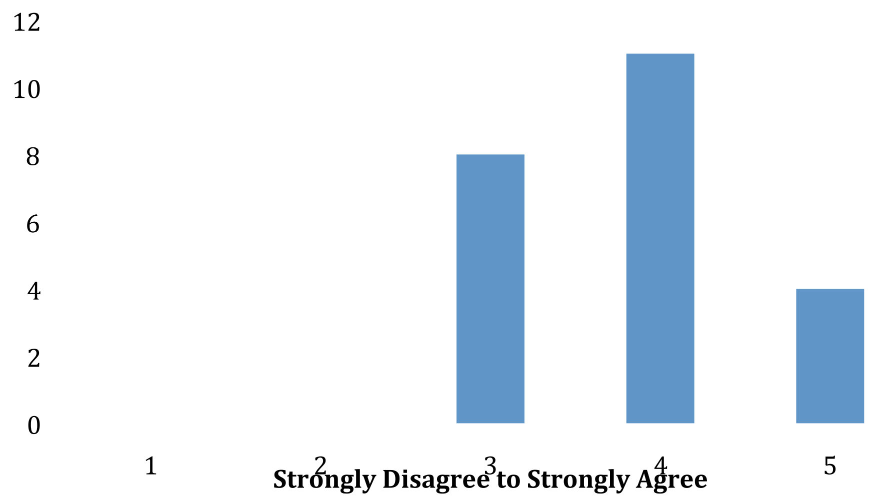
The fourth question was: ‘The exercise improved my basic engineering skills.’



Graph 4: 'Improved my Engineering Skills'

A total of 65.2% agreed.

The fifth question was: 'I have a better understanding of the conflicting requirements in engineering design.'



Graph 5: 'Understand Conflicting Requirements in Design'

A total of 65.2% agreed.

STUDENT COMMENTS

Only 11 of the 23 who completed the survey added a comment. Most of the comments were positive, and validated the aims of the exercise.

Two students who commented on the integration aspect said (all comments sic):

> was good tied most of what we learnt during year together.

> This would be a great excersize to do regularly with students because it ties together things you have learnt in almost every area of the course we are doing ie. maths, computers, materials, mechanics and IPT.

One commented on the team-work aspect:

> I feel overall it was very good as it made you think more rather than just been shown. Working in the groups also helped a lot as we fed off each other well.

Some felt the exercise was too hard, and the objectives not clear enough:

> The design exercise was too hard and there was not enough help when needed.

> Could of been clearer on the objective of the exercise and what the finished product was meant to be.

CONCLUSIONS

The exercise has now been done twice, once in 2009, during Professor Bucciarelli's visit, and again in 2010. The students found it a challenging exercise, and without prompting, identified some of the key aims, such as integration across modules, in their comments.

The good students produced excellent work, almost entirely on their own initiative. The weaker students learnt from the stronger ones, so that most students submitted good work.

It is hoped to further and more rigorously evaluate the project, and to expand this type of exercise across each year of the course. It is vital to identify new ways of using the open design technique to get students thinking like engineers, for as Professor Bucciarelli once said: "Design, in this general sense, is what engineers do most of their waking, professional hours."

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The effect of inquiry-based laboratory teaching on the views regarding the Nature of Scientific Knowledge: Turkey sample

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This study aims to investigate the effects of laboratory teaching implemented through inquiry-based approaches on the understanding related to the nature of scientific knowledge. A 14-week teaching program with focus on inquiry based learning was followed by 76 classroom teacher candidates in the framework of the laboratory classes in the fall semester of 2009-2010 educational year. 'Nature of Scientific Knowledge Scale' developed by Taşar (2006) to determine the view of students towards the nature of scientific knowledge was used both at the beginning and end of the process. Various teaching activities based on inquiry-based learning were implemented during the study (14 weeks).

At data analysis phase, a *t*-test was applied in order to see the relationship between the pre-test and the post-test. A scale with 6 factors (morality, creativity, developmental, parsimonious, testability and unity) displayed a meaningful and positive difference both in the difference between pre and post test scores and in many of the subscales. When analysis were undertaken in subscales, it was found that whereas the first two subscales (morality and testability) did not show a meaningful difference, the subscales 'creativity, developmental, parsimonious and unified' displayed meaningful and positive differences. It was observed that the teaching activities undertaken were highly effective in developing the understanding regarding the nature of scientific knowledge.

INTRODUCTION

The most important task of high quality science education is to train and educate individuals who inquire, do research and can think like a scientist. In order to create the desired model of individuals, it is necessary to start with teaching the students the elements of scientific knowledge and the nature of science; in plain language *how to do science*.

The approach that allows the transmission of scientific content in a manner that reflects the formation of scientific knowledge is the inquiry-based approach and in recent years the said approach has been seen as the cornerstone in all science programs (Bayır, 2008). In fact, inquiry-based research is both a process of discovering the external world and a method of learning and teaching. Although the definition of inquiry based approach as a teaching and learning method shows variations in the literature, in general it can be regarded as the reflection of the works and working principles of scientists on the teaching process and the on the works of the students. Due to this reason, the elements/characteristics of inquiry-based approach and nature of scientific knowledge show parallelism with each other.

Chippetta & Adams (2004) suggest in their study five reasons to utilize the inquiry-based methods in learning environments and one of the reasons they provide has been expressed as 'to acquire an understanding related to the operations of the nature'. In this context, it can be seen that inquiry-based approaches are fundamental in developing an understanding about the knowledge of nature (Abd-El-Khalick, 2001).

In Turkey, the majority of studies are related to the identification of student views regarding the nature of science and there are few studies that focus on the development of student perceptions or views in scientific knowledge and nature of science. This study aims to investigate the effects of laboratory teaching implemented through inquiry-based approaches on the understanding related to the nature of scientific knowledge. Student views were first identified and later a laboratory teaching program to contribute to the development of these perceptions was developed in order to create a deeper understanding. In this context, this study is believed to provide a meaningful contribution to the existing literature.

METHOD

Research design: The research is quantitative with a single group pre-test/post-test design.

Participants: The study was undertaken by 76 classroom teacher candidates attending the Second Year of Classroom Teaching Department in the fall semester of 2008-2009 educational year. It was possible to reach all the students in their second year of study through this research.

Data collection tool: 'Nature of Scientific Knowledge Scale' developed by Taşar (2006) to determine the view of students towards the nature of scientific knowledge was used both at the beginning and end of the process. Reliability co-efficient for the scale was found to be α=0,71 by Taşar (2006). The scale is comprised of 6 sub-dimensions; namely *morality, developmental, creativity, parsimonious, testability* and *unified*. The scale has 48 items with even number of items distributed to each sub-dimension.

Implementation: Various teaching activities (worksheets, theoretical information, group discussions, brainstorming, research homework etc) centered on inquiry based research were implemented in the lab during the study process (14 weeks). In addition to the activities, students were asked to come up with an original project based on scientific knowledge. Through the help of directed research, students were provided with opportunities to internalize the nature and characteristics of science by learning how science is done and how scientific knowledge is formed.

Data analysis: Three value analysis and test of normality were undertaken firstly and it was observed through the use of a Kolmogorov-Smirnov test that the distribution was normal. Later, a *t*-test was applied in order to see the relationship between the pre-test and the post-test.

FINDINGS

A scale with 6 factors (morality, creativity, developmental, parsimonious, testability and unity) displayed meaningful and positive differences (p=0.0001 and p<0.05) both in the difference between pre and post test scores and in many of the subscales. Table 1 displays the pre and post test results in terms of the general effect of teaching and learning.

Table 1: *t*-test results for understanding in the nature of scientific knowledge.

	N	X_{ort}	sd	t	p
Pre- test	76	169.01	75		
				-8.33	0.001
Post- test	76	182.80	75		

From the results in Table 1, it can be argued that laboratory training based on inquiry based approaches is very effective in developing perception and understanding towards the nature of science. Information related to the scale and data regarding each sub-dimension is provided below in detail. Table 2 provides numerical data about the dimensions.

Table 2: *t*-test results for the dimensions of 'Nature of Scientific Knowledge Scale'.

		N	X_{ort}	*sd*	*t*	*p*
Morality	Pre- test	76	30.51	75	-1.12	.266
	Post- test	76	31.10	75		
Parsimony	Pre- test	76	24.50	75	-8.96	.0001
	Post- test	76	28.81	75		
Developmental	Pre- test	76	30.20	75	-3.11	.0003
	Post- test	76	31.61	75		
Creativity	Pre- test	76	27.27	75	-6.10	.0001
	Post- test	76	31.63	75		
Testability	Pre- test	76	33.38	75	-.04	.964
	Post- test	76	33.40	75		
Unity	Pre- test	76	23.12	75	-4.52	.0001
	Post- test	76	25.21	75		

FINDINGS FOR THE FIRST DIMENSION; MORALITY: Science is subject to influences stemming from the specific historical period and social, economic and cultural influences (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002). Although it was seen that the views of the teacher candidates regarding the items based on morality changed due to the implementation, this difference (p=0.266) was not found to be statistically meaningful. When we consider the fact that being social beings, it is natural for human beings to be affected from the societal norms, we will come to realize that it is also possible for the social norms to create resistance towards developing or changing the views related to scientific knowledge. Due to this reason, this dimension of the study is not only related to the activities implemented in the laboratory but also to the culture individuals live in. When we think of this dimension in these terms, it is only natural not to see an immense change in this regard in the participants.

***FINDINGS FOR THE SECOND DIMENSION*; *DEVELOPMENTAL*:** Scientific knowledge, although continuous, is not static. It is in a state of continuous development and change. Analysis of scientific knowledge may change in the light of new evidence or even with different interpretations of the same data (Schwartz, Lederman & Crawford, 2004). Teacher candidates believe that science is in a continuous state of change. The study displays statistically that these views and perceptions changed positively at the end of the teaching process (p=0.0003)

FINDINGS FOR THE THIRD DIMENSION*; *CREATIVITY: Production and development of scientific knowledge consist of human imagination and creativity in addition to the observation of the nature itself (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002). Participants took part in activities in the laboratory environment in which they had a chance to utilize their creativity during the teaching-learning process and additionally, they presented an original project as their final work at the end of the process. This way, creativity remained as a continuous theme that was focused on throughout the process. Creativity was found to be one of the dimensions in which high level of development was documented (p=0.0001).

FINDINGS FOR THE FOURTH DIMENSION; PARSIMONIOUS: The fundamental purpose of science is to ensure the understanding of the physical universe by the human beings by their very own methods and explain the workings of the universe by providing simplified rules. In this context, it can be argued that science can be done by very basic (and simple) principles and tools. Due to both the experiments with very basic materials form daily life during the teaching process and the simple and clear explanation of the scientific knowledge obtained as a result of these experiments, teacher candidates were able to determine that science could be undertaken in a very simple (and basic) manner. It was agreed that science can be done everywhere and that it does not always necessarily involve complicated knowledge. It was seen that as a result of the teaching activities, teacher candidates were able to gain more depth in their views regarding the topic and that this acquisition was statistically meaningful (p=0.0001).

FINDINGS FOR THE FIFTH DIMENSION; TESTABILITY: Scientific knowledge is empirical. Scientists need empirical evidence in order to create scientific knowledge. Hence, the existence of new evidence requires the review and retesting of existing scientific knowledge (Abd-El-Khalick, 1998; cited in Ayvacı, 2007). Although teacher candidates undertook several repeat experiments in the lab with the existing data in order to reach healthier results, they were sometimes ineffective in proving the scientific knowledge. The researcher in the study observed the challenge and frustration in the utilization of the new evidence and proofs. It is believed that this problem played an important role in not being able to show a meaningful difference in the said dimension (p=0.964).

FINDINGS FOR THE SIXTH DIMENSION; UNIFIED: Various sciences contribute to the formation of a regular, single body of knowledge. If we want to explain it more clearly, we can say that although biology, physics and chemistry look like different scientific branches, their principles, theories and concepts are interwoven. In the lab training, experiments and activities in the above mentioned science branches were undertaken in an equal manner but none of activities or experiments were singled out for a specific science. When we examine the findings related to this dimension, we can argue that there is a positive change in participant views (p=0.0001).

DISCUSSION

In their study, Abd-El-Khalick & Lederman (2000) hypothesize that students and teachers can learn the nature of science by doing science and participating in scientific activities. In other words, they argue that science is best learned by doing. Starting from this point, teacher candidates were given opportunities to do science in inquiry-based lab classes by thinking and working like a scientist in a manner consistent with the methodology of scientific knowledge and they participated in scientific activities during the process (14 weeks) to learn the nature of scientific knowledge actively. At the end of the process, deepening of perceptions in many points related to the nature of science was found to be possible.

The teacher candidates were found to think at the result of the teaching activities that creativity is necessary in the formation of scientific knowledge which has a changeable nature. Additionally, they think that science does not always consist of complex information but rather has a parsimonious nature and that different branches of science can form a unity that involves interrelations. However, it was also observed that the teaching activities have little changed the views of teacher candidates regarding the morality and testability of science. Suggestions in the light of the findings of the study were provided at the end of the study.

RESULT AND SUGGESTIONS

In each age group, there are possibilities for each student to relate to their daily lives and to make sense of the nature of science and scientific knowledge according to the age and level of the specific student. Because of this reason, inquiry-based activities which can develop perceptions related to the nature of science and scientific knowledge should be a part of both formal and informal teaching environments. It is especially a must to reorganize science teaching programs in such a manner to allow the students gain an understanding about the nature of science (Küçük & Çepni, 2006).

Nature of science is best taught to youngsters. In this context, it will be useful to include and incorporate supporting and auxiliary classes which can help in the understanding of the nature of science (history of science, philosophy of science etc) in teaching programs starting from primary classes.

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The effect of inquiry-based laboratory teaching on the views regarding the Scientific Process Skills: Turkey sample

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The study aims to investigate the effect of inquiry-based laboratory teaching on the views regarding science process skills. A 14-week teaching program with focus on inquiry based learning was followed by 88 classroom teacher candidates in the framework of the laboratory classes in the fall semester of the academic year 2009-2010. The 'Science Process Skills Test' was used both at the beginning and at the end of the process to determine the scientific process skills of student teachers.

The scores related to the total scale and its subscales were analyzed separately. Meaningful and positive differences were observed between pre and post test scores both in the total score and in many of the subscales. There was no significant difference in one of the subscales of the study (design investigations). The other four subscales (the ability to identify variables, the ability to operationally define, the ability to form and state hypothesis and data and graph interpretation) showed meaningful and positive differences.

It was observed that the teaching activities undertaken were highly effective in developing scientific process skills and scientific understanding. Suggestions in the light of the findings of the study are provided at the end of the paper.

INTRODUCTION

One of the fundamental aims of modern science education is to create individuals who employ research, who ask questions, who examine concepts, who can relate their daily lives to science topics, who can use the scientific method in solving the everyday problems that are found in every field of life and who can look at the world with the perspective of a scientist (Tan & Temiz, 2003). In order to make this possible, science lessons should be taught in a manner that is compatible with the nature of science and lessons should be dependent on research, scientific methods and skills that these methods consist.

The procedures and skills that the students need in order to learn the science topics, to explain and describe the natural phenomenon in a correct manner are regarded as mental skills that are called scientific processing skills (Ateş & Bahar, 2002).

One of the techniques in science classes with which science process skills can be effectively implemented is an inquiry-based research technique. An inquiry-based approach aims to teach about the products of science by having students utilize several scientific processes used by scientists themselves (the methodology of doing science) such as observation, assessment, data collection and hypothesis testing. Regarded in this context, it will be seen that a pillar of the inquiry-based approach is science process skills (Bayır, 2008).

Arena (1996) states that the best manner to develop process skills is through the use of inquiry-based style classes and indicates that students seriously pursue the problems in such classes. His research revealed that workshops based on inquiry-based approaches had a meaningful and positive effect on the chemistry student teachers in terms of developing 'belief in self sufficiency in teaching chemistry, science process skills, understanding of the nature of science and attitudes towards teaching science'.

METHOD

Research design: The research is quantitative with a single group pre-test/post-test design.

Participants: The study was undertaken by 88 classroom teacher candidates attending the Second Year of Classroom Teaching Department in the fall semester of 2008-2009 educational year. It was possible to reach all the students in their second year of study through this research.

Data collection tool: The 'Science Process Skills Test' developed by Burns, Okey & Wise (1985) was used both at the beginning and at the end of the process to determine the scientific process skills of teacher candidates. The multiple choice test, comprised of 36 questions, measures *the ability to identify variables* (12 questions), *the ability to operationally define* (6 questions); *the ability to form and state hypothesis* (9 questions); *data and graph interpretation* (6 questions) and *the ability to design investigations* (3 questions). The reliability of the test was found to be α=0.82 by Özkan *et al*.

Implementation: Various teaching activities (worksheets, theoretical information, group discussions, brainstorming, research homework etc) centred on inquiry based research were implemented in the lab during the study process (14 weeks). In addition to the activities, students were asked to come up with an original project based on scientific knowledge. Through directed research, students were provided with opportunities to internalize the nature and characteristics of science by learning how science is done and how scientific knowledge is formed. In this study, all activities involve a holistic approach towards basic and integrated process skills.

Data analysis: In the data analysis phase, test of normality was undertaken first and it was observed through the use of Kolmogorov-Smirnov test that the distribution was not normal. Later, a Wilcoxon signed rank test was implemented.

FINDINGS

A scale with 5 factors (identify variables, ability to operationally define, form and state hypotheses, data and graph interpretation, design investigations) displayed meaningful and positive differences (p=.0001 and p<.05) both in the difference between pre and post test scores and in many of the subscales. Table 1 displays the pre and post test results in terms of the general effect of teaching and learning.

Table 1: Wilcoxon test results for understanding of science process skills

	N	X_{ort}	z	p
Pre- test	88	22.51	-3.77	0.0001
Post- test	88	26.81		

According to the results in Table 1, it can be argued that laboratory training based using inquiry based approaches is very effective in developing perception and understanding of the science process skills. Information related to the scale and data regarding each sub-dimension is provided below in detail. Table 2 provides numerical data about the dimensions.

Table 2: Wilcoxon test results for the dimensions of 'Science Process Skills Scale'

		N	X_{ort}	z	p
Identify variables	Pre- test	88	6.27	-6.56	.0001
	Post- test	88	8.85		
Ability to operationally define	Pre- test	88	3.18	-3.99	.0001
	Post- test	88	3.87		
Form and state hypothesis	Pre- test	88	6.29	-4.00	0.209
	Post- test	88	7.01		
Data and graph interpretation	Pre- test	88	4.29	-3.05	.0001
	Post- test	88	4.72		
Design investigations	Pre- test	88	2.46	-1.25	.209
	Post- test	88	2.35		

FINDINGS RELATED TO THE FIRST DIMENSION; ABILITY TO IDENTIFY VARIABLES: It is the ability to identify the elements or components of an event that is fixed or variable by condition (Bayır, 2008). The maximum score that can be obtained from this part of the test is 12 since it consists of 12 items. The mean average of 6.27 at the beginning of the process was found to increase to 8.85 after the laboratory training. Since p=.0001, a statistically meaningful difference is reached.

FINDINGS RELATED TO THE SECOND DIMENSION; THE ABILITY TO OPERATIONALLY DEFINE: It is the ability to generate definitions by utilizing the information derived form observations and experiences (Bağcı Kılıç, 2003). There are 6 items related to operational definitions, hence the maximum score that can be obtained is 6. The mean pre-test score of the participants was 3.18 whereas the post-test mean score was found to be 3.87. There is a quantitative increase which creates a meaningful difference.

FINDINGS RELATED TO THE THIRD DIMENSION; THE ABILITY TO FORM AND STATE HYPOTHESIS: a hypothesis is known to be a proposition that is based on unproven scientific suppositions. Forming hypothesis is a logical process that is a much more internal and creative process rather than a plain and clear behavior (Kanlı, 2007). There are 9 questions in the scale related to forming and stating hypothesis. Although the maximum score that can be obtained is 9, students could get 7.01 at the end of the process while their starting score was 6.29. When looking at the data based on percentages, it is seen as one of the dimensions which proved to be a success with 77%.

FINDINGS RELATED TO THE FOURTH DIMENSION; DATA AND GRAPH INTERPRETATION: It is the ability to assign meanings to and explain the data in the graphs and the ability to comprehend the relationships, trends and structures gathered form experiments. There are 6 items in this dimension of the scale and the maximum score to be obtained is 6. Student teachers proved the effect of the implemented teaching-learning program quantitatively by showing a rise from 4.29 to 4.72. It proved to be the most successful dimension at the end of the study, with a 78% success rate.

FINDINGS RELATED TO THE FIFTH DIMENSION; THE ABILITY TO DESIGN INVESTIGATIONS: It is the planning of a research by identifying the appropriate steps and materials in the framework of procedure and the designing of an experiment in order to test a hypothesis. Since there are 3 items related to designing research, the maximum score that can be obtained is also 3. Student teachers with a 2.46 mean pre-test score got

2.35 as post-test mean score. The dimension that inquiry-based teaching was not effective was found to be this dimension. It also exists in many studies in literature that not all science process skills can be acquired as a result of teaching activities regardless of the teaching technique that is used (Bayır, 2008; Şimş ekli & Çalış, 2008; Bağcı Kılıç, Yardımcı & Metin, 2010).

Designing research was found to be the dimension that proved to be the hardest for the students. Designing a research and turning it into a project was assigned as the final work for the students at the end of 14-week teaching period. Due to the fact that ability to design research is a complex skill and involves other science process skills (making hypotheses, identifying the variables, interpreting graphics and data, etc.) caused the students often ask help from the instructor (the researcher herself). In addition to that, teaching these skills may take time since designing research is a skill that requires original ideas and creativity.

DISCUSSION

This study investigates the effect of laboratory teaching based on inquiry-based learning on science process skills. Results show that the inquiry-based approach is effective in developing most of the science process skills however teacher candidates did not gain the science process skills fully at the end of the study. The most important reason for that is the fact that development of science process skills is a long-term acquisition. It is thought that only a year of laboratory classes during the bachelor's degree with a low classroom time (two hours) may be a reason for not effectively learning these skills. It is believed that longer implementations will lead to more positive results.

Another finding of the study is the result that student teachers were found to be at medium level in science process skills as seen in pre-tests; in other words, pre-lab training with inquiry-based approach. This finding is parallel with the results of many other studies in the literature (Demir, 2006; Akar, 2007; Ercan, 2007; Korucuoğlu, 2008). It is known that many university students both in classroom teaching departments and other departments are at the medium level in science process skills and cannot rise to the desired levels. Starting from these results, it is thought to be beneficial at early ages to begin providing programs and activities which involve science skills processes and allow students to think like scientists. It would also be beneficial to increase the importance attached to laboratory classes.

RESULT AND SUGGESTIONS

The effectiveness of laboratory-based teaching and active and hands-on learning is a known fact; however, new studies are required in order to test which method or integration of methods would be more efficient in implementation. It is believed that studies investigating the effects of both the inquiry-based approach and other approaches suitable for use in laboratory training would contribute to the literature immensely and therefore are suggested.

Although a positive difference was seen in the scientific thinking of the participants during the teaching process, the desired level could not be obtained in some dimensions of the study. This result shows that science process skills need to be developed in various classes with many implementations. Though there are many lessons in which students can learn how to think like a scientist and undertake scientific research, science classes are the most appropriate classes for the task of teaching science process skills. Hence, the students at the Classroom Teaching Department, who will be future teachers, should be provided long-term laboratory (science) programs that will help develop these skills.

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Using student presentations for peer-assessed learning of feedback concepts by physics students: experiences and reflections

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This contribution reports on, reflects on and evaluates the author's experiences, over three academic years, of using formal student presentations as a means of learning and assessment on an introductory engineering module taken by students in the third year of the B.Sc. in Medical Physics and Bioengineering at Dublin Institute of Technology. The module covered basic concepts in feedback systems as applied to medical and biological applications. Students were asked to prepare an individual PowerPoint presentation on a previously unseen homeostatic application (e.g. blood glucose control). Peer and tutor assessment of the presentations was employed, following a structured guideline agreed with the students. The contribution discusses the peer assessment experience in detail, including formal student feedback on the process.

BACKGROUND

The Level 8 B.Sc. degree in Physics with Medical Physics and Bioengineering at DIT (http://physics.dit.ie/programmes/medicalphysics.html) is a four-year, modularised and semesterised programme. In third year, students take six modules in the first semester; the second semester is devoted fully to industrial work placement. One of the modules in the first semester is composed in equal part of Physics of Medical Devices and Feedback and Control; the author has had responsibility for the latter part of the module since its introduction in 2007. In this portion of the module, there is 1 lecture hour scheduled per week (over a 12-week period) and 8 laboratory hours scheduled per semester (in two 4 hour sessions in the middle of the semester). The portion of the module subject is assessed by examination (with a weighting of 65%) and continuous assessment (with a weighting of 35%). It was decided to devote 20% of the 35% weighting for continuous assessment to traditional laboratory work, based on work done on laboratory experiments, carried out over a six hour period. The other 15% weighting for continuous assessment was devoted to peer and tutor assessed individual student PowerPoint presentations, following a structured guideline; a maximum of two hours were set aside for this activity.

A significant literature exists on peer assessment issues, both as applied to student group work (for example, McDermott, Nafalski & Göl (2000)) and individual student work, which is the focus of this paper. For example, Falchikov (1995) and Morris (2001) provide an interesting and comprehensive literature review on peer assessment issues; some other authors (e.g. Magin & Helmore (2001)) focus on the validity of peer and teacher assessment of technology students oral presentations skills. Some authors give more specific advice on how to structure the peer assessment process (e.g. Falchikov (1986)), suggesting that the provision of explicit assessment criteria to the peer assessors is important. Other authors (e.g. Kwan & Leung (1996)) focus on the agreement (or otherwise) between tutor and peer group assessments, using statistical techniques. Peer assessment of oral presentations, taking into account factors such as gender, university affiliation, time of day at which the assessment was carried out and participation in the development of the assessment criteria are considered by Langan, Wheater, Shaw, Haines, Cullen, Boyle, Penney, Oldekop, Ashcroft, Lockey & Preziosi (2005), for example. Other contributions are also of interest (e.g. the peer assessment of poster presentations, as discussed by Orsmond, Merry & Reiling (1996)). The contribution closest to the approach adopted in this paper (both from an assessment methodology and presentation procedure) is that of MacAlpine (1999), who considers peer assessments of undergraduate engineering students in a final year option subject.

ASSESSMENT EXPERIENCES

Students were asked to prepare an individual 10-minute PowerPoint presentation; relevant references, principally in technical papers, were provided as assistance. Presentation topics were chosen at random; a full list of topics is available from the author. Peer and tutor assessment of the presentations was employed, following a structured guideline agreed with the students (also available from the author). Credit was given both for the individual presentation and for individual student feedback to other presenters. Altogether, 20 students participated in the assessment over three academic years (2007-10).

Analysis shows that there a borderline (p=0.019) statistically significant relationship between the average peer assessment result and the tutor assessment result, with a correlation coefficient of 0.52 (though these results must be interpreted with some caution, as the number of students is small). On average, students are able to distinguish in a limited way between good and poor work produced by their colleagues. This justifies the decision made that peer assessment should compose a small contribution of the module credit; marks for weaker students tend to be enhanced, with marks for stronger students reduced, by the peer assessment process.

STUDENT FEEDBACK ON THE LEARNING AND ASSESSMENT PROCESS

Formal student feedback was gathered using a questionnaire, which is available separately from the author. The questionnaire uses a 5-point Likert scale, with 1 corresponding to ‘strongly disagree’ and 5 corresponding to ‘strongly agree’. The questionnaires are constructed with alternating positive and negative questions to avoid directional bias. For example, in the first question, students were asked to indicate whether they thought that the feedback from peer assessment would help their own learning (positive direction). Then, in the second question, they were asked to indicate whether they were uncomfortable assessing the work of their peers. The negative items are reversed for scoring. Overall mean questionnaire results for 2007-10 are provided in Table 1; 17 of the 20 students completed the questionnaire.

Students were also requested to give general unscripted comments. All students chose to give some comment; details are provided in Table 2.

Table 1: Student questionnaire results 2007-10 (mean values).

I think the feedback from peer assessment will help my own learning	4.00
I was comfortable (uncomfortable) assessing the work of my peers	3.41
I feel that assessing the work of my peers will help me to better improve my own performance in the future	3.76
I did (did not) enjoy the process of peer group assessment	3.18
I feel that I was able to be completely objective in marking the presentations	3.35
My confidence has increased (decreased) as a result of peer group assessment based on PowerPoint presentation	4.18
I feel the process of peer group assessment has developed my own critical thinking skills	3.65
I learned more from the peer group assessment than I would have if the lecturer only assessed my presentation	3.47
I was able to assess others work with confidence using the criteria provided	3.76
I feel positive about assessing the work of my peers	3.53
I felt that I was more confident in making my presentation knowing that my presentation mark was largely determined by my peers, rather than by the lecturer	3.35
I feel that assessing my peers does not involve too much work for me	4.35
The assessment breakdown (in the marking scheme) is about right	3.71
I feel I was treated fairly by my peers in their marking of my presentation	3.76
I feel that there was much (little) learning benefit to me in making my PowerPoint presentation	3.88
I learned from the positive (and less positive) features of the presentations of others	4.24
I feel that skills and practice in presentation are likely (not likely) to be useful in my working life	4.59
I think I learned more from the presentations that I would have learned if the time was devoted to lectures and labs	3.41
Devoting 15% of the subject mark to this activity is about right	4.00
Mean numerical value	3.77

DISCUSSION AND CONCLUSION

The author's experiences are that the learning and assessment method enhances student communication skills and further develops student ability to work effectively, particularly as individuals. More generally, the method is learner-centered, motivates independent learning, caters to a diverse student background, raises awareness of ethics, and unlocks previous student work and learning experiences to the benefit of all learners. The author agrees with the conclusion of Kwan & Leung (1996) that "although only a moderate degree of agreement has been found between tutor and peer group assessments … we believe that peer assessments should be introduced to students because the educational benefits of the learning experience may greatly outweigh the risks on an unreliable assessment outcome, particularly if peer assessment contributes only a relatively small part of the formal assessment". Overall, the learning and assessment approach assists in the aim of providing students with the fundamental skills required for life-long selflearning.

Table 2: Student unscripted comments 2007-10.

What did you like BEST about the assessment? Why?	*N*
Honest feedback on my presentation from others is good	4
Peer assessment enabled an objective point of view from audience	3
The work required for the presentation is good motivation for learning	3
Practice presentations in a comfortable environment	2
Explaining the topic in my own way	2
Interesting topic; real subject	2
Grading of feedback	1
Researching, preparing and presenting the presentation – these are skills required in the workplace	1
Everyone presented on different topics, so no boring repetition	1
What did you like LEAST about the assessment? Why?	
Very difficult to assess friends/mark others	4
Public speaking; I was nervous	3
Topic given hard to research	3
Time allocated for feedback insufficient in some cases	1
Getting bad feedback	1
I don't see the point in gaining credit for my feedback to other presenters	1
Marks given by peers; most do not seem to be interested in listening and learning from my work	1
Other comments	
Interesting/enjoyable experience	2
Peer marking was an interesting element to the assessment	1
I didn't realise we were being marked on feedback given to others	1
Feedback to other presenters is subjective so how can this be marked?	1
If the grid to be completed had other criteria such as time management, organisation etc it would be easier to assess the presentations	1
The marking scheme was helpful for me	1
I don't understand why giving feedback for others presentations was part of my mark	1

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Experiences of project based learning with students on first year modules

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This contribution reports on, and evaluates, the use of mini-projects for enhancing the learning of first year students at Dublin Institute of Technology, with particular reference to Level 7 students on the electrical engineering programme. The project objective was to design, build and test an everyday device that can generate electricity from sources of "free energy". The project aims to encourage first year engineering students to use their natural design creativity in a freeform, brainstorming manner. The project allows students to further develop their academic interests, assists student retention and facilitates student interaction, among other advantages. The work encourages students to appreciate that engineering is a creative activity, and helps bring some excitement and fun to the first year experience.

INTRODUCTION

The learning method has been used by the author, over a number of academic years, with first year students on the Level 7 degree in Electrical Engineering (2005-10), the Level 7 degree in Mechanical Engineering (2008-9) and the Level 8 degree in Electrical/Electronic Engineering (2009-10). Candidates apply for such programmes (in common with all higher education programmes) through a national office, in which points are given for examination results in six subjects taken in the Leaving Certificate, or equivalent. The maximum point score possible for a candidate is 600, with 55% of candidates scoring more than 300 points in 2009, for example (CAO, 2009a). Minimum points levels for programmes are set by student demand for the limited number of course places; in common with worldwide trends, student demand for technology courses is decreasing. Taking the Level 7 programme in electrical engineering (on which this paper is focused), the minimum points level was 185 in 2009 (CAO, 2009b), with the median points level being 265 (DIT, 2010, p. 61). Median points levels have remained below 300 in each of the past five academic years. Though there is some debate as to whether the points scored by candidates in an examination process dominated by a terminal examination is the best predictor of subsequent success on an engineering programme, nevertheless it is clear that many, if not most, of the students entering the programme have lower academic ability when compared to their wider peer group.

In a typical year, 30 learners commence the degree programme, the majority of which come directly from second-level education; there are a small number of students who are mature learners (categorised as students over 23 years of age) and a further small group of international students. Level 7 programmes are distinguished from Level 8 programmes, which in Engineering are four years in duration, require a much higher minimum standard in Mathematics at the Leaving Certificate examination (or equivalent) and allow successful graduates to work directly for chartered membership of engineering professional bodies. Successful Level 7 graduates in engineering may directly achieve associate (or equivalent) membership of the professional bodies.

FIRST YEAR ISSUES IN ENGINEERING PROGRAMMES

There is increasing evidence of a gap between student expectation and experience of engineering programmes. In surveys conducted of incoming engineering students at Dublin Institute of Technology (DIT) from 2003 to 2005, the most popular reason for choosing an engineering programme was '*I was always interested in how things work*' (Conlon, 2007), followed by '*I am interested in designing things*', '*Engineering is a good career*' and '*I want to build things*'. This practical orientation of students is reinforced by responses to a question asking why students came to DIT specifically; the most popular response was '*DIT has a good reputation for engineering*' followed by '*DIT courses are more practical and applied*'. However, having attended their programme for an average of two months, 43% of students admitted that they had '*no clear understanding of what their course was about before they came to DIT*', with many expressing surprise at the extent of the mathematical and scientific content of their programme. Such experiences are also documented by Edward (2002), among others, who suggests that incoming engineering students 'expect practicality and find abstraction… expect physical construction and find mental reduction'.

In summary, many students choose to become engineers because they like the idea of inventing, designing, building and creating products. However, first year college experiences often involve theoretical study and didactic, 'follow the procedures', laboratories. It was our experience that total concentration on these (necessary) aspects led to student disengagement and retention problems. Since 2005, the author has had academic responsibility for the Electrical Systems subject, one of the central technical subjects in the first year of the Level 7 degree in Electrical Engineering that is the main focus of this paper. This subject is structured into two thirteen-week modules; in each module, students are scheduled for two hours of lectures and two hours of laboratories in the subject each week. The subject is assessed as follows:

- Terminal examination (50% of subject mark), held after the completion of the second module.
- Laboratory work (25% of the subject mark), assessed continuously over both semesters.
- Individual student project work (12.5% of the subject mark), assessed in the middle of the second module.
- Module 1 assessment (12.5% of the subject mark); this is an exclusively multiple choice examination, held after the completion of the first module.

EXPERIENCES OF INDIVIDUAL STUDENT PROJECT WORK

The project objective, as outlined to the students, was to design and build a, possibly innovative, everyday device that can generate electricity from sources of "free energy". Students were given some background information, given real world instances of energy transfers and some examples of sources of "free energy" (an energy generating rucksack, a clockwork radio). The project could be done individually, or as part of a team of two persons; most students chose to do individual projects. The project assessment (which took place towards the end of the module) was weighted as follows: originality (20%), hardware design and construction (60%) and written explanation by means of a report of two pages maximum length (20%). The learning objective was to encourage first year engineering students to use their natural design creativity in a freeform, brainstorming manner, with little formal guidance from the tutor. Participation was not mandatory, though strongly encouraged.

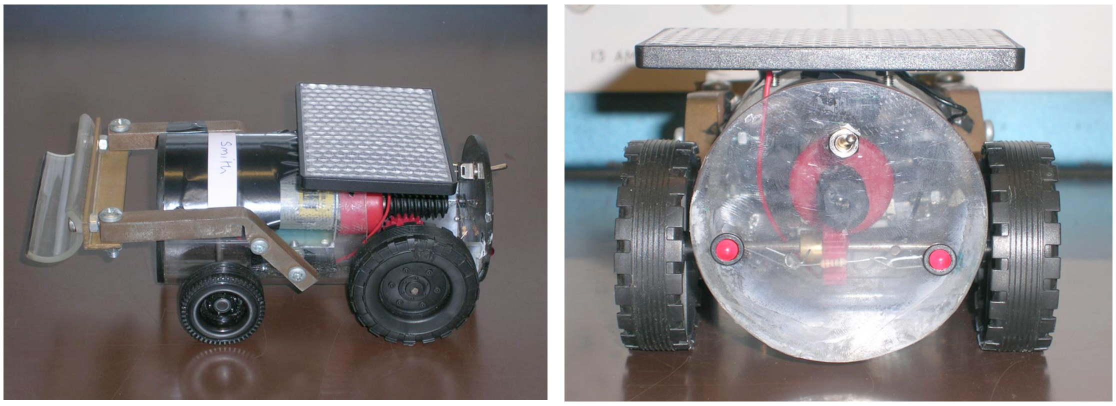

Figure 1: Solar powered tractor. Student from the 2007-8 cohort.

Figure 2: Bog battery. Student from the 2008-9 cohort.

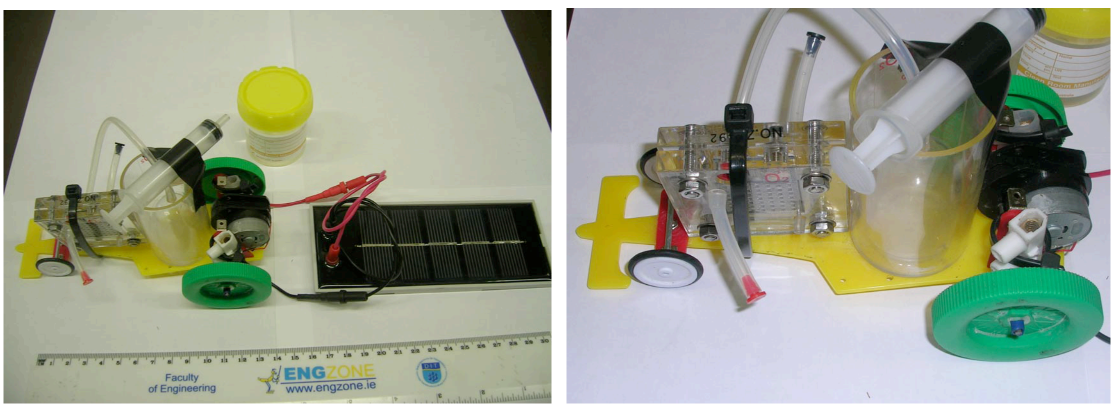

Figure 3: Hydrogen powered car. Student from the 2009-10 cohort.

A flavour of the project work submitted is provided by the photographs in Figures 1 to 3, taken by the author, of student projects in each of the last three academic years.

CONCLUSIONS

The author has used a freeform design project as part of a suite of learning and assessment options in a first year module in electrical engineering for the past five academic years. The benefits of the design project are as follows:

- it allows young engineering students to use their creativity and to further develop their academic interests;
- it establishes a balance between students’ expectations of their programme, and the nature of the academic work;

- it assists student retention;
- it introduces competitiveness in a fun and undemanding form;
- it allows students to interact and associate with one another through a common interest;
- it gives students an opportunity to show interesting work to their friends and family.

Up until 2009, a significant minority of students did not participate, or participated in a minimal manner, in the design project. In the 2009-10 academic year, the author put increased effort into student motivation, by demonstrating the successful projects of previous students and by discussing the learning benefits to be obtained from such project work. As a result, greater student engagement was produced, with the average project mark increasing from 46 in the three previous academic years to 65 in the 2009-10 academic year. In tandem, the percentage pass rate of the module at the first attempt was, in 2009-10, at the highest level for five years. The author intends to continue this motivation work with future cohorts of students on the module. As mentioned in the introduction, the author has used the approach with other first year student cohorts with success, though experiences are less detailed when compared with the students on the Level 7 electrical engineering programme.

POSTER SESSION

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Investigating the effectiveness of an inductive teaching and learning scenario used as a paradigm during a teacher preparation course

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POSTER SESSION

INTRODUCTION

Research on student cognition has demonstrated that learning is the result of interactions between people's everyday experiences and existing prior conceptions, which create a framework for understanding and interpreting information. According to this perspective, factors which have an effect on science learning outcomes, such as social interactions and emotions, do not receive primary attention. Knowledge is personally constructed by the learner through the interaction between his/her knowledge schemes and experiences of the environment. However, the existence and persistence of students' alternative conceptions in science gave rise to different research efforts to identify conditions that encourage or guide conceptual change. For example, the socio-cultural perspective considers the construction of knowledge as a social process, where social transactions and discourse are considered to be the basis for any subsequent learning (Wertsch, 1991).

The need for further investigation of the mechanisms or processes of change, and in particular those which are associated with factors beyond the cognitive domain, which might facilitate or impede conceptual change, has been emphasized in research (Pintrich, Marx, & Boyle, 1993; Pintrich & Sinatra, 2003). Pintrich *et al* (1993) proposed a model to pioneer a "warmer view" of conceptual change by articulating how affective factors interact with cognitive factors to promote knowledge change. Since Pintrich *et al*'s (1993) influential article, several models have been proposed (Dole & Sinatra, 1998; Lee & Kwon, 2001) portraying a "warming trend" in conceptual change research.

As a result of this broader view of conceptual change, there has been an emergent need to reform science teacher preparation programs (Bryan & Abell, 1999), since elementary teachers are nowadays charged with the responsibility of developing scientifically literate citizens, who are inquisitive and autonomous in learning and who are able to use their knowledge for solving everyday problems. However, teachers are often reluctant to teach science, because they lack disciplinary and/or pedagogical expertise required to promote science learning outcomes (Bencze, 2010).

The purpose of the present study was to investigate prospective elementary teachers' views on an inquiry-based module, which was implemented during a teacher preparation course. Taking into consideration that the affective dimension of pre-service teacher training has generally been neglected, this study aimed to propose a module incorporating the affective domain in the process of learning to teach basic science concepts. This study is part of a larger longitudinal research study aiming towards investigating cognitive and affective parameters involved in science teaching and learning.

METHODS

The sample consisted of 5 prospective elementary teachers who were in their third year of undergraduate studies. Participants were randomly selected from a group of 20 female students attending the course "Inquiry-based study of Science" during the fall semester of the 2009-10 academic year. Participants were given the identification codes T_1-T_5. The study followed a qualitative research design and it explored the case of a group of pre-service teachers' professional development through their involvement in a specially designed inquiry model. Data were collected from pre-service teachers' reflective journals in order to gain information concerning the contribution of this module as a paradigm to the development of their science teaching competencies.

The module was implemented in a fourth-grade class with 15 pupils. Pupils were involved in an inquiry-based science module concerning the concepts of floating/sinking. The facilitator was an expert elementary science teacher and the process was observed by the five pre-service teachers who created reflective journals on their experience. In the journals, each female pre-service teacher was required to answer to open-ended questions regarding their experience while observing the inquiry-based module and the contribution of this approach on the development of her science teaching competencies. Both cognitive and emotional parameters of learning were addressed.

The module was a five-stage process where the researcher used several combinations of the four identical cylinders in Figure 1. Two of the cylinders contained equal volume of water-like liquids (A and B) and the other two cylinders contained a larger quantity (volume) of water-like liquids (C and D). In each cylinder, there was an egg that was either sinking (B and D) or floating (A and C). Two of the cylinders contained tap water and the other two contained saline solution. The participants were not informed at any point about this difference, while there were no observable differences among the liquids in the four cylinders. The four cylinders were hidden from the participants, but the researcher had easy access to them and to other materials (*i.e.*, salt, tap water, saline solution, etc.).

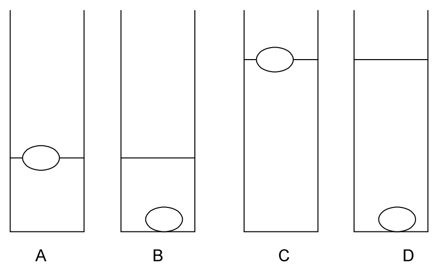

Figure 1: The four cylinders used in the study.

Initially, students were presented with cylinders B and C, and were called upon explaining why each egg was either sinking or floating in the two cylinders. Pupils were also asked to explain the position of each egg after switching the two eggs in the two cylinders, or after pouring water in cylinder B, so that the liquid in Cylinder B reached the same height in it. During the second phase, several tactics were used in an attempt to challenge students' expressed ideas relating to the reasons why one egg was sinking and the other was floating. The different steps of this strategy were aligned to pupils' conceptions, as these were expressed during the first stage. It was thus expected that pupils would realize the discrepancy of their initial conceptions and the subsequently presented evidence, and would be interested in bridging this discrepancy. The researcher went on with a 30-minute intervention. During the intervention (third stage), pupils actively participated in a series of activities aiming towards experimentally examining each of their conceptions in an attempt to construct the scientifically accepted explanation of the phenomenon. Students' questions were carefully discussed. The students were subsequently presented with the whole set of the four cylinders in Figure 1 and were asked to provide written answers (fourth stage) to open-ended questions in which they were required to implement their newly constructed knowledge. For example, they were required to identify which of the four cylinders contained tap or salt water and to predict the positions of the eggs in each of the cylinders in case either salt or more tap water was added and to justify their answers. At the end of the session, pupils were required to express the progression of their emotions as it occurred through their involvement in the inquiry, while the facilitator supported them by raising relevant questions.

ASPECTS OF PRE-SERVICE ELEMENTARY TEACHERS' ENGAGEMENT IN THE MODULE

In this part of the study, we focus on two parameters, namely, re-service elementary teachers' affective involvement in the process as observers and on the contribution of this specific experience towards the development of their science teaching competencies.

All participants stated that their involvement in the project enabled them to develop skills related to scientific inquiry and, thus, it contributed towards realizing the need to facilitate their future students to become consciously aware of their involvement in each step of the problem-solving methodology. Participants focused their attention on various aspects of the scientific inquiry and therefore on various skills related to problem solving through scientific inquiry, such as, identifying a problem, asking scientific questions, formulating hypotheses, designing experiments, collecting and analyzing data, drawing conclusions and communicating results.

For example, participant T_1 focused on the active participation of the learners in the process of knowledge construction. As demonstrated in the following excerpt, she emphasized the teacher's role in facilitating the students in the process of knowledge construction and the importance of inquiry and thinking skills in the process of learning.

> As future teachers, we have to facilitate students to discover knowledge. We have to make them inquisitive and able to create science questions, and to answer them by themselves. In order to construct knowledge, students have to be able to observe the world around them and to be able to analyze and synthesize information (Participant T_1).

Participant T_2 focused on both the contribution of a psychologically positive environment for the learner in the process of inquiry towards effective learning outcomes and also on the metacognitive skills, which can gradually be developed through the learner's repeated active engagement in scientific inquiry. Participant T_2 referred to both the positive emotions that she experienced as an observer and also on the module's contribution in developing participants' metacognitive skills, since the process of inquiry requires constant monitoring.

> During our involvement in this process, we were very enthusiastic. I believe that if we manage to make our students enthusiastic about our lessons in class, they will be more alert and ready to learn things and most importantly to improve their metacognitive skills. By being actively engaged in the process and by monitoring the process by themselves, it is easy to develop positive attitudes for science (Participant T_2).

As far as prospective teachers' emotional engagement in the process was concerned, all reported that they experienced positive emotions, but they attributed those emotions to different parameters involved in the process. For example, participant T_5 attributed the enthusiasm that she experienced to the fact that she had the opportunity to observe pupils "playing" with materials during their experimentations and she also emphasized the student-centered nature of the intervention. According to Ashbrook (2010), playing with a variety of materials during scientific investigations promotes learning through the senses and creates a positive learning environment in which learners build on common sets of experiences. The following excerpt from participant T_5's reflective journal clearly demonstrates her feelings.

> I did not expect that children would experiment with the concepts of floating/sinking with such great enthusiasm! By observing them "playing" with the materials, I realized how much I could learn through this process. The children would be most enthusiastic in being involved in similar projects as well. They would be able to discover knowledge! Time management was an issue for our group, since exchanging opinions on the experiments took a lot of time. (Participant T_5)

Participant T_3 supported that the module was interesting to her and different than anything she had done during her teacher preparation courses. She found the scenario to be very engaging for the pupils, and especially the fact that they interacted with simple materials in order to examine science concepts and to construct science content knowledge.

Finally, as demonstrated in the excerpt below, participant T_4 stressed out the fact that both male and female pupils were equally interested in being involved in the project. She also referred to gender stereotypes that exist in science and that learners' involvement in similar projects could contribute towards alleviating these stereotypes.

> At the beginning of our inquiry we felt anxiety about being involved in a project with experiments. However, during the process, we felt enthusiasm and the joy of learning , since we had the opportunity to experiment like scientists! Female scientists! Therefore, although most of us were negative in the beginning, we felt secure during the process, because we had the opportunity to be familiarized with the factors affecting floating/sinking. (Participant T_4)

DISCUSSION

The need to reform science teacher preparation programs has been pointed out in research (Bryan & Abell, 1999). Moreover, a "warming trend" in conceptual change theory has also been proposed (Pintrich *et al* 1993) according to which non-cognitive elements should be incorporated in the study of science learning. Therefore, science teachers are called upon incorporating elements, such as students' emotions, interests and social interactions in their everyday teaching practices. The purpose of the study was to investigate prospective elementary teachers' affective engagement in the process of observing an inquiry-based intervention implemented within a fourth-grade class and to examine whether they considered the module as useful for the development of their science teaching competencies.

Qualitative data analysis revealed that they acknowledged the contribution of the module on the development of their science teaching competencies, but they focused on different aspects of this contribution, such as, on the inquiry and science thinking skills, its student-centered nature, and on the active participation of the learners, especially when it relates to interacting with materials in order to construct science content knowledge. All participants expressed positive emotions for the process and attributed those emotions to various parameters, such as, the originality of the scenario, the relationship between the module content and students' everyday experiences. and to the positive classroom climate.

Due to the small sample size and to the qualitative nature of the study, we cannot that these conclusions are conclusive and undisputed. Further research should be conducted on other inquiry-based modules concerning other authentic scenarios in order to provide future science teachers with the necessary theoretical background and teaching materials facilitating their efforts for effective and authentic science teaching.

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The ‘More of’ and ‘Equally Likely Outcomes’ Sense-Making Resources in Probabilistic Thinking when Engaged in a Computer-Based Microworld

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This paper reports part of the findings from a bigger study, aiming to explore eleven-years-old children’s probabilistic understandings in a computer-based environment. The evolution of probabilistic thinking was investigated in a setting that afforded exploration and reflection on any initial understandings and the development of new understandings. Tools were created within the ToonTalk microworld and a three-phase setting was constructed to facilitate observation of children’s probabilistic thinking. The three-phase setting involved children: 1) playing chance games, 2) manipulating the tools in order to complete unfinished games, and 3) building their own games. This paper focuses on discussing the evolving sense-making drawn directly from the settings where children were involved in. The term ‘inductive image’ was formed to include evolving sense- making within the setting and refers to discovering, developing and applying a general principle from a set of facts and observations of the available tools. While the children were interacting with the computational environment, the inductive images were formulated and aided towards the development of mathematical understandings.

INTRODUCTION

Research studies in maths education (Noss & Hoyles, 1996; Noss & Pratt, 2002; Pratt, 2000; Sirivianou, 2006) have placed emphasis on constructing particularly rich and well thought-out environments in which meaningful and dynamic learning occurs. This view can be seen as an optimistic approach for the construction of probabilistic understandings, since it gives an exploratory analysis of children *thinking-in-change* (Noss & Hoyles, 1996) and allows construction of knowledge through direct manipulation of the tools inside the microworlds.

The present study investigated the evolution of probabilistic thinking in a computer-based and game-playing microworld setting that affords exploration and reflection on initial understandings, while allowing the development of new understandings. The focus of the paper is on the emergent sense-making concerning stochastic thinking, coded as ‘inductive images,’ and explores the connections that were made available through children’s engagement with the environment. It demonstrates that this evolving sense-making has a developmental character and gains priority in the children’s sense making throughout their interactions with the environment.

In this study, we decribe episodes from three case studies of children age 11 to 12, Christina, Kyriakos and Constantine[1], who were engaged in playing chance video games, while expressing their understandings of randomness, and constructing new understandings by making connections between the setting and their sense making.

[1] The names do not relate to the real names of the children.

METHODOLOGY

Ten case studies of children age 11 to 12 were conducted and video-taped. The project took place in a school in Cyprus over a period of two months. The children were engaged with a specially designed computer microworld in which each of them had three weeks to play six games (phase A), finish two unfinished games (phase B), and create his/her own chance game (phase C). The project was divided into three phases in order to provide opportunities for the children to play and build games by gradually introducing them to the tools created in the computer-based environment. A qualitative research approach was also employed, where, in addition to the video-recording process, data from observations, tasks interviewing, focus sessions, children's diaries and computer interactions were collected.

In order to create a computer-based environment where children could play and create games, the ToonTalk microworld was chosen. ToonTalk is an animated interactive world, where children build and run programs, not by typing text or arranging icons, but by performing actions upon concrete objects (Kahn, 1999). The idea in using ToonTalk was to create an environment where the tools within it could afford ways of linking seeing, doing and expressing (the prepared games and the unfinished games), while the environment could also enable testing of these links when the children manipulated the tools.

Figure 1 illustrates four of the six games created for the first phase of the project. The games intended to familiarize children with the environment, and to bring out children's initial understandings and sense-making resources in probability, while providing a variety of chance situations, with the aim of inspiring exploration of the connections which form probabilistic thinking.

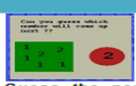
	How does it look	Aim of the game	Tools: Visible	Tools: Hidden	Areas of probability
1	 Guess the next number	To guess the next number	-Replacement sample space of {1,1,1,1,2,2} -Outcome tool		Non – conditional probability
2	 Lucky fishing	To guess the color of the next fish in the outcomes	- Non-replacement sample space of five green fish and six yellow fish -Outcome tool		Conditional probability
3	 Card game	To get the higher score. The player who plays with number1 gets 1 point, and the player, who plays with number 2, gets 2 points	Knowledge: The sample space has ones and twos - Outcome tool	Replacement sample space of {1,1,2}	Fairness
4	 Chances are up to ten!	To get as close as possible to a sum of ten. Each player has his own hidden sample space of numbers 1 to 7	Knowledge: Each sample space has numbers 1 to 7 - Outcome tool	2 non-replacement sample spaces with numbers 1,2,3,4,5,6,7	-Conditional probability -Probability comparison

Figure 1: Games created within the ToonTalk microworld.

RESULTS

Based on the analysis of the case studies, a theoretical framework was constructed, where children's initial understandings and emergent sense-making were mapped in a three-dimensional network of understandings. The first dimension, 'personal understandings,' contains initial resources that children bring to the task; the second dimension, 'inductive images,' conceptualizes emergent sense-making as the general strategies developed from the connections that are made between the features of the activity; and the third dimension, 'mathematical understandings,' involves mathematical understandings of probability. As the focus of this paper is on the second dimension, the inductive images, this dimension will be explored in more detailed.

An **Inductive Image** constitutes a sense-making resource that emerges through activity and is articulated in specific situated terms. An inductive image acts as a resource based on a set of new connections that are made by the child, and are situated within the features of the computational environment. The description will focus on the development of two inductive images, the '**more of**' (*the more frequent an object is in the garden, the bigger the chance of getting that outcome)* and the '**equally likely outcomes**' (*if the proportion of the objects inside the garden is equal then the objects have the same chance of coming up*), which initiated connections within the setting and the mathematics embedded in it. Furthermore, these inductive images were the first to be constructed and facilitated the development of the others.

CONSTRUCTING THE 'MORE OF' INDUCTIVE IMAGE, WHILE OBSERVING THE SAMPLE SPACE AND THE OUTCOMES

The first inductive image to be developed throughout the case studies was the inductive image of '*more of.*' Initially, Christina articulated for the very first time the inductive image of 'more of' in the 'Lucky Fishing' game (Figure 1). In a sample space of {4 yellow fish, 5 green fish}, Christina stated that '*I think that the next outcome is going to be a green fish, because it has more chances of coming up, there are more green fish than yellow fish inside the garden… it will be easier for the computer to pick up a green one.'* Although connections were made between the frequency of the objects inside the sample space and the outcomes, deterministic and causal connections are present. In the 'Card' game (Figure 1) when the children played the game twice and they won once each, Christina made a hypothesis about the frequency of the objects inside the sample space and she related that to the outcomes: '*I think that inside the garden must be more ones than twos, because my number (number 1) was coming up more times than number 2.*' In the 'Chances are up to 10' game (Figure 1), Christina assigned numbers to the probability of getting an outcome when making her predictions: '*I have 1 out of 5 chance of getting my outcome, because I already got 7 and 1, 8 altogether, and I need number 2 to get to 10. So, there are 5 numbers left and I need one of them only.'* She was in control of the frequency of the objects inside the gardens, in the sense that she knew which numbers were extracted and which numbers were still available in it. At the same time, she came to see the garden as a random generator and the desirable outcome as a predictable portion that she could calculate and make estimations on it.

THE CONSTRUCTION OF THE 'EQUALLY LIKELY OUTCOMES' INDUCTIVE IMAGE

During this inductive image, the children make connections between the random generator, the equal proportion of the objects inside it and the outcomes. Usually this inductive image starts developing just after the inductive image of 'more of'; alongside the 'more of' inductive image, or as an alternative to the 'more of' inductive image; and it takes its final form when the inductive image of 'more of' is fully developed.

In the 'Lucky fishing' game (Figure 1), Kyriakos' inductive image of 'more of' had started to develop up to a point that he was paying attention to the frequency of the objects inside the random generator, and he reasoned about the effect that they might have on a potential outcome. In an equally likely situation, the inductive image of '*equally likely outcomes'* was constructed: '*I don't think that we can predict the outcome now,… because there are 4 green and 4 yellow fishes and that makes them equal, they have the same chances of coming up.*' However, his inductive image of '*more of'* was not fully developed and these new connections that he made were influenced by his personal understandings: '*if I was to predict the next outcome though I would say, that a green fish will come up next, I have a hunch …or maybe, because it looks like a pattern… yellow, green, then yellow again.'*

Another example of how this inductive image is constructed is shown in Constantine's case study, in which he is using this inductive image as an alternative to the inductive image of 'more of' in which he stated that '*there are 5 yellow and 5 green fish in the garden, we can't make a prediction now, because both have the same chance of coming up.*' At this point, Constantine had developed his inductive image of 'more of' a step further than Kyriakos.' He came to recognize the garden as a random generator and the proportion of the objects inside it as a way of predicting which outcome is more likely to come next.

DISCUSSION

Children started forming inductive images from the basis of their personal understandings, while they were looking for deterministic ways of predicting the next outcome. When their interaction with the environment advanced, they were progressively identifying the mathematics embedded in the features of these connections, and eventually constructed and developed their mathematical understandings. While interacting with the environment, children were observing connections between the features of the computational environment, and how they were operating either together or separately. As a result, children progressively realized the properties of each probability tool and made connections between the properties of each tool that was built into the tool's relatedness to the other tools.

It appears that the development of probabilistic thinking can be facilitated, if children are actively engaged in an environment that is rich in representations of the concept. If the children have the opportunity to develop probabilistic thinking within a meaningful context where utility and purpose are continuously scrutinized within an environment, then mathematical emergent sense-making can be developed.

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The Effect of Individual Characteristics and Argumentation Contexts on Scientific Argumentation Ability

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Sixty-one undergraduate primary education students were administered the Argumentativeness Scale and were then allocated to 15 four-member, mixed-trait argumentativeness groups. Each group participated in one argumentation activity for a scientific issue, and another for a socioscientific issue. Participants discussed on line and then formulated their individual standpoint on each issue. Scientific Argumentation Ability (SAA) was measured using a scheme based on the one proposed by Sadler (2006). A 3×2×2 mixed factorial design with repeated measures of SAA was then applied, with trait argumentativeness as a between-subjects factor and argumentation issue (scientific or socioscientific) and form of argumentation (individual or dialogical) as within-subjects factors. Analysis indicated a significant interaction between argumentation issue and form of argumentation. SAA for the socioscientific issue was higher in its dialogic form, whereas, for the scientific issue, it was higher in its individual form. A significant main effect of argumentation issue was also observed, indicating significantly higher SAA for the socioscientific issue. Trait argumentativeness did not have any significant effect on SAA. Scientific argumentation is considered both the process and the outcome of justifying scientific claims and comparing competing theories, and should be an integral part of science teaching and learning. Educational implications of the results are discussed and recommendations for further research are made.

INTRODUCTION

Scientific argumentation is considered both the process and the outcome of justifying scientific claims and comparing competing theories. Therefore, scientific argumentation must be an integral part of science teaching and learning. Scientific argumentation ability (SAA) has been attracting the interest of science education research in recent years (Jimenez-Aleixandre & Erduran, 2008). Much of the research is conducted in an effort to develop learning activities that effectively foster SAA. Curriculum developers worldwide are also setting standards that underline the importance of scientific argumentation (Jimenez-Aleixandre & Erduran, 2008). Despite its importance, scientific argumentation is absent from typical science teaching and learning practices activities (Driver, Newton, & Osborne, 2000). Developing scientific argumentation is considered an extremely difficult task, especially for children (Andriessen, 2006; Kolsto, 2001; Kuhn & Udell, 2003). A way to foster scientific argumentation relates to focusing on factors that can affect SAA. Trait argumentativeness is an individual characteristic that depicts the extent to which someone tends to participate in and enjoy argumentative activities (Infante & Rancer, 1982). Argumentation contexts can be defined by the issues being discussed and the form that argumentation takes. Scientific argumentation can be expressed dialogically or individually and at the same time can either address scientific issues, without specific societal interest, or socioscientific issues with societal impact. It has not yet been adequately investigated whether trait argumentativeness and argumentation contexts can affect SAA. The present study examined whether trait argumentativeness and argumentation contexts (issue and form) affect scientific argumentation ability.

METHOD

Sixty-one undergraduate primary education students were administered the Argumentativeness Scale (Infante & Rancer, 1982) and allocated to 15 four-member, mixed-trait argumentativeness groups. Each group participated in two argumentation activities: one for a scientific (effects of atmospheric pressure on the level of water contained in a glass volumetric tube implicated in a series of demonstrations) and one for a socioscientific issue (an argumentative text related to the Kyoto protocol and global warming). Students accessed material, studied it individually, and discussed anonymously on line. Finally, they formulated their individual standpoint on the issue.

ANALYSIS AND RESULTS

According to Toulmin`s Argument Pattern (Erduran, Simon, & Osborne, 2004), scientific arguments are justified with data, warrants, backings, qualifiers or rebuttals. Sadler's analysis scheme (2006) integrates different argument elements into justifications, and argumentation is assigned six predefined levels of a rubric. In this study, the total number of justifications included in students' argumentation yielded the SAA score (four measures of SAA). Mean SAA scores were higher for higher trait argumentativeness groups. Mean SAA scores were also higher for the socioscientific issue and for individual argumentation, compared to the scientific issue and collaborative argumentation, respectively (Table 1).

Table 1: SAA by Trait Argumentativeness Group and Argumentation Contexts

	Argumentation Issue			
	Socioscientific		Scientific	
Argumentation Form	*M*	*SD*	*M*	*SD*
Low Trait Argumentativeness (*n* = 20)				
Collaborative	5.05	2.76	3.45	3.30
Individual	6.90	2.71	3.15	1.39
Both	5.98	2.26	3.30	2.15
Medium Trait Argumentativeness (*n* = 22)				
Collaborative	6.27	2.68	3.82	1.97
Individual	6.50	1.87	3.05	1.05
Both	6.39	1.97	3.43	1.22
High Trait Argumentativeness (*n* = 19)				
Collaborative	6.00	2.92	4.21	2.78
Individual	7.53	2.27	3.84	1.74
Both	6.76	1.95	4.03	2.03

A 3 (Trait Argumentativeness) × 2 (Argumentation Issue) × 2 (Argumentation Form) mixed ANOVA was applied. Trait Argumentativeness was a between-subjects factor, whereas Argumentation Issue and Argumentation Form were the two within-subjects factors. No significant differences between the three Trait Argumentativeness groups were found. Results revealed a significant interaction between Argumentation Issue and Argumentation Form $F(1, 58) = 17.981$, $p = .000$, $\eta^2 = .237$, because SAA for the Socioscientific Issue was higher in its Individual Form, compared to the Collaborative Form ($M = 6.95$, $SD = 2.30$, and $M = 5.79$, $SD = 2.79$, respectively), whereas SAA for the Scientific Issue was higher in its Collaborative Form, compared to the Individual Form ($M = 3.82$, $SD = 2.69$, and $M = 3.33$, $SD = 1.42$, respectively). Analysis also revealed a significant main effect of Argumentation Issue on SAA. Thus, SAA was higher for the Socioscientific Issue and lower for the Scientific Issue (M=6.37, $SD = 2.05$, and $M = 3.57$, $SD = 1.82$, respectively).

DISCUSSION AND CONCLUSIONS

In this study, trait argumentativeness was measured using a context-free instrument. Johnson, Becker, Wigley, Haigh and Craig (2007) suggested that actual trait argumentativeness varies across argumentation contexts and can be more precisely measured for more familiar argumentation issues. Thus, actual trait argumentativeness might have been more correlated with Argumentativeness Scale scores for the socioscientific issue. Additionally, research showed that individuals exhibiting high argumentativeness can equally express complex or quite simple arguments (McPherson & Seburn, 2003).

The observed interaction between argumentation issue and form of argumentation can provide valuable information towards understanding how argumentation contexts affect SAA. Individual argumentation was followed by collaborative argumentation on the same issue and was found to be more elaborated only for the socioscientific issue. Research findings suggest that prior engagement in collaborative argumentation benefits individual argumentation if argumentation issues are complex and familiar (Dong, Anderson, Kim, & Li, 2008; Reznitskaya, Anderson, & Kuo, 2007; Reznitskaya, Kuo, Clark, Miller, Jadallah, Anderson, & Nguyen-Jahiel, 2009). Socioscientific issues can be characterised as being complex and familiar, contrary to scientific issues, which are not perceived by most people as such (McClelland, 1984).

The finding that SAA was superior for the socioscientific issue corroborates many other research findings (Erduran et al., 2004; Sadler, 2006; Sadler & Donnelly, 2006; Zohar & Nemet, 2002). Socioscientific issues are considered complex and unresolved, and offer multiple viewpoints, allowing individuals to consider multiple arguments and counterarguments (Chinn & Brewer, 1993).

In conclusion, argumentation contexts should be considered as potentially affecting SAA. This study showed that designing effective scientific argumentation activities should take into consideration argumentation contexts and that it is possible to foster argument development by carefully configuring them. Therefore, when developing scientific argumentation activities, using issues from the socioscientific sphere can potentially facilitate the development of complex argumentation that can be integrated into individual argumentation. The interaction of argumentation issue and argumentation that was identified by the present study is also indicative of the complexity of factors affecting SAA and needs to be further investigated.

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Primary School Students' Investigation Strategies

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The study provides evidence concerning primary school students' experimentation strategies. Semi-structured individual interviews were conducted with 80 fourth- and sixth-grade students as they were investigating the functioning of an improvised device. The device consisted of a wooden box having on its surface eight electric light bulbs in a line and five switches in another line underneath. The light bulbs and the switches were connected in a hidden circuit inside the box, while a red push button, beneath the bulbs and the switches, was used for testing the functioning of the device. The red push button was a general switch of the hidden circuit (i.e., only by pushing the button one could find out whether one or more bulbs could light on). The students were explicitly instructed to think aloud prior and after any experiment with the device, and to keep a record of their experiments and the consequent results. The interviews were tape-recorded and transcribed for detailed analysis in conjunction with the individual ways of recording the experimental data. The results showed that students mainly used five distinct investigation strategies during their experimentation with the device. The majority of the students were inclined to mainly collect evidence from the experimental space and failed to co-ordinate their hypotheses with the collected evidence. They had also difficulties to effectively organise their results anddid not take full advantage of their recorded data. The results of the study can guide further research for identifying patterns of children's investigation ability and design teaching scenarios conducive to accelerating their cognitive growth.

INTRODUCTION

Scientific thinking refers to the mental processes used when reasoning about the content of science or engaged in typical scientific activities, or specific types of reasoning that are frequently used in science (Dunbar & Fugelsang, 2005). Scientific investigation broadly defined includes many procedural and conceptual activities, such as, theory generation, experiment design, hypothesis testing, control of variables, data interpretation, coordination of theory and evidence, evaluation of evidence, use of apparatus, performing statistical calculations and many others (Zachos, Hick, Doane & Sargent, 2000; Zimmerman, 2007). Due to this complexity, earlier studies had limited their scopes by giving attention either on the procedural or on the conceptual aspects of scientific reasoning. Klahr and Dunbar (1988, Klahr, 2000) developed an integrated model that incorporated domain-general strategies with domain-specific knowledge. This model conceived scientific reasoning as problem solving that is characterized as a guided search and information gathering task. The model is known as SDDS model (Scientific Discovery as Dual Search). According to this model scientific discovery is accomplished by a dual search process. The search takes place in two related problem spaces, namely, the hypothesis space and the experimental space. Searching the hypothesis space involves the process of generating new hypothesis based on some knowledge about the domain either as prior knowledge, or as knowledge through experimentation. Searching the experimental space involves the performance of experiments that will yield interpretable results. Search in the two spaces is mediated by a third process, the evidence evaluation process. Evaluation assesses the fit between theory and evidence, and guides further research in both the hypothesis and the experimental spaces.

In the years since the appearance of the Klahr and Dunbar's model of scientific reasoning (1988), there has been a move toward research in which participants take part in all three phases of scientific activity (Keselman, 2003; Klahr, Triona & Williams, 2007). These approaches are called self-directed experimentation research (Zimmerman, 2007). In self-directed experimentation studies, individuals learn about a multivariable causal system through activities initiated and controlled by the participants. The present study was based on the Klahr and Dunbar model (1988, 2000) and took into account self-directed experimentation research. The study attempted to investigate fourth- and sixth-grade students' investigation strategies and related cognitive abilities.

METHODOLOGY

Initially, ten fourth- and ten sixth-grade classes were randomly selected from a geographical district in Cyprus. The total number of 498 students (250 sixth graders and 248 fourth graders) was administered a six-item questionnaire consisting of three problems relating to control of variables and three other problems relating to combinatorial reasoning. Based on students' performance on this questionnaire, two different groups of students were separated. The first group included students who had low score on the questionnaires (the low achieving students), and the second group included those students who had high score. Thus, four strata of students were formed, namely, high achieving students (fourth and sixth graders), and low achieving students (fourth and sixth graders). Finally, 20 students from each stratum were randomly selected. Individual interviews were conducted with these 80 students as they were investigating an improvised device. The device consisted of a wooden box with eight small electric bulbs in a line and five switches, in another line below the bulbs, which could move up and down. The bulbs and the switches were connected in a "hidden" circuit inside the box, in a way that only one or none of the bulbs could light on, while a "tester," or a general switch, located below the five switches, was used to test whether one or more bulbs were lit on. The bulbs and the switches were connected in such a way, so that only one lamp could light on with different combinations of the switches. Switch number 3 constituted the general switch of the device and switch number 5 constituted a dummy switch that was not connected to the electric circuit of the device.

The interviewer, in a game-like fashion, explained the function of this device and the role of the switch and the tester. Then, students were asked to form "initial hypotheses" about its functioning. Subsequently, they were asked to carry out experiments and test their hypotheses. The students were instructed to "think aloud," prior and after any experiment using the device. Each interview was tape-recorded, and transcribed for data analysis. In the present paper, the results of the qualitative analysis are presented focusing on the 80 students' investigation strategies.

RESULTS AND DISCUSSION

The results indicated that students used five distinct investigation strategies, during their experimentation with the experimental device. The five strategies and the number of students who followed each strategy, across grade level (age) and across students' abilities are presented in Table 1.

Table 1: Students' Investigation Strategies across Grade Levels and Abilities

	Frequencies						
	4^{th} Grade		6th Grade		All Students		Total
	Abilities		Abilities		Abilities		
Strategies	Low	High	Low	High	Low	High	
Strategy 1 (Random search in the Experimental Space)	8	0	5	0	13	0	13
Strategy 2 (Systematic search in the Experimental Space)	3	3	10	0	16	0	16
Strategy 3 (Dual search, but random experiments)	7	2	3	2	10	4	14
Strategy 4 (Dual search, but without coordinating evidence and theory)	2	10	2	9	4	19	23
Strategy 5 (Dual search, by coordinating evidence and theory)	0	5	0	9	0	14	14
	20	20	20	20	40	40	80

In the first strategy, students employed a trial-and-error strategy by performing different random experiments that did not follow from any previous hypothesis. These students searched only the experimental space, and were not able to reach any conclusion relating to the functioning of the device and most of them did not achieve to light up all the bulbs. The students who employed the second strategy tended to also search only the experimental space, but in very systematic way. Thus, they indicated that they were not randomly searching the experimental space and provided evidence indicating that they developed, in some degree, their combinatorial reasoning. The students who adopted this strategy were more systematic in performing experiments, but they did not search the hypothesis space and attempted to draw conclusions based on their experimental results only.

The students who employed the last three strategies started to search the hypothesis space as well. Thus, those who employed the third strategy had the ability to formulate several hypotheses by searching the hypothesis space, but were not able to verify their hypotheses based on the experimental results, although they did not move the switches up and down in any systematic way. Consequently, they were not able to co-ordinate hypotheses and experiments in order to investigate the functioning of the device.

The students who followed the fourth strategy were able to identify the general (GS) or/and the dummy switch (DS), but their conclusions took into consideration only the the experimental results. So, they managed to solve the problem when they finally re-examined their recorded data carefully. All students who followed this strategy, apart from the systematic movement of the five switches, formulated more hypotheses than students who adopted the previous strategies (more than three hypotheses), but they did exhibit the ability to coordinate their results with their stated hypotheses. As indicated in Table 1, this strategy was used mainly by high ability students from both grade levels.

The students who adopted the fifth strategy had to a great degree developed their ability to formulate hypotheses and also exhibited an ability to verify them using contradictory data. They formulated more hypotheses and, for each hypothesis, they formulated a relatively small number of sub-hypotheses, indicating an ability to test their hypotheses based on the experimental data and shift to a new hypothesis guided by their experimental evidence. The students who followed this strategy were more successful in finding answers relating to the functioning of the device (i.e., the identification of the GS and DS) by co-ordinating their hypotheses (theory) and their experimental data (evidence). Some of these students also exhibited elements of mature combinational reasoning and they were systematically searching the experimental space without repeating any experiments.

As indicated in Table 1, the more popular strategy was Strategy 4, while the majority of students with low abilities (irrespective of class) employed strategies 1 and 2, and the majority of students with high abilities used the more developed and complex strategies, namely, strategies 4 and 5.

The five strategies seem to represent a developmental sequence from a not-well developed strategy, to a more complex one, involving progressively a more systematic search of the experimental space and then the search in the hypothesis space as well. Moreover, only strategy 5 incorporated not only the dual search in both the hypothesis and the experimental spaces, but the coordination of theory with evidence (the evaluation phase). The co-ordination of hypotheses (theory) with experimental data (evidence) constitutes the heart and the most difficult process of scientific investigations. This process requires higher cognitive abilities and individuals should, by coordinating their experimental data with previously stated hypotheses, decide whether their hypotheses should be accepted, modified, or rejected. This ability integrates not only the two related searches in the hypothesis space and the experimental space, but the evaluation process as well. Similar research designs can be very useful for identifying patterns of children's cognitive development and for the design of teaching scenarios conducive to accelerating students' cognitive growth.

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Authentic science experience to improve teachers' ability to implement inquiry learning

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Since a few years, standards in science education in Germany prioritize inquiry-oriented learning approaches to actively engage students in scientific processes and promote scientific literacy. However, there is still al lack in well suited approaches to encourage science teachers in using inquiry-based scientific reasoning and processes in instruction. Until now, many teachers in Germany view inquiry as difficult to realise and may be still confused about what constitutes inquiry teaching.

Several studies have shown some promising intervention strategies to foster teachers' understanding of inquiry teaching and help to implement inquiry-based learning in science education (Brown & Melear, 2006; Roth, 1999; Windschitl, 2002).

Realising authentic science inquiry projects seems a promising way to foster preservice teachers' understanding of the inquiry-process (Schwartz et al., 2004). We assume that teachers need professional development programs in which authentic science experience is related to explizit-reflective inquiry-instruction.

The purpose of our study is to investigate approaches to improve preservice teachers' ability to create inquiry-based lessons and implement inquiry-based science learning in their classrooms.

The following research questions will be investigated:

1. What are the preservice teachers' conceptions of inquiry?
2. What conceptions of inquiry emerge from preservice teachers experience in authentic science?
3. How effective are authentic science experiences in changing preservice teachers' conceptions of inquiry when
    a. authentic science experience is accompanied by reflection processes?
    b. authentic science experience is accompanied by reflection processes and preservice teachers' engagement in design activities?

The design of the study will be presented.

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Friday Morning Session 1,
17th September 2010

Centre for the Advancement of Science Teaching and Learning

CASTeL

Learning and Teaching Through Inquiry: Bringing change to the science classroom

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Increasing concern is being voiced worldwide regarding the quality of science and mathematics education. The release of the TIMSS (Trends in International Mathematics and Science Study) results in 1999 heightened this concern and ongoing studies have helped validate the need for change in science and mathematics education. Effective reform requires bringing inquiry teaching and learning to the forefront in K-12 schools. In order to meet this challenge successfully, substantial changes in teacher preparation and professional development, as well as teaching practice, are necessary. Physics by Inquiry, by Lillian C. McDermott and the Physics Education Group at the University of Washington, provides both a curriculum and an instructional approach that helps teachers develop a deep of understanding of physics and physical science topics relevant to the K-12 classroom. These research-validated, professional development materials provide an opportunity for teachers to learn as they are expected to teach, that is, through a process of inquiry. The results of studies conducted to assess the effects of the curriculum on changes in teachers' content understanding, their teaching practice and their students' achievement will be discussed.

With increasing concern regarding the state of K-12 science education, greater attention has been directed toward the need for better-prepared teachers in elementary and secondary science classrooms. In response to concerns regarding the quality of K-12 science education, a parallel concern regarding the means by which teachers are prepared to enact educational reform in their classrooms has emerged. The need for more extensive professional development programs for inservice teachers has been fueled by the belief that preservice teacher preparation cannot adequately prepare teachers for the procedural and propositional knowledge required for the everyday functions of the classroom (Knight, 2000). These concerns have prompted significant attention directed toward the reform of professional development and enhancement for K-12 teachers, with emphasis placed on providing opportunities for teachers to revise and realign their practice with current research, evolving learning theory, and shifts in the social paradigm of schooling (Broome and Tillema, 1995). Prior to the current reform movement, professional development, often referred to as traditional professional development, was characterized as intellectually superficial and lacking in the depth necessary to promote changes in teachers' practice. In addition, teachers were portrayed as technicians implementing the research findings of others (Ball, 1999). Most often these pre-reform professional development efforts consisted of one-day workshops designed around a belief that teaching practice could be affected by having trained "experts" pass on their skills to eager "novices." This top-down model for professional development rarely accomplished its intended goal. This, however, was not the only model of traditional professional development. Other attempts were designed as ancillary components of new curriculum materials, often conceived as an afterthought for the purpose of marketing the new instructional aids. These traditional efforts are in sharp contrast to the emerging models of professional development that involve teachers in meaningful and substantive work that contributes to their professional knowledge base and improved practice. Doing so, however, requires extended periods of time and moving away from the one-day workshop approach (Supovitz & Turner, 2000). Several authors (Darling-Hammond, 1997; Fullan, 1991; Lieberman, 1995; Little, 1993; and Sykes, 1999) further clarify specific characteristics of effective professional development, indicating that professional development with the greatest potential for meeting the needs of inservice teachers and for increasing student performance must include opportunities for teachers to develop specific content understanding and pedagogical content knowledge.

THE SUMMER INSTITUTE IN PHYSICS AND PHYSICAL SCIENCE

For more than thirty years, the Physics Education Group (PEG), a research group in the Physics Department at the University of Washington, has conducted a Summer Institute for K-12 science and mathematics teachers. The Summer Institute is funded by the National Science Foundation and has served through the years as a model for other professional development programs. Teachers from throughout the United States are encouraged to participate and are eligible to do so for three summers. With a focus on improving the teachers' understanding of physics and physical science concepts relevant to the K-12 curriculum, it also provides an opportunity for the teachers to learn through inquiry; that is, to learn as they are expected to teach. The instructional approach employed in the Summer Institute inseparably links content and pedagogical content knowledge. The guiding principles of the Summer Institute include the belief that special courses for teachers should:

- focus on the subject-matter content that teachers are expected to teach
- develop the ability to articulate the reasoning, both quantitative and qualitative, that is commensurate with this understanding
- enhance the ability to apply skills such as reasoning with ratios and proportions
- increase the teachers' ability to apply and interpret scientific representations such as graphs, equations, and diagrams
- provide a model for instructional approaches effective in bringing inquiry teaching and learning to the K-12 classroom (McDermott, 1990).

Teachers participating in the Summer Institute experience an intensive six-week program of study, attending class for twenty-two hours each week. Additional time is spent completing weekly homework assignments and writing two content-intensive papers. Exams are also administered twice during the Summer Institute. The curriculum used during the Institute is *Physics by Inquiry* (Wiley, 1996), a set of instructional modules developed by the Physics Education Group. These materials are based on the research conducted by the PEG and address the common conceptual and reasoning difficulties present in populations including pre-service and in-service teachers, as well as students in introductory university physics courses and physics graduate students. Topics include Properties of Matter, Kinematics and Dynamics, Electric Circuits, Heat and Temperature, Light, Astronomy by Sight, and Waves and Physical Optics. Each year the teachers attending the Summer Institute study two or three of the curriculum topics, selected so that they are aligned with the topics the teachers at the various grade levels are expected to teach. Teachers who participate for more than one year do not repeat the study of a topic. The teachers dedicate three hours each day for six weeks to the study of one of these topics, and the remaining two topics are each studied for three weeks for two and one half hours each day.

During the academic year, teachers who participated in the Summer Institute and who live within commuting distance of the University attend a Continuation Course. There is no limit to how long a teacher can participate in the Continuation Course after attending the Summer Institute. Many attend for several consecutive years while others must balance school related and family activities with their participation. Instructors from the Summer Institute also participate in the Continuation Course. During the Continuation Course the teachers continue translating their Summer Institute experiences into best practices in their classrooms. Teachers usually choose to focus their efforts on:

- developing content understanding by continuing to work through modules from the curriculum materials used during the Summer Institute
- adapting curriculum they are expected to teach to reflect an inquiry approach
- designing assessment tools (pretests and post-tests) for use in their classrooms

ASSESSING THE DEVELOPMENT OF CONTENT UNDERSTANDING

During the Summer Institute, the participating teachers work with partners at their own pace as they complete the selected modules. Before beginning each section of the various modules, a pretest is administered to determine the teachers' pre-instruction understanding of the topics that will be addressed in that particular part of the curriculum. The pretest responses are not graded, but rather are used in the ongoing research on common difficulties with particular topics and provide insight into the teachers' instructional needs. At critical points in the curriculum, the teachers are required to check their understanding with an instructor before continuing to progress through the curriculum. What has come to be known as a “checkout” is an opportunity for the teachers to engage in semi-Socratic dialogues in which they discuss their experimental investigations, the data that they collected, and the conclusions they have been able to construct. It is only after the instructional staff has determined that the teachers have articulated full understanding that they can proceed to the next section in the module.

The summative assessment of the teachers’ content understanding occurs during two examinations that occur during the six-week Institute. The teachers are required to complete both a midterm and final exam on the topics that they have studied. The exams require the teachers to apply their understanding to questions closely aligned with the pretest questions that assessed their pre-instruction understanding, but in different and more complicated contexts. By carefully designing exam questions, an analysis of the teachers’ pretest and post-test responses to the questions provides data regarding the changes in content understanding that have occurred as a result of having participated in the Summer Institute. For example, the following pre- and post-test questions were administered to 35 elementary, middle and high school teachers studying the Electric Circuits module of *Physics by Inquiry*.

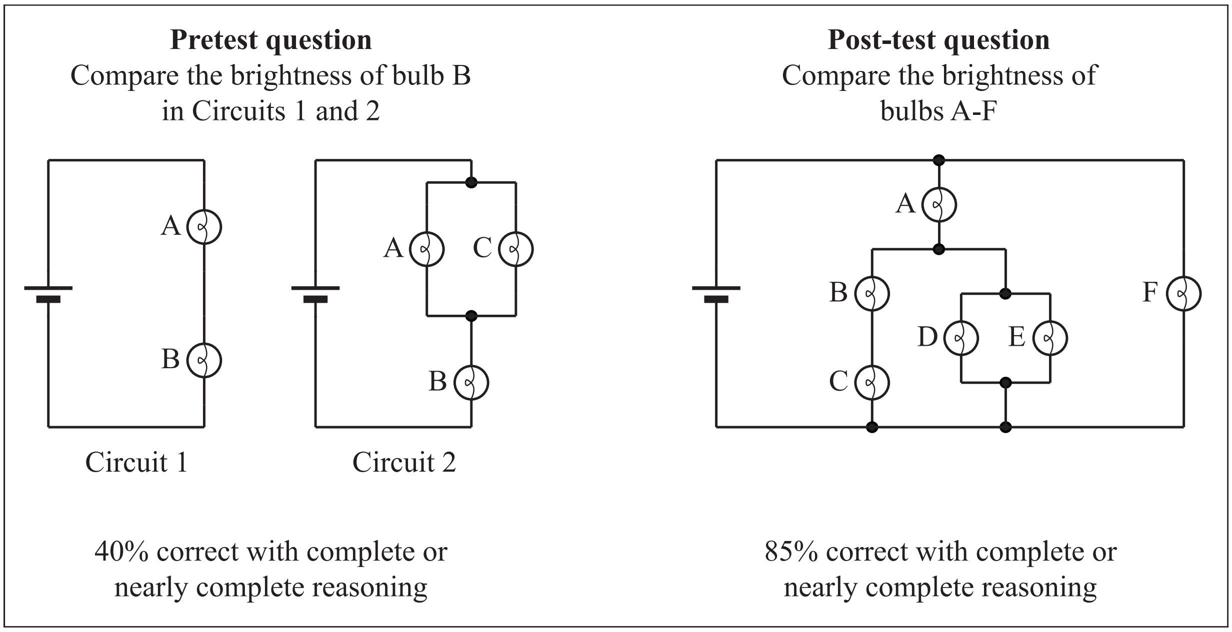

Figure 1: Pre- and post-test questions.

Prior to the study of the Electric Circuits module of *Physics by Inquiry*, only 40% of the 35 teachers studying the topic in the Summer Institute correctly answered the pretest question and provided complete or nearly complete reasoning to support their responses. Upon completion of the Electric Circuits module, nearly all of the teachers provided correct answers with complete or nearly complete reasoning on the post-test exam question. This analysis indicated that these teachers confronted their misconceptions and used observations and experimental data to develop a coherent and comprehensive understanding of the concepts. To develop this level of understanding required the teachers to also develop the reasoning skills that provide a basis for not only being able to demonstrate what has come to be understood but also the process through which the understanding was developed. Similar results were obtained for pre- and post-test analysis of other topics including kinematics, dynamics, optics, heat and temperature, astronomy, and properties of matter (Boudreaux, Shaffer, Heron and McDermott, 2008; McDermott, Heron, Shaffer and Stetzer, 2006; Marshall and Dorward, 2000; Wosilait, Heron, Shaffer and McDermott, 1998).

ASSESSING CHANGES IN PRACTICE

Observable changes in teaching practice serve as the definitive evidence of the enactment of reform or inquiry in the K-12 classroom (Supovitz, 2000). It is only when teachers are informed by both content knowledge and pedagogical content knowledge that they are able to return to the classroom and begin to implement change in their teaching practice (Fickel, 2002).

In order to document changes in teaching practice, the Reform Teaching Observation Protocol (RTOP) was used as a lens for looking into the teaching practice of local 40% correct with complete or nearly 85% correct with complete or nearly complete reasoning complete reasoning teachers who had attended the Summer Institute. The RTOP is a 5-point Likert scale (0 [not observed] – 4 [very descriptive]) used to assess the degree to which reform instruction is implemented in the classroom (Falconer, Turle, Benford, and Bloom, 2000). This assessment addresses four major aspects of teaching practice: lesson design and implementation, content, classroom culture, and student/teacher relationships. The RTOP was used during visits to the teachers' classrooms before, immediately after and several years after attending the Summer Institute for the first time. The RTOP scores illustrate a spectrum of what is possible when teachers translate their own learning experiences into best classroom practices.

Although the changes in the RTOP scores for most of the teachers were encouraging, the scores of a limited number of teachers (for example, 1/6 in one group of Summer Institute K-8 participants) did reveal some contradictory evidence.

Table 1: RTOP scores.

Teacher	Pre-Summer Institute RTOP Scores	Post-Summer Institute RTOP Scores
Theresa	23	7
Anne	5	20
Craig	54	73
Paul	29	76
Jessica	26	89
Rebecca	11	78

These results suggest that the Summer Institute provides a model for reform science teaching that a teacher can translate into best classroom practice; that is, instructional practice that is standards and inquiry-based and student centered (McDermott, 1990). However, further probing revealed possible reasons why a teacher may not alter his or her teaching practice.

During informal conversation with Theresa it became evident that, although she had participated in the Summer Institute, she believed that she did not have the instructional time it would take for her students to delve deeply into a topic and develop a robust understanding of the concepts she was teaching. While observing in the classroom, however, it was noted that class time was not constructively used and instruction was often interrupted for the purpose of addressing student behavior. She spoke of her doubts as to whether or not her students could develop such understanding and often chose activities that she believed the students would enjoy rather than those that could contribute to an understanding of particular topics and the process of science.

At the other end of the spectrum of RTOP results, Craig, typical of nearly all of the teachers who participated in the Summer Institute, demonstrated changes in his teaching practice that indicate a more inquiry-based instructional approach. Having developed his content understanding through the process of inquiry, he was better able to recognize "what inquiry looks and feels like." He became aware of the requisite skills one needs to teach by inquiry, particularly in the area of questioning and probing students' understanding. He learned to hear differently what his students were saying in their responses to his questions. Craig had become more competent in his content understanding and more confident in his teaching practice. His professional growth was recognized not only by those involved in the Summer Institute, but also those in his school and district. He assumed leadership roles in the district and found a voice not only as a second-grade teacher but also as a second-grade science teacher who others recognized as having strong content understanding, the ability to teach through inquiry, and the desire to continue to develop professionally.

Long-term changes in teaching practice were also identified by observing teachers and recording RTOP scores up to three years after first attending the Summer Institute. Nearly all of the teachers who were observed showed continued growth in their teaching practice. The changes, however, were varied, and there were the occasional contradictory examples. For example, two high school teachers (Mark and Barry) and two middle school teachers (Charles and Betsy) who were observed over the course of three years demonstrated different outcomes in terms of the changes in their teaching practice. These changes in teaching practice were influenced by a variety of circumstance. Informal conversations with these and other teachers observed over a period of time revealed that in addition to personal circumstances, support at their school sites and district expectations had an impact on the degree to which they were able to implement inquiry in their classrooms.

Table 2: 3-year RTOP scores.

Mark RTOP scores: a. Pre SI = 31 b. Immediately after 1st SI = 50 c. 3 years after initial SI = 82 Assumed a leadership role in school as department head	**Barry** RTOP scores: d. Pre SI = 33 e. Immediately after 1st SI = 26 f. 3 years after initial SI = 30 "I got married, bought a house, had a baby...but I still came to the SI. I still want my teaching to change."
Charles RTOP scores: g. Pre SI = 38 h. Immediately after 1st SI = 66 i. 3 years after initial SI = 76 Became actively involved in professional outreach (mentoring new teachers, presenting at professional conferences, etc.	**Betsy** RTOP scores: j. Pre SI = 29 k. Immediately after 1st SI = 49 l. 3 years after initial SI = 30 After 1st year began experiencing ongoing job insecurity due to school/district reorganization

SUMMARY

The primary goal of the Summer Institute is to provide the opportunity for the participating teachers to learn or re-learn physics and physical science concepts in a way and at a depth that would enable them to be both competent and confident in their knowledge of the subject matter they are expected to teach. Analysis of the pretests and post-tests taken by the teachers participating in the Summer Institute indicate that, as a result of working through the carefully sequenced experiments and exercises in *Physics by Inquiry,* nearly all of the teachers confronted their misconceptions and used observations and experimental data to develop a coherent and comprehensive understanding of the concepts. To develop this level of understanding required the teachers to also develop the reasoning skills that provide a basis for not only being able to demonstrate what has come to be understood but also the process through which the understanding was developed.

Although the Summer Institute may be described as a one-size-fits-all model of professional development, observations in the teachers' classrooms revealed differences in not only how the teachers who participated the Summer Institute implemented inquiry in their classrooms, but also the pace at which they were able to bring about change in their teaching practice. In addition, there is a variety of circumstances, including life circumstances and the professional climate within the school, that influence the teachers' ability to translate their own experiences in the Summer Institute into best classroom practice. For some teachers, change comes quickly, while for others there is a need to proceed more slowly. However, regardless of the pace of implementation, by being more reflective about their teaching, most of the Summer Institute teachers developed a new awareness of what their science teaching could be and what would be required of them in achieving their instructional goals.

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Sci-Fest: Science inquiry in action

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Sci Fest is a series of one-day science fairs funded by Intel Ireland and Discover Science and Engineering as project partners and hosted nationwide by the Institutes of Technology. The aim is to encourage a love of science through active, collaborative, inquiry-based learning and to provide a forum for students at local/regional level to present and display their scientific investigations. The learning experience coupled with the opportunity of sharing their results with their peers and the judges at Sci Fest takes students to another level beyond just memorising facts. Students are then more likely to leave school equipped with the necessary skills for solving real world problems. They will also have learned to work collaboratively and to communicate and present their ideas.

Sci Fest supports the approach to teaching and learning science promoted by the revised Junior Certificate science syllabus introduced in 2003. The revised syllabus emphasises an inquiry based teaching methodology and recognises student practical work through the allocation of 25% of the final marks in the examination to project work.

SciFest is a highly successful collaboration between the second and third level education sectors and between education, government and industry. It is an example of an easily scalable, cost effective model for the establishment of a network of regional science fairs. In the three years since its launch in 2007 over 6200 students have participated and the number of venues has increased to fifteen.

'Like a real scientist': Evaluation of Science Clubs as Sites for Informal Learning

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The importance of science education outside the formal setting has received much attention in recent years. Despite this interest, little attention has focused on ways of assessing the effectiveness of programme content and delivery and, especially, children's own experience with informal science.

Science Clubs are an example of these informal science learning activities and are considered a useful tool to engage young people in inquiry-based science learning. However, in Ireland participation in out-of-school clubs is rare, even though international studies found that taking part in extra-curricular science activities is linked to a positive attitude towards science and increased academic achievement (e.g. Durlak and Weissberg, 2007; Vandell, Reisner and Perice, 2007).

The Education and Outreach Team (E&O) of the Biomedical Diagnostics Institute (BDI) hosts out-of-school science clubs for primary and second level students, amongst a range of innovative science communication initiatives. These clubs aim to provide authentic learning opportunities in a science research environment. Participants were encouraged to use scientific equipment, engage in hands-on activities, discussions and cooperative learning tasks. The sessions were designed to provide an enjoyable experience with science, while giving students experience in methods used by scientists.

This paper describes the development of a framework for the evaluation of authentic learning experiences and will present findings from the science club pilot studies. It will also address wider practical and theoretical issues in evaluation of informal science learning initiatives and outline some of the challenges encountered in creating age-appropriate and unobtrusive tools for data-collection.

INTRODUCTION

Science learning happens not only in classrooms. The laboratory of a science research institute can be the setting for science education. This paper will outline the challenges and opportunities in evaluating an after-school science club as a place for learning for second level students, present some of the findings and look at the implications.

Places that are designed to facilitate science learning are numerous – not only in formal education. Settings, such as museums, zoos and libraries have long established their value in engaging school groups and individuals in inquiring, discovering, discussing, and evaluating, in short their potential to facilitate learning (Fenichel & Schweingruber). A science research centre might less readily come to mind, but places such as the Biomedical Diagnostics Institute (BDI) provide space and resources for school field trips and out-of-school clubs. The BDI engages in Science Outreach, a term that is commonly used to describe projects and events that are designed to interact with members of the public. Similarly to university outreach, it can be understood as using the organisation's core competencies (in this case scientific research) for the benefit of the wider community. The organisation takes on a task that is not traditionally a function of this organisation (in this case education and information to the community). The Education and Outreach Team (E&O) provides a range of Science Outreach activities, that enable people of a variety of ages to experience and explore what it means to 'do science' or to work as a scientist. The activities vary in intensity from a 10-week research internship to one-off activity workshops in a children's hospital.

The term Science Outreach is often associated with learning activities outside the formal educational setting or by tutors whose usual tasks do not include teaching in schools (Eshach, 2007). This can take on the form of 'enhancing and enriching' the formal school curriculum, e.g. when a class group visits the BDI lab and is offered a themed workshop on topics that use biomedical sciences to explain and work with science phenomena related to the curriculum. Other activities allow an even more active exploration of science. One of these activities is the out-of-school BDI Science Club (BDI Sci). Science clubs and other out of school clubs have been found to have positive effects on social, emotional and academic development of youth (e.g. Falkenberg, McClure &McComb, 2006; Durlak and Weissberg, 2007; Vandell, Reisner and Perice, 2007). In BDISci Club the learning focus is shifted from specific learning outcomes to more generic ones: To instil a scientific identity by increasing interest in and information about the subject matter and to enable an engaging and entertaining science experience that creates a positive association with science. BDISci Club aims to provide authentic learning opportunities in a science research environment. The programme is interested in transmitting what it means 'to do science' and its relevance for everyday settings. It provides experience of science and scientific inquiry, fosters an affinity for science, aims to increase confidence that one can do science, and introduce science as a career option. It also aims to raise the profile and understanding of the biomedical sciences. It aims to set a 'virtuous cycle' in motion, where increased confidence and interest in science leads to seeking out further science experiences and lead to more positive associations. In consequence, the programme kindles a scientific identity, an understanding of oneself as somebody who is involved with and can do science.

BDISci Club is a student-centred rather than curriculum-centred project that uses guided inquiry to provide a 'taster' of being a research scientist. Furthermore, real-world research is shown, that is based on the principles and insights that the participants investigate. The science club of the BDI consist of a series of workshops that are held in a dedicated lab with a facilitator. The sessions focus on physics, chemistry and biology, as well as overlap between the subjects. The workshops are a mixture between presentation, demonstration and hands-on experimentation.

PROGRAMME EVALUATION

Evaluation of BDISci Club is an integrative part of the project. Programme evaluation is "an applied inquiry process for collecting and synthesizing evidence that culminates conclusions about the state of affairs, value, merit, worth, significance, or quality of a programme." (Fournier, 2005, p. 140).

In Science Outreach there are certain challenges to overcome. One of the core tensions in evaluation is between the mechanisms and processes whereby a result is achieved and assessing effectiveness and demonstrating the achievement of results. For example an important mechanism in science education could be the additionality that might stem from greater capacity of a community or individual to address science issues in the future, whereas a result or outcome might be improving attitudes to science or the attractiveness of science careers. This tension between process vs. outcome evaluation reflects the conflict of where to best to focus time, energy and other resources – on delivery of the programme or improving it. In evaluating Science Outreach both aspects need to be addressed.

The flexibility that the small participant numbers and the adaptive syllabus offers is one of the strengths of the format, but poses a difficulty for evaluation. As these sessions change and adapt quickly, questions arise when it is the best time to evaluate is, e.g. evaluate at the time of first implementation, or when the programme is established.

Another set of issues arises in regard to evaluation use. Often evaluation is a funder's requirement, but information that is useful for a funding body might not necessarily be as helpful for the people on the ground. People on the ground need to be involved to arrive at an evaluation procedure that is useful. Dedication of staff to the evaluation project has a strong influence over whether the results of that evaluation will be used (Patton, 1997). To increase the acceptance and use of findings, BDISci Club decided to have a team member evaluating their programmes, so that resistance or anticipation by the team is avoided. For evaluation results to be used, documenting the results is important, as the science outreach follows an often seasonal schedule and is intermittent in nature (Clavijo, Fleming, Hoermann, Toal & Johnson, 2005).

In respect to data collection for the evaluation of Science Outreach more challenges arise. In the spirit of Science Outreach to provide a positive learning experience, measures or instruments that resemble a test need to be avoided (Harlen & Deakin Crick, 2003). Subsequently some of the more established and traditional methods, such as questionnaires, are not suitable due to their similarity with a pen and paper test. Data collection must be brief and engaging to participants, be seen as part of the programme and contribute to the participants' experience. It is also very difficult to track students once the clubs are finished, and the data collection needs to be conclusive. Data collection can take on more creative forms, like drawings, peer-interviews or games. Focus groups have proven to be useful as young people feel comfortable in the presence of their peers, they can take on an informal character and questions can easily be adapted to individuals levels. It also allows for the flexibility to investigate unintended outcomes.

These challenges add to the basic challenge of evaluation to document or measure what the programme is about and who attended it.

EVALUATION OF BDISCI CLUB

The greatest challenge in evaluating Science Outreach is to find useful indicators for the successful outcomes of a programme. Only few applicable standardized measures exist (e.g. WASP, Wareing, 1982 or STAQ-R, Simpson & Troost, 1982) and many of the available instruments are not sufficiently sensitive (Nicholson, Weiss & Campbell, 1994) or cannot be applied to a broad age range. The programme's goals are large and long-term, but actual contact with the participants is relatively brief and immediate. Outcomes need to be thought of as short-term indicators for long-term goals (Nicholson et al., 1994). Subsequently, it is essential to find short-term measurable outcomes that are good predictors for the longer-term goals.

The indicators for BDISci Club were developed from an existing framework: The generic learning outcomes (Hooper-Greenhill, 2004; Friedmann, 2008) that was developed in museum's education and is successfully used to measure outcomes of cultural learning in the UK in places such as museums and libraries as well as being suggested in evaluation by the National Science Foundation, US for informal science activities that they fund.

The generic learning outcomes reflect the multifaceted nature of learning. The main focus is on outcomes regarding participants' interest and motivation, as these are seen to be closely linked to building a science identity (Fenichel & Schweingruber, 2010). Sustaining and intensifying interest will lead to a change in identity. Identity is understood as a subjective sense of belonging—to a community, in a setting, or in an activity related to science (Fenichel & Schweingruber), an understanding of oneself as somebody who ‘can do’ science and is competent in science. The generic learning outcomes are: firstly, awareness, knowledge, or understanding; secondly, attitude or values; thirdly, activity, behaviour or progression, and fourthly, skills. The fifth and final differs between the NSF and the UK in terminology. The NSF names it engagement or interest, whereas Hooper-Greenhill (2004) identifies it as enjoyment, creativity or inspiration. However, it seems that the understanding of engagement and interest as to “capture the excitement and involvement of participants in a topic, area, or aspect of STEM” (Friedman, p.22) is identical to the engagement that enjoying an activity or being inspired elicits, rather than understanding interest as sustained positive attitudes towards an object or issue. Additionally to these learning outcomes the personal learning outcomes of the individual are also considered.

EVALUATION METHOD

The objects of evaluation are two pilot out-of-school science clubs. The method used was focus groups. The students were recruited by contacting teachers that had previously worked with the BDI, to approach interested parents or students.

In the first group were 4 girls in senior cycle for a condensed science club, a three day workshop. The second group had four boys and two girls from junior cycle for a once a week workshop for 1½ hours for six sessions that were preceded by a group interview session. For the last group data was supplemented by audio recordings and observation of the sessions. Focus group interviews were transcribed verbatim.

RESULTS

Enjoyment/Inspiration/Creativity

In both groups the young participants enjoyed the personal nature of the experience. This was facilitated by the small group size. The participants felt that they got individual attention and personal contact to the facilitators. This instilled the feeling that they are accepted as individuals, and it helped them to make the workshops interesting and non-threatening. For the junior cycle participants, the difference to school science was one of the emerging themes, and it was emphasized as a positive factor. People enjoyed that they were “doing everything by yourself instead of somebody telling you” and felt that they had certain freedom and autonomy.

An important point that people emphasized in both groups was that it contributed hugely to their enjoyment to not have to write up experiments or having to do homework. Especially physics was perceived in a new light by the older girls. The possibility of hands-on activity in physics made it less abstract, more ‘fun’, and hence, more interesting as a subject.

Activity, Behaviour and Progression

BDISci Club had an influence on the participants’ ideas for future plans regarding areas of science to study or work in. The biomedical focus of the workshop made the participants feel that they gained a thorough background knowledge and some of the older children were much more interested in entering the biomedical field. The junior cycle participants also showed resolve for future activities, and would like to attend further science clubs. They also frequently brought some of the experiments home and re-created them with their families.

Attitudes
The initial attitude to science of the older children was already quite positive, but the perception of the nature of science changed: It became a group activity. Science turned from something that is learnt (consumed) to something in which they actively participated; they knew “what is going on” and felt in charge. Their attitude towards science became more positive as the perception of the nature of science changed.

Another area where attitude changed was the attractiveness of a science career. Especially the younger group was very concerned with status and earning in different professions, and found that they are more attracted to a career in science after meeting some science professionals.

Identity/Practices
Especially for the younger group the ‘insignia’ of science, namely lab coats and goggles are important to develop their scientific identity ‘Like a real scientist’.

The older girls felt positive about their experience. They felt that they had a good insight into what university life is like and felt that they are better informed about daily life as a student. However, their insights were not as strong into what life as a scientists or researcher is like. As one girl puts it she felt they participated “on the educational side of things.” They felt it would have been beneficial to see a variety of labs and be able to talk about career paths with people in the field.

In the course of the sessions the children developed a relationship with each other and the facilitator, e.g. they started to police each other’s behaviour and language and decide amongst themselves without the intervention of the facilitator what is acceptable.

The children developed an understanding of themselves as investigators and referred to their activities as ‘doing research’.

Their personal aims and learning outcomes
The motivation to attend for the older students was very different from younger ones. The older students were attracted to science and chose the course consciously. They saw it as a chance to gain insights into possible career paths and study areas, that they felt they had only vague insights. Most of the younger group was initially not particularly interested in science. The younger children were chosen by their teacher either by being drawn out of a hat or as a ‘prize’ for good achievement in other subjects.

Discussion
BDISci Club had a strong influence on children’s understanding of science and scientists in general, and the biomedical sciences in particular. The young people developed a feeling of themselves as researchers, as people capable and comfortable ‘doing science.’ They developed practices and started to form a scientific identity. For the older participants, some of the practices and identity were those of being a university student more than a scientific researcher. This is also a very welcomed outcome, as familiarity with the university lowers the threshold to entering (Kezar, 2000).

One of the issues that would need to be addressed when the programme is rolled out further is if the success of these workshops can be sustained when participant numbers increase. The scalability of the experiences is in question, as one of the main factors for the enjoyment was the small group sizes leading to the individual treatment.

The other issues that arises is the question of just how realistic or authentic is the picture that Science Outreach activities give of working as a research scientist.

An issue with evaluation of these activity is the self-selecting participants. It would be interesting and informative to investigate the reasons for non-participation. A further issue in the development of these activities is the relationship with formal science education. Informal science education has the advantages of not needing to assess the individual's progress, can choose its class sizes and does not need to work to a strict curriculum.

The outcomes of the science club pilots are very promising, and further evaluation will happen when the programme is fully rolled out. Science clubs can play an important part in science learning in their own right. They deliver much more than simply to 'enhance and enrich' formal education.

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An Examination of Lower Secondary Science Teachers attitudes & beliefs to the 'revised' science syllabus

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In 2003 a revised syllabus for Junior Certificate Science was introduced. This course is activity based and emphasises practical experience of science for each individual student. The syllabus brought with it a new form of assessment for Junior Science, disregarding the traditional 100% exam. However, the Junior Cycle has subsequently been described as "subject-based in structure and largely traditional in style" and is currently under review by the NCCA. This study examines teacher's attitudes and beliefs towards the revised Junior Certificate syllabus, across three domains, curriculum development, teaching & learning methodology and assessment. This paper draws on teacher's perspectives from the curriculum development and teaching & learning methodologies domains of the research. The research methodology incorporated a postal survey which was conducted on a national level to lower secondary science teachers. A random cohort of 500 participants was selected to partake in the study and a 43% response rate was achieved. Results have indicated that teachers are quite positive about the benefit to students. Nevertheless, results show that over 56% of those teaching identify the revised syllabus as being less teacher friendly than the old syllabus. Teacher time and a lack of laboratory facilities and technicians are a source of discontent.

INTRODUCTION

Second level education consists of a three year junior cycle (lower secondary), followed by a two or three year senior cycle (upper secondary) (Department of Education Ireland 1965, p. 10 & Department of Education and Science Ireland 2004, p. 13). Lower secondary education is provided to children aged between twelve and fifteen. It comprises of three years on entry to post primary education and ends with a state commissioned exam, referred to as the Junior Certificate Examination (Department of Education and Science Ireland 2004, p. 13). The principal objective of the junior cycle is designed around completing a broad and balanced, relevant, coherent study in a variety of curricular areas (Department of Education and Science Ireland 2002; 2003; 2004, p. 13). The curriculum for post primary is determined by the Minister for Education and Science who is advised by the NCCA (National Council for Curriculum and Assessment undated).

SCIENCE AT LOWER SECONDARY

Science within lower secondary comprises of three main components, biology, physics and chemistry, and provides suitable preparation but is not mandatory for the study of science at upper secondary (National Council for Curriculum and Assessment undated). The original junior certificate science syllabus was established in 1989.

The structure of the 1989 Junior Certificate Science syllabus was devised into two parts the core, and the extension. The core was developed around four key areas scientific knowledge, skills, concepts and attitudes. There were five extensions available which were to be studied at both levels (Department of Education and Science 1989, p. 6).

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Higher level students took four of the five extensions, while ordinary students had to choose three extensions of their choice plus the core (Department of Education and Science 1989, p. 7). The examination of this syllabus was a 100% terminal exam.

2003 saw the introduction of the revised syllabus. It was activity based and placed emphasises on the practical experience of science for every student. Assessment was now divided into 3, Coursework A[2], Coursework B[3] and a terminal exam, the percentage was broken down, 10%, 25% and 65% respectively (National Council for Curriculum and Assessment 2003, p. 32).

TEACHING AND LEARNING SCIENCE

Science has traditionally been taught through deductive and didactic methods of teaching and learning (Prince & Felder, 2007). Research has shown however that pupils carry their own meanings and interpretations (Osborne & Freyberg, 1985), it has shown that students taught in this deductive and transmissive manner become quite passive and as a result become quite disengaged and alienated from the classroom environment and what is being taught (Carr et al. 1994, p. 148; Driver & Bell, 1986, p. 443). Teaching in this manner, transferring ideas from expert to novice attempts to transmit to learners concepts which are precise and unambiguous (Carr et al. 1994, p. 147). It gives the learner the impression that science is a body of knowledge to be memorized (Lyons, 2006, p. 595).

There is a current international disquiet over the condition of science education (Lyons, 2006, p. 592). Concerns about decline in enrolment and student interest have increasingly been expressed internationally including Ireland. Society calls for a more demanding and active curriculum, a more scientific and technologically advanced population is needed to meet the demands of the economy (Bennett, 2003, p. 14). Science education literature offers continuous studies on how students learn, where difficulties lie, and what makes learning science easier (Driver et al., 1994; Lyons, 2006; Bennett, 2003). Research identifies that learning requires active involvement of the learner (Bennett, 2003; Mortimore, 1999; Prince & Felder, 2006). An aim of the revised syllabus was to foster an appreciation for science through active participation and contribution.

METHODOLOGY

The researchers set out to identify teacher's attitudes and beliefs towards the new revised Junior Certificate syllabus, across three domains; 1) Curriculum Development, 2) Teaching & Learning Methodology, and 3) Assessment. The survey design was guided two key research questions:

1. To what extent are lower secondary science teachers in Ireland currently involved in new teaching and learning methodologies?
2. What motivations and concerns do lower secondary teachers have towards curriculum development and becoming future policy makers?

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[2] Coursework A, comprises of 30 mandatory experiments', pupils are required to complete reports on all 30 with pro-forma checklist sent to the SEC

[3] Coursework B involves student investigations. There are two options, option 1 pupils' complete two prescribed investigations provided by the SEC from a choice of 3 or option 2, students compile their own investigation, there is only one investigation needed with this option.

A variety of question styles, including open, category, and scale type were incorporated. Reliability was tested using Cronbach's alpha which scored 0.843, proving the instrument was reliable. To optimize response rates, it the layout was attractive and clear, subsequently the survey was divided into five specific categories: i) General school information ii) Teacher information iii) Curriculum development iv) Teaching & Learning methodologies and v) Assessment.

Data collection was conducted through a postal survey and to obtain a national sample the survey was distributed to Junior Certificate science teachers across Ireland. A random sample of 500 schools was selected from the 733 identified from the Department of Education and Science, post primary providers database for 2006/2007. Prior to sending the survey was piloted with junior certificate science teachers outside the sample, third level academics, postgraduate students and members of the general public. Of the 500 surveys distributed, a total of 213 were returned, giving a response rate of approximately 43%.

BACKGROUND INFORMATION

While the sample achieved (43%) was low, Table 1, identifies that, the sample gathered was representative of the national cohort of school types.

Table 1: Classification of Survey participant schools.

	My Sample	National Sample
Secondary School Sector	55%	54%
Vocational/Community Sector	32%	34%
Community/Comprehensive Sector	13%	12%

61% of schools involved in the survey were co-educational, 21% were single sex girls, with a further 18% single sex boys. 50% of the study cohort was from schools with a pupil population up to 400, 43% of the cohort coming from schools with a pupil population from 401 – 800, and the remaining 6% representing the larger schools of 801+. Gender breakdown of participants was strongly dominated by females (62%), while 38% were male. This would be representative of the situation in secondary education in Ireland, the TALIS study identified that over 69% of the teaching cohort for lower secondary was female staff (Shiel et al., 2009). Table 2, identifies years of experience.

Table 2: Participant Years of Experience.

	Numbers of years teaching					
	0-5	5-10	10-15	15-20	20-25	25+
% of participants	10%	15%	10%	11%	15%	39%

MAIN FINDINGS

Within the main findings of the research, two main themes have emerged; these are curriculum development and teaching & learning, both of which will be outlined below.

Curriculum Development Domain

Two themes emerged from analysis of the curriculum development domain, these included: 1) Pupil friendliness and participation and 2) Teacher friendliness.

Pupil Friendliness and Participation

78% of teachers surveyed regarded the new 'revised' syllabus as being more pupil friendly than the previous. Teachers indicated that the level of participation and input by the pupils was realistic and adequate with over 66% disagreeing with the statement "Pupil participation and input in the programme is too little". There is a slight trend towards newly qualified/recruited teachers agreeing that participation is too little. An overwhelming majority (88%) of teachers agreed that the new curriculum contained adequate practical experience for the pupils.

Teacher friendliness

Fifty-seven percent of the cohort disagreed that "The new science programme is more teacher-friendly than the previous syllabus". There is a slight trend indicating those teaching longer felt that the syllabus was not teacher friendly. Over 90% of the participatory cohort is currently teaching in mixed ability, interestingly 48% identified that they felt the new syllabus did not suit a mixed ability teaching environment.

Over 52% agreed that the allocated time was not sufficient for the delivery of the programme. This unhappiness with length of programme and allocation of time is reinforced throughout the survey data, including:

> There is an absolute need for technical support for teachers – the workload makes it impossible to fully implement the new syllabus effectively.
> (Male, city school, 20-25 years experience)

> It is a huge workload if teachers are implementing it properly with no extra teaching hours e.g. investigations done in my free time and other teachers giving me students otherwise no time.
> (Female, city school, 10-15 years experience)

Cross tabulations indicate that 59 participants (28%) who agreed that time was too short, acknowledged if they were given the chance they would reduce content across some if not all three key elements of the curriculum [physics, chemistry and biology.

45% of participants acknowledged dissatisfaction with the level of input by teachers into curriculum development, with a further 85% thinking that teachers should have more input. Below is a sample of reasons why they feel this:

> Practising teachers have the trait knowledge and experience of what works in a classroom situation and what doesn't work.
> (Female, city school, 5-10 years experience)

> We are the people on the ground delivering the curriculum.
> (Male, city school, 25 years + experience)
>
> Realistic approach.
> (Female, small town school, 25 years+ experience)

Teaching & Learning Methodologies Domain
Analysis of the Teaching and Learning Methodology domain identified two themes; 1) Classroom Practices and 2) Professional Support.

Classroom Practices
Seventy five percent of the cohort agreed with the statement *"I make frequent use of active learning methodologies"*. Of those that agreed 71% identified group work as the most frequently employed method. Peer learning, role play and pupil led investigations were notably less used. Context based learning also experienced rather low status with only 24% sometimes or always taking trips to industry and 31% sometimes or always having visitors to the classroom.

98% of participants sometimes or always use the textbook in their classroom for teaching, while 80% use the whiteboard. 99% of participants sometimes or always use teacher demonstrations in comparison to 61% pupil demonstrations. Where available, only 36% of teachers use interactive whiteboards, posters and films are used more. Only 7% 'always' use the internet in their teaching and learning of junior science. Usage of the computer room and specific ICT software is always considerable low.

Handouts, mixed groups and variation in lesson presentation were the three most frequently used techniques to improve teaching and learning for mixed ability. Others included re-arrangement of the room, change in activity and different homework for different students. Additional techniques included different questions for different abilities, use of DVD's, mind maps, games, quizzes & ICT. The setting of individual goals was the lowest used technique.

Teaching Support
When asked to rate how supported they felt in the development of their teaching and learning teachers ranked the Junior Certificate Support Service the highest (67%), followed closely by their school principal, and head of science. Only 28% of participants found the NCCA supportive in developing their teaching and learning.

66% were affiliated with the Irish Science Teachers Association (ISTA), with affiliation to other professional bodies significantly lower. Data-logging, laboratory practical and ICT enhanced learning in-services were the highest rated of in-services offered by the professional organisations. Interestingly inquiry based activities such as active learning, discovery learning were significantly lower, while mixed ability and special needs in-services were shockingly low, 12% and 7% respectively.

DISCUSSION

The emerging issues from this piece of research documented include 1) lack of teacher voice and 2) low levels of inquiry based learning methodologies.

Lack of Teacher Voice
We have in Ireland a very centralised approach to curriculum development and curriculum change. Literature has shown that centralised or top down approaches to curriculum change, only create a 'surface change' (Fullan, 1991). Teacher voice can

often be missing from the development of the 'revised' syllabus due to its top-down approach.

For 'deep change' to occur, teachers must have a voice, they must have a personal ownership within the change. Greater levels of teacher involvement may have lessened the view that the revised syllabus was not teacher friendly. A high number of participants in this study feel that teachers should have a more active role in curriculum development. While it is acknowledged that the teachers are represented in the curriculum development process through the teacher unions, only 9% of teachers felt they had support from these unions in relation to teaching and learning.

Matters which have emerged in this research could easily have been reduced or eliminated if teachers had a voice in the change process. Problems with time, and length of programme, working with mixed ability, could all have been incorporated and catered for if practising teachers were involved. After all, as one participant said:

> We are the people on the ground delivering the curriculum.

Perhaps Trant's (1998) idea of curriculum as "partnership" approach to curriculum development could help alleviate some of these concerns.

Inquiry Based Learning

In recent years Ireland has not fared well in research carried out on teaching and learning practices. Going from the data of the current study, there seems to be some signs of improvement with teachers frequently making use of group work. However, teachers still heavily rely on textbooks and teacher demonstrations. The recent TALIS report indicated that Irish teachers have strong preference for 'structured practices', opposed to 'enhanced activities' or 'student-orientated practices'. The level of inquiry based teaching and learning in science classrooms can still be improved but that more CPD is needed. However, even if CPD is provided, one constraint on levels of inquiry based teaching may be the issue of time and classroom support. It is important to acknowledge that if these matters were addressed perhaps a more inquiry based environment would be created by teachers.

> There is an absolute need for technical support for teachers – the workload makes it impossible to fully implement the new syllabus effectively
> (Male, city school, 20-25)

CONCLUSION

The discontentment within the teaching community towards the 'revised' syllabus needs to be addressed. There is a need for teacher's voice to be heard and taken into consideration. The top-down approach is having a negative effect on the education of our students. The junior cycle is currently under review, the NCCA should strongly adopt a "partnership approach" as suggested by Trant (1998) involving the teacher at all levels of consultation. Increased inclusion of teachers in the curriculum process would not only allow deep change to occur but it would strengthen relations between teachers, the DES and the NCCA and create a more positive attitude to teaching and learning.

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ITEMS project: Improving Teacher Education in Maths and Science

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This work describes two elearning sequences for teaching geometry and electricity in lower secondary school created by the ITEMS (Improving Teacher Education in Mathematics and Science) project. Sequence design is based on results from science education research about students' difficulties in understanding elementary science and mathematics concepts and models. The sequences consist of a set of activities embedded in a Moodle environment aimed at supporting students learning by inquiry.

INTRODUCTION

Taking into consideration the recommendations of the Rocard report (2007), the central objective of the ITEMS project is the development of a framework aimed at improving the competences of science and mathematics teachers and, consequently, increasing the students' attainment and interest in these areas. In order to achieve this aim, the work programme is organised in three stages:

1. Development of educational material for secondary school students in Science and Mathematics using a new model of course production based on the packaging of Learning Objects in an elearning format
2. Dissemination of such material through training courses aimed at familiarising teachers in the management of the modules in a classroom environment using an on-line/blended approach
3. Mentoring teachers' trialling the materials in their classroom in order to facilitate sustainable accessibility to the ITEMS materials.

To achieve ITEMS objectives a consortium with diverse background has been created. It is composed of European Schoolnet, a European institution, CEFIRE (Spain) and SLSS (Ireland), teacher training institutions at regional and national level respectively and finally, Gymnasium Isernhagen (Hannover, Germany) and Gimnazija Poljane (Ljubljana, Slovenia), secondary schools that help to keep connected the consortium to the everyday reality of the school life. Project developed material is available at the following URL: http://www.itemspro.net/moodle/ and
http://www.google.com/url?q=http%3A%2F%2Fwww.itemspro.net%2Fmoodle%2F&sa=D&sntz=1&usg=AFQjCNHzgdNGgSNMncvOiTeDQ95BsOQUYA

DESCRIPTION OF THE GEOMETRY MODULE

The scientific content of the Geometry module is the standard content of the plane geometry, but limited to lines, angles and circles and adapted for students aged between 12-14 years of age. This geometrical content is related to everyday examples, mainly related to astronomical observations and models, as it is well known that students have great difficulties in this field (Martínez Sebastià, B. & Martínez Torregrosa, J., 2005). The main aim is to extend students' spatial representation abilities in order to help them to gradually "reinvent" astronomical models through a continual process of checking the fit of models against observations. In this way, the flat Earth model is discussed and later the spherical model. Finally, the method first used by the Greek astronomer Eratosthenes (276 B.C. – 194 BC.) to calculate the radius of the Earth is discussed.

The approach used in this module could be described as 'innovative' when compared to the traditional exposition, exercise and reliance on the textbook. The ITEMS approach is based on the use of a great variety of learning activities (Flewelling & Higginson, 2001). The expectation is that all learning activities foster the highest degree of teacher-student, student-content, and student-student interaction.

In every unit the learning tasks are organized in a sequence defined as follows:

1. Taking account of student ideas which alerts the teacher to common misconceptions and assists them to identify the students' own ideas;
2. Developing and using scientific ideas by introducing concepts and models meaningfully and representing ideas effectively;
3. Promoting student thinking by inquiry. This is done by encouraging students to explain their ideas about phenomena and experiences and by guiding student reasoning;
4. Assessing progress by encouraging students to think about what they've learned and testing for understanding.

Most of the content is organized in quizzes. The quiz activities have a double role. One is to present information so that students become acquainted with the material and the other is to provide learners with a quick way to check their understanding of course content. Sometimes the information is presented directly using just text and static images. But for the most part, the information is introduced by means of an animation which students can manipulate by varying some parameters. This simulation is accompanied by a multiple-choice test with an automated score evaluation designed to stimulate an accurate manipulation of the parameters and the observation of the response of the simulation. In the geometry module about 30 simulations have been designed using dynamic mathematics software (Geogebra) to allow students learn and investigate geometric relationships.

DESCRIPTION OF THE ELECTRICITY MODULE

The electricity learning thread is defined in terms of learning outcomes, process skills and key skills. It is heavily influenced by the work of the Institute of Physics (IOP), the University of York Science Education Group (UYSEG) and the Centre for the Advancement of Science and Mathematics Teaching & Learning (CASTeL). It incorporates elements of Assessment for Learning (AFL) and relies throughout on student use of the Physics Education Technology (PhET) simulations.

The module begins with some probing questions to encourage student thinking and identify misconceptions. Some activities on conduction are then developed. The rope model and the big circuit activity are presented in order to help students think about electricity, linking real work in class to work with simulations. Students perform some investigations on voltage, current and resistance while simple work with multimeters and energy monitors is also encouraged.

The module integrates simulations, animations, video and images into a variety of formative question types with tailored feedback. Questions are for learning as students can repeat questions many times over. In conjunction with this, social constructivist activities and investigation assignments are also provided.

Understanding is developed through formative questioning and students develop investigation skills as activities progress from the very simple to a full report on an investigation of the student's own choice, which can be submitted in any format. Virtual investigations may encourage teachers to allow students to attempt their own choice of investigation in class.

ASSESSMENT AND GRADING

The Moodle system allows student activities to be graded and can track students' scores. Quizzes are automatically graded taking account of the number of attempts made. Tailored feedback is given, Forums, glossaries and investigation assignments must be graded manually by the teacher while there is also an option to record a grade for the usual student work in class. All this information is stored in the grade report which should give a fair composite assessment of the students' work. Students and potentially their parents are aware of their own performance while the teacher can monitor the whole class.

CONCLUSIONS AND PERSPECTIVES

We have just started to explore how the use of an online sequence of material can improve the teaching and learning of secondary students. We have built the pedagogy around quizzes and forums using computer simulations and practical activities. It is too early to draw conclusions, but the first results seem to be promising. In 2009, the Geometry module was used by by 8 groups of Spanish students (N=135) of 12-14 years of age, using a blended learning approach, combining face-to-face with computer-mediated instruction. At the end of the module, students were invited to answer a questionnaire. 91 students submitted their results which can be seen at http://itemspro.net/eval/students_asses.pdf. To summarise, we can say that the use of ITEMS materials has increased student motivation and that students recognize that it has helped them to learn science and mathematics.

Modules were then used in teacher CPD especially with non-specialist teachers. To bridge the gap between theory and practice the teachers' activities in the ITEMS project are strongly related to their regular work at school. Several training courses (at national and European level) have been organised aimed at familiarising teachers in the management of the modules in a classroom environment. In these training activities teachers are prompted to test and evaluate the ITEMS didactic material and finally optimize them on the basis of their experiences.

The final objective is to support teachers to experiment with the project material in their own classroom. Teachers are guided and coached by the ITEMS team in order to motivate them and develop their sense of self-efficacy. A network of schools using the ITEMS approach has been established to encourage teachers to work collaboratively. It is well known that teacher collaboration has strong positive effects on their professional learning and can help to improve classroom practices

Finally, all the learning environments and activities, after being tested in school, are evaluated and optimized. They are then made available for public use at a European level in order to be tested in as many places as possible.

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FRIDAY AM - 1

Exciting First Year Students about Science through a Multidisciplinary Enquiry Based Learning Approach

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This paper reflects the perspectives of 34 first year students who engaged with an "inquiry based learning" module. This module was implemented as a philosophy of learning, as well as a facilitative strategy, and used alongside other educational methods. Five interdisciplinary science lecturers worked in teams to facilitate the students' exploration of biology, chemistry, physics and maths concepts in a Health and Safety context. The scenarios were framed around topics relevant to the learners' experiences. For example, a scenario such as "The Physics of Electric Picnic" was developed to excite and engage the learners about Science.

The Logic Model of Evaluation (Rush and Osbourne, 1991) enabled the lecturing team to collect and analyse the students' perspectives of the module and its desired outcomes in a systematic and visual way. Qualitative and quantitative feedback was captured using innovative research approaches embedded in the module design.

Upon commencement of the module in semester two, students reported on their experiences and expectations of inquiry-based learning. Changes to assessment, class activities and teamwork were suggested and incorporated into the module design. Mid-way through the process, students evaluated the module learning outcomes. Post-evaluation surveys, videos and interviews explored the students' experiences and recommendations.

Key findings revealed that students perceive this authentic team-based, student-led approach to learning science to be challenging and fun. Students regarded the workload to be manageable and the assessment method to be a fair reflection of their team's effort. The paper concludes with lessons learnt, and suggestions for enhancing the students learning experience and improving practice.

INTRODUCTION

Enquiry based learning has a long established reputation in medicine and nursing education (Feletti, 1993) due to its capacity as a pedagogical approach to develop real world critical thinking and problem solving skills. More recently (AISHE, 2005) it has become a core component of many science courses in Ireland as education developers respond to calls for a different type of science graduate. A national survey (NAIRTL, 2009) of 38 higher education staff and students as well as employers in Ireland revealed that "*the ability to apply knowledge in practical situations"* was ranked the most important competence while being able *"to work as part of a team*" was considered the most important skill set. An emerging T-shape profile of 21st centrury science graduates is being used by the European Commission to emphasise the importance of generic transferrable competences while recognising the significance of specialist science knowledge (New Skills for New Jobs, 2010).

Learning science through enquiry based learning acknowledges and embeds the importance of socio constructivist perspectives of science education (Duit, & Treagust, 1998) which can empower learners to develop these competences and skills in team based environments (Leach & Scott, 2002). One of the most important aspects of the process is tailoring team based learning activities within close proximity or slightly above learners development zone (Krause et al, 2003; Vygotsky, 1978) through open-ended science scenarios. This offers an opportunity for groups of learners to be challenged and gain confidence by actively applying science concepts and modeling the scientific method of enquiry to their area of study (Lemke, 1990).

In 2008 the Occupational Safety and Health (OSH) programme team in IT Sligo sought and received validation to teach one fifth of its programme using Enquiry Based Learning (EBL) approach across all four years of the programme. This module complements and integrates the traditional core science modules of first year science. This paper will examine the experiences of the second semseter of first year learners of the 2009/2010 iteration of a broader action based research project.

SETTING THE CONTEXT

The first year EBL module was designed to transition first year learners to the self directed aspects of tertiary education in a fun and engaging manner. The OSH team recognised the importance of developing workplace transferrable skills (Forfás,2008) as well as cognitive specific science concepts of biology, physics, maths and chemistry. The minimum expectation of each learner in terms of learning outcomes is outlined in Figure 1 aswell as the assessment opportunities which provide evidence of this.

Table 1: Module learning outcomes and assessment strategies.

Learning outcomes	**Assessment Strategies** (100% CA)
By the end of this module the learner will be able to: 1. *Identify their learning needs and develop solutions* 2. *Develop effective and efficient self directed study skills* 3. *Communicate knowledge of basic principles for securing safety and health topics in the workplace* 4. *Relate basic principles of biology, chemistry, physics and maths to workplace hazards* 5. *Participate in and contribute to team based activities*	Wiki/Blogs Learning logs Interactive clicker quiz Presentation Reports Videos Posters/Flyers

The semester was divided into four themed cycles with one anchor lecturer and four specialist science lecturers timetabled according to the science discipline theme. The facilitating team (lecturers) strived to ensure that scenarios related to prior experience and learners' interests (O'Loughlin 1992; von Glasersfeld, 1995) and applied to their Health and Safety course. These led to scenarios such as: Biology of Energy Drinks, Physics of Electric Picnic, Hazards of Industrial Chemicals and Making Sense of Health and Safety Statistics. Generic scenarios required learners to devise a study timetable, make study skills videos and contribute team based exam paper solutions to a class database. Moodle was the primary virtual learning platform which enabled students to create wikis, upload course work and access weekly scenarios.

Within the first session teams were randomly selected and established ground rules which offered a code of conduct for team members. Team names were agreed which represented the diversity and similiarities of each team. This was the first step in establishing a fun environment as names such as "*do it later*" and "*spice girls*" offered unique insights into the personalities within the teams. Each week teams were given a scenario which was scaffolded in complexity (O'Hanlon *et al*, 1995). This findings section will present learners' evaluation of this experience.

EVALUATION METHODOLOGY

The Logic Model of Evaluation (Rush and Osbourne, 1991) enabled the lecturing team (*n*=5) to collect and analyse the students' perspectives (*n*=34) using innovative research approaches embedded in the module design as presented in Table 2.

Data Collection and Analysis

A variety of methods were used at the 3 stages of data collection.

Table 2: Research Methods, Analysis and Participation Rates.

Method	Method	Analysis	Participation Rate
Pre-evaluation	Focus Group using live scribe pens and templates	Livescribe, Nvivo and SPSS software packages	100%
Mid-evaluation	Scenario based learning outcome and assessment review activity and learning logs		100%
Post-evaluation	Survey and focus group		88%

Pre-evaluation strategies involved focus groups (*n*=34) using scribe live pens which recorded learners spoken and written word which was uploaded to the computer for data analysis using Livescribe and Nvivo software. Having already experienced a semester of EBL the learners were encouraged and guided to give feedback of their experiences by a template which required them to identify: *what worked, what work but could be improved, what did not work and what they gained from the experience.*

A team based scenario during week 8 of the semester embedded a mid-evaluation opportunity. Each team had to complete a set of five questions and provide a team presentation on: the *appropriateness and relevance of learning outcomes, on achieving these outcomes, the effectiveness of assessment strategies and their favourite and worst aspect of EBL*. This offered the learners an opportunity to contribute and take ownership of the learning process.

Post-evaluation survey consisted of ten questions which examined learners perspectives of: *learning approaches and scenarios, workload, assessment and experiences of team based activities*. The facilitating team reviewed the learners performance in scenarios and weekly quizzes to explore learners' ability to acquire and apply scientific concepts.

FINDINGS

Pre – Evaluation

Significant changes in the structure and assessment of semseter two EBL was implemented as a result of analysing the findings of pre-evaluation data. Written peer assessment was removed as the facilatiing team believed that learners needed to gain evaluation skills before critically evaluating individual performances. Marks were allocated instead to teams asking questions of other teams and evaluating output work. This approach was devised to develop a positive dynamic within teams while exciting the first year learners about science concepts through competition between teams.

A much more structured format was adopted for weekly in class activities to ensure that learners participated and developed appropriate time management skills. As scenarios were posted on Moodle in advance learners were expected to complete and present the solutions to the scenarios within the allocated 3 hour period of the first session while the subsequent two hour session involved review, feedback and team based quizzes using interactive clickers.

Mid-Evaluation

After eight weeks the teams completed a scenario which required them to evaluate the appropriateness of the learning outcomes and assessment strategies for the module. There was general agreement that learning outcomes were relevant and appropriate however a number of teams indicated that number three and four could be merged as they both related to communicating and relating science concepts to Heath and Safety in the workplace. The learners believed they were achieving the module outcomes however recognised that their time management skills required further attention to ensure they were maxmising learning opportunities in class.

Additional learning outcomes that the teams considered to be gaining from the EBL process which are not explicit included: gaining confidence, excited about learning science, and information technology skills. There was general agreement that the assessments were appropriate and the diversity of weekly continuous assessment activities kept them engaged and focused. The learners regarded the fun environment, getting to know their classmates and diversity of sceneario to be the best aspects of EBL. They identified the pressure of communicating and presenting in front of their peers as well as contributing on a weekly basis to wikis to be the worst apsects of EBL.

Post-Evaluation

Many of the mid-evaluation findings were reinforced by data collected during the post evaluation phase. Learners (*n*=29) completed an anonmyous in-class survey in the last week of the semsester. All learners regarded their experiences of EBL to be positive or very positive while also recognising the challenging aspects of the process. 36% indicated that the workload is “about the same” when compared with other modules however 64% indicated that it was “more but manageable”.

> Student 1: I enjoyed team work, having a laugh yet getting all the work done, it is hard but worth it in the end.

In reviewing the scenarios for level of interest and learning; 21% of learners indicated that all scenarios needed some work while the the majoriy regarded the biology sports drinks scenario to be good or very good. More application to Health and Safety aspects were the key areas highlighted to enhance the scenarios. In open ended questions when asked what they learnt from the experience learners identified gaining confidence (*n*=8), team work (*n*=10) and develoing communication and presentations skills (*n*=11) most frequently. This was reiterated when asked about what they learnt about themselves however some students gained a more specific understanding of the learning process with comments about the importance of feedback and recognising their strengths.

> Student 2: I got over my initial shyness and grew into presenting.

> Student 3: I am dedicated to the task and a good team player.

> Student 4: Getting feedback is a great way to learn from my mistakes.

All learners regarded the variety of science topics, team learning and doing presentations and exam questions to be very important or essential as illustrated in Figure 1.

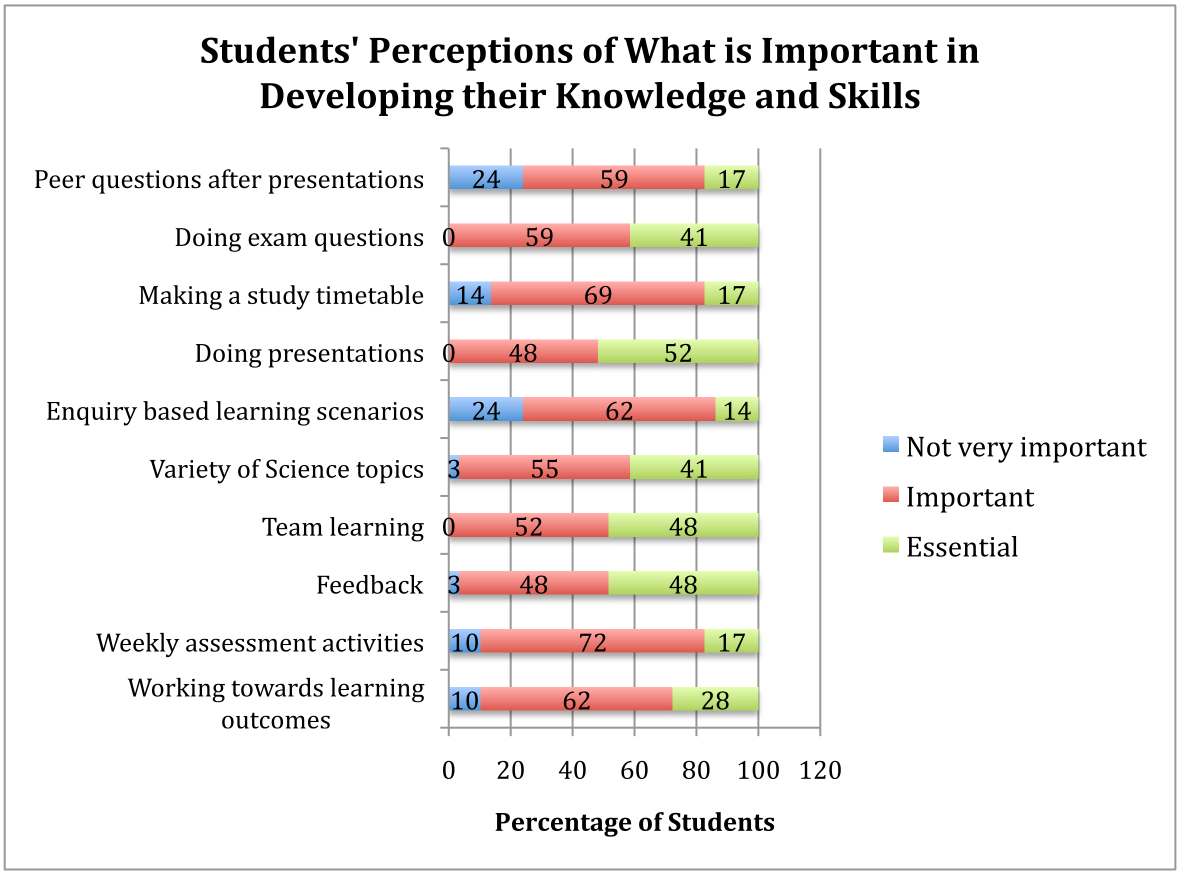

Figure 1: Student perceptions of how they developed their knowledge and skills.

Feedback and variety of science topics were also highly ranked while peer questions and enquiry based learning scenarios were not considered as important. The majority of learners regarded Moodle, interactive quizes and making videos as useful or very useful however blogs and wikis were considered to be of not much use by half the group as presented in Figure 2.

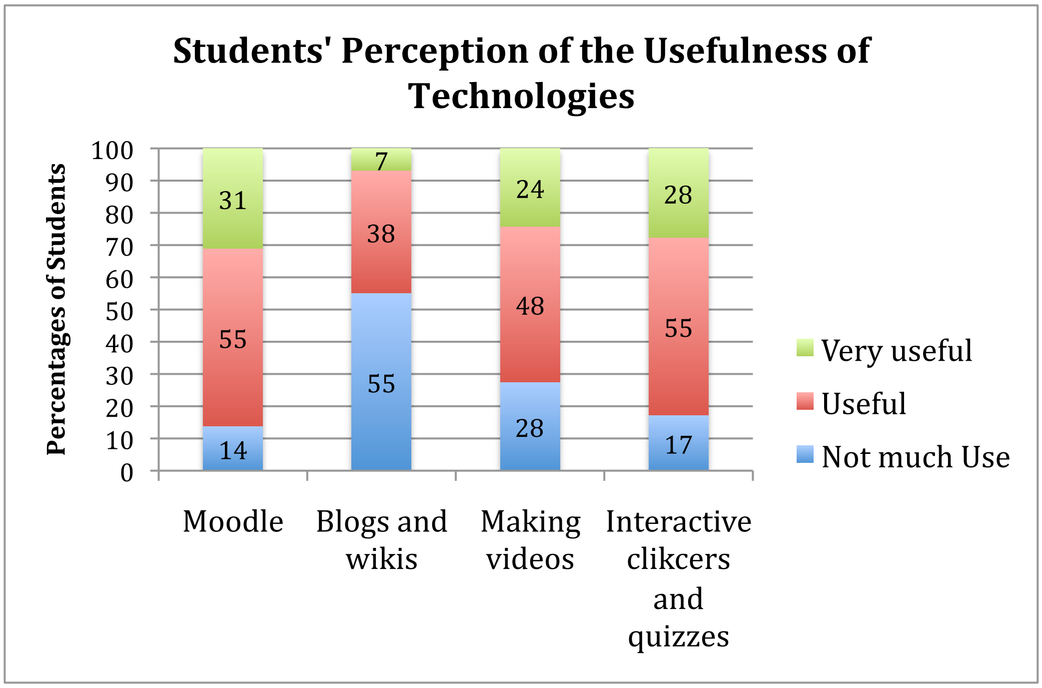

Figure 2: Student Perceptions of the Usefulness of Technologies.

In open ended questions relating to the learners favourite elements of EBL making videos was regarded to be the most fun while wikis and blogs were considered to be the worst aspects. Examples of learners comments included:

> Student 10: I would change the Moodle thing and having to put up wikis because I found it pointless.
>
> Student 15*:* Making videos was a lot of fun and it took the pressure off, we didn't have to stress about standing up in front of everyone.

All the learners enrolled in the module achieved the learning outcomes with the exception of two learners who dropped out. The average participation rate of learners averaged at 78% (7 hours a week) including the average attendance of the two learners who dropped out. 71% of learners indicated that they believed their assessment marks and feedback "reflected their team efforts" while the remaining 29% indicated that "it somewhat reflected their teams effort". Two groups dominated by mature students far surpassed The class average mark average mark was 62%. with average marks of 89% and 86%.

FUTURE WORK AND SUGGESTED DEVELOPMENTS

Key findings of this study reveal that students perceive this applied team-based, student-led approach to learning science to be challenging and fun. The majority of learners regard the workload to be manageable and the assessment method to be a fair reflection of their team's effort. Developing communication and team skills as well as confidence were identified as the key skills and competences gained by learners which aligns to the requirements of 21st century graduates (NAIRTL, 2009; Forfás, 2008)

Two key areas the development team will focus on during the next phase will be to: (1) engage that learners in developing written skills through blogs and wikis and (2) communicate clearly the Health and Safety application of all scenarios. The facilitating team have compiled resources for learners and facilitators to aid the process of setting up and implementing enquiry based learning opportunities. These are freely available for download at www.learningscience.ie and include a *Template Guide for EBL*, a

Facilitator's Handbook (includes the art of questioning and feedback) as well as *Sample Science Scenarios*. This site also contains video clips of learners experiences.

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Using mathematical identity to gain insight into how students prefer to learn mathematics

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Inquiry and problem solving in the science teaching laboratory are the essence of good science education practice. These elements can contribute to a problem-based learning approach to teaching in the science laboratory. This paper gives an overview of a research study which aimed to identify the problem solving processes Year 1 science students used while undertaking problem-based learning tasks in the laboratory and to develop more specific focused support for such learners to make their endeavors more successful and enjoyable. This research study draws from two cohorts of students; B.Ed. primary science students at the University of Plymouth and B.Sc. students at Dublin City University. The study was guided by a phenomenographic framework using a qualitative research methodology of observation, followed by in-depth semi-structured interview. The findings of the research will be shared and discussed. Suggestions regarding the nature of the different strategies identified are offered as topics for discussion in relation to well established problem-solving strategies in other curriculum areas, such as the Dreyfus and Elio and Scharf models. Attributes of the novice and expert problem-solver will also be put forward. Furthermore, implications and recommendations for laboratory teaching staff are made.

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Friday Morning Session 2,
17th September 2010

Centre for the Advancement of Science Teaching and Learning

CASTeL

Stimulating authentic learning experiences through the integration of science and mathematics teaching and learning

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The aim of the research project was to facilitate authentic learning experiences in mathematics and science in first year, at second level education. This was assisted by the development and implementation of specific lesson plans that integrated the teaching and learning of both subjects. The content of the lesson plans supported the development of a deeper conceptual understanding of the topics of speed, distance and time. The focus within the science lesson plans was on the mathematics underpinning the science concepts. By using data generated in the science lessons it facilitated, an increased use of contexts and applications in the mathematics lessons that enabled students to relate mathematics to everyday experiences. It was intended that the students experienced science and mathematics in a new way, using technology and examples that had a real-life application, and accordingly it facilitated a deeper understanding of key science and mathematical concepts. An inquiry-based approach was supported in the science lessons, with the mathematics lessons promoting a teaching for understanding method. This paper will focus on the specific integration of speed, distance and time through the examination of the content and teaching approaches in the interdependent lesson plans utilised in the science and mathematics lessons.

INTRODUCTION

The aim of the research project was to design, implement and evaluate a collaborative teaching approach to develop students' conceptual understanding in physics and mathematics at post-primary education. This was assisted by the development and implementation of specific lesson plans (3 double science lessons and 4 single mathematics lessons) that integrated the teaching and learning of both subjects utilising technology. Three schools took part in the pilot study, with a mathematics and science teacher working in collaboration in each of the schools, to facilitate authentic learning experiences in mathematics and science in first year post-primary education (approx. age 13-14 years old). The implementation of the collaboration between the science and mathematics teachers was facilitated by the use of technology – the TI-Nspire (graphical calculator and data logger) that allowed real-life data to be collected, analysed and explored both in the mathematics and science lessons.

MATHEMATICS APPROACH

The mathematics lesson plans were designed to promote a teaching for understanding approach through the use of rich mathematical tasks which provide students with the opportunity of specializing and generalizing in the mathematics class (Mason, 1999). A new mathematics curriculum, *Project Maths*, is being introduced in all post-primary schools in Ireland. Emphasis is being placed on student understanding of mathematical concepts, with increased use of contexts and applications that will enable students to relate mathematics to everyday experiences (Project Maths, 2008). The mathematical approach adopted in this research project is consistent with the new mathematics curriculum being introduced in order to provide teachers with the opportunity of developing skills for implementing *Project Maths*.

Rich Mathematical Tasks

Mathematical tasks that are referred to as 'rich' are those that are most likely to engage students positively and effectively with their mathematical learning. Rich mathematical tasks were a critical component of the pedagogy that underpinned the mathematics element of the TI-Nspire project. The importance of incorporating 'rich mathematical tasks' into the teaching and learning of mathematics has been highlighted by many researchers (Boaler & Staples, 2008). They can be described as incorporating some of the following characteristics (Ahmed, 1987):

- Are accessible and extendable.
- Allow individuals to make decisions.
- Involve students in testing, proving, explaining, reflecting and interpreting.
- Promote discussion and communication.
- Encourage originality and invention.
- Encourage "what if?" and "what if not?" questions.
- Are enjoyable and contain opportunity to surprise.

By employing rich mathematical tasks it allows students to find something challenging and at an appropriate level to work on (Swan, 2005).

Specializing and Generalizing

Within the mathematics element of this project we are also concerned with how students approach problem solving. Mason (1999) emphasises the central core of mathematics as *Specializing* (constructing particular examples to see what happens), and *Generalizing* (detect a form; express it as a conjecture; then justify it through reasoned argument). Specializing involves trying specific examples in order to develop an understanding in relation to what a mathematical concept is proposing. Therefore, the purpose of specializing is to gain clarity as to the meaning of a question or statement, and then to provide examples which have some general properties in common – the process of generalizing (Mason, 1999). Generalizing has to do with noticing and describing properties common to several mathematics questions/problems. The mathematics teacher should employ questions which encourage students to think deeply about the problem/examples presented. By looking at the examples that the students have completed, they should try to see what is common among them, guided by what the problem or text asks for or states. Generalizing is more difficult, because it involves noticing or stressing things that are common to numerous examples, and ignoring features which seem to be special to only some of them (Mason, 1999).

SCIENCE APPROACH

Research has highlighted the importance of building the development of scientific concepts and skills on concrete experience (Rosenquist and McDermott 1987). The learning theory most commonly embraced by science education researchers today is constructivism (Piaget 1928; 1952). In the context of this study the term constructivism proposes that knowledge is constructed in the mind of the learner based on their experiences or by reflecting on their experiences (Brooks and Brooks 1999). The science lesson plans were designed to promote this approach through inquiry based learning. They were designed to engage the students in the active use of concepts in concrete situations. Everyday objects and experiences from their everyday lives were used in the science lessons. The enquiry based approach helps the students close the gaps in their knowledge through repeated exercises that are spread out over time and are integrated with the subject matter of both the science and mathematics courses. To help the learner assimilate abstract concepts, it is essential to engage the learner's mind in the active use of the concepts in concrete situations (Arons, 1990). The concepts must be explicitly connected with immediate, visible, or kinaesthetic experience. Furthermore, the learner should be led to confront and resolve the contradictions that result from his or her own misconceptions (Arons, 1990).

DISTANCE – SPEED – TIME: SOME UNDERPINNINGS

There are several learning difficulties that are involved in the development of the concepts of distance, speed and time. Many of these learning difficulties can be found in the 'Teaching Introductory Physics' by Arons (1990). Kinematics can be represented through ratios and division. It can also be represented through graphical representations.

'A powerful way of helping students master a mode of reasoning is to allow them to view the same reasoning from more than one perspective' (Arons, 1990). It is necessary to ask questions that lead the students to articulate the interpretations and explanations in their own words (Arons, 1990). Many students have great difficulty giving verbal interpretations of ratios or of graphs, for example. Arons (1990) recommends that in each encounter the students should have to interpret the representations in their own words. It is impossible to deal with back and forth motion without discriminating between positions, changes in position, and distances travelled by the body (three different concepts to which the term 'distance' is frequently indiscriminately applied) (Arons, 1990). An effective way of reaching many students who have difficulty in relating position on a graph to motion is to lead them through direct kinaesthetic experience. Giving them problems in which they must translate from the graph to an actual motion and from an actual motion to its representation on a graph. Students should be given the opportunity to solve problems both graphically and algebraically, not just in one mode. This gives the students time to review basic ideas and at the same time connect these ideas with a familiar physical situation. 'Mastery develops slowly as the concept matures in the mind through use and application' (Arons, 1990).

THE INTERDEPENDENT LESSON PLANS

The active research of the integrated science and mathematics lesson plans took place during March and April, 2010, over the course of three weeks. What follows is a description of each of the lesson plans and they are presented in the order that facilitated the integration.

Science Lesson 1
The first double lesson attempted to engage the students in the ideas and concept of motion. The teacher facilitated a discussion on speed drawing on their experiences from everyday life. With the teachers as the facilitator, the students would generate ideas on how to measure speed and how it can be represented. With household material the students built their own balloon rocket cars. The purpose of the balloon rocket car is to help the students take ownership in the design of their cars and it would be used to aid the development of the concepts of distance, speed and time over the 3 weeks. At the end of the first lesson the student would have built and tested their balloon rocket cars and would have also generated ideas of how to measure speed using their cars, the TI-Nspire and the motion probe.

Mathematics Lesson Plan 1

It was anticipated that students may have some experience of drawing and interpreting graphs from previous science lessons and from encountering them in everyday contexts such as in opinion polls, weather reports, etc. However, the teachers involved in this research project felt that it was essential that students' basic graphical skills were well developed to ensure that the implementation of the other mathematics and science lesson plans were successful. Therefore, the purpose of the first mathematics lesson plan was to provide students with key skills required for drawing graphs. Student learning outcomes from this lesson included:

- Drawing axes and labelling them appropriately.
- Interpreting graphical information.
- Plotting coordinate points on a graph.
- Connecting coordinate points.

Science Lesson 2

The second science lesson began with a recap of how speed can be measured leading to a discussion on how speed can be represented. Using their hand made cars they were asked to predict, analyse and test their ideas about motion. Through the aid of the motion probe and the TI-Nspire they tested their predictions and collected data on the handheld. Using the data generated the students drew a distance-time graph in their lab copies. With the aid of several other distances versus time graphs the students were challenged to apply their experience with the balloon rocket cars to interrupt the new graphs. Thus, to generate the relationship between distance, speed and time from their experience.

Mathematics Lesson Plan 2

The purpose of the second mathematics lesson plan was to develop further students' understanding of graphical concepts in relation to travel graphs. Key student learning outcomes from the lesson included:

- Stating the scale/units being used.
- Developing an understanding of speed - straight lines correspond to motion with a constant speed; the slope of the line indicates the value of the speed.
- The steeper the slope, the faster the speed; a horizontal line shows the object at rest – indicates no movement at all (slope = 0 = speed).
- Lines with a positive slope indicate movement away from the starting point.
- Lines with a negative slope indicate movement back towards the starting point.

Mathematics Lesson Plan 2 also incorporated the use of data generated from the previous science lesson to draw distance-time graphs, while also encouraging discussion and explanation of variations in their findings in relation to the key concepts developed.

Science Lesson 3
The final double science lesson involved the students actively acting out their motion using the TI-Nspire and the motion probe. In the previous mathematics lesson students examined questions in relation to the direction of the motion and the slope. The active experience of acting out this motion helped the student connect the graph on paper to actual motion. For example, being able to distinguish between positive slopes, negative slopes, no motion etc., all concrete experiences. Thus they developed further the relationship between distance, speed and time by predicting and acting out the motion of the graphs.

Mathematics Lesson Plan 3
The overall aim of the lesson was that students themselves would generate the average speed formula through completion of mathematical rich tasks concerned with speed, distance and time. These tasks incorporated real-life applications, thus making the material relevant for student learning.

Mathematics Lesson Plan 4
The last mathematics lesson plan was concerned with furthering students' understanding of the concept of average speed through engagement in the different sets of distance and time data they had collected in the science lesson. Students were required to demonstrate key learning outcomes acquired from the previous science and mathematics lessons, while appreciating the application of mathematics in science and real life applications.

DISCUSSION AND CONCLUSION

This pilot project was evaluated through a number of means, a teacher's reflective log, an independent observers' log, two focus group meetings and the authors' observations. Overall, the teachers found the lessons enjoyable and they all reported a very positive learning experience for both themselves and the students. The teachers and the observers also reported that the students' level of engagement and enjoyment was excellent. In general, the inquiry based approach of the science lessons was not adopted as expected by the authors. Teachers failed to give the students enough time to respond and come up with their own ideas. However, some tasks were done very well by individual teachers in both the mathematics and science lessons. The teachers reported some issues they had concerning the lesson plans which were time constraints, technology and car construction problems, and length of lesson plans. They felt that there were too many tasks per lesson and they felt under pressure to get the lesson plans completed, thus rushing through some tasks. The observers also expressed the same concerns. The observers reported some specific issues in the mathematics classroom which included poor use of mathematics language, missing out on some key concepts and not enough time for student development of ideas and discussion. The teachers felt that the mathematics were appropriate and consistent with the learning outcomes. They liked the tasks but found it difficult to adapt to the new style of teaching. They also stated that there was too much time between mathematics lessons and they felt they needed time for recap. All teachers involved in this pilot are interested in taking part in the second phase of the project. Preliminary findings have shown that the integration of science and mathematics teaching and learning at post-primary education facilitated authentic learning experiences for the students and teachers involved in this pilot study.

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A Study of Students' Ability in Transferring Mathematics to Chemistry Informing Inquiry-Based Learning in Mathematics

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Undergraduate students evidencing mathematical problems in a chemistry context is a common occurrence. One problematic area in particular is that of basic calculus concepts, whereby a significant amount of undergraduate students appear unable to utilise this knowledge in a chemistry context—despite being taught about this calculus knowledge in a mathematics context. Notwithstanding this observed difficulty, there appears to be a scarcity of literature addressing the possible reasons for its occurrence. This scarcity has spurred the following two questions: Can students transfer mathematical knowledge from a mathematics context to a chemistry context?; and what are the possible factors associated with students being able to transfer mathematical knowledge to a chemistry context? These questions were investigated in terms of basic mathematical knowledge which chemistry students need for chemical kinetics and thermodynamics using the traditional-view-of-transfer-of-learning research methodology. The study was carried out amongst 54 2nd-year undergraduate students attending Dublin City University during the 08/09 and 09/10 academic years. Overall findings suggest that: 1) the issue of the mathematics problem in chemistry may not be due entirely to students' inability to transfer mathematical knowledge; instead the problem may be as a result of students simply not possessing the necessary mathematical knowledge in a mathematics context; 2) an ability to explain one's reasoning in a mathematics context associates with students being able to transfer. The reasons why our results are informing the design of an inquiry-based mathematical curriculum in order to improve transfer are discussed.

INTRODUCTION

Literature in the field of chemistry education raises the issue of the appearance of a mathematics problem amongst chemistry undergraduate students (Beressen, 2005; Monk, 2006; Steiner, 2008 & Yates, 2007). Despite the highlighting of such an issue, there is a scarcity of literature attempting to answer a particular aspect of this perceived difficulty, namely: is the problem which students have with using mathematics in a chemistry context due to the fact that students cannot transfer mathematical knowledge pertinent to chemistry, which they have been taught in a mathematics context? This encouraged us to address a number of questions in the context of our study, namely: *Can students transfer mathematical knowledge from a mathematics context to a chemistry context? (Q.1); Do students who evidence an ability to explain their answer in a mathematics context for a particular mathematical item associate with transferring this mathematical item more so than students who do not? (Q.2(I));* and: *Do students who show a capability to translate pertinent algebraic expressions into their graphical representation associate with transferring these algebraic mathematical items more so than students who do not? (Q.2(II)).*

RESEARCH METHODOLOGY

In addressing our question of transfer *(Q.1)*, the traditional view of transfer of learning or the classical view of transfer, as described by Lobato (2006) has been adopted. The traditional view of transfer is composed of a number of dimensions. The research question dimension, which parallels our research questions, asks: was transfer obtained?;

and: what conditions facilitate transfer? This traditional view of transfer is in contrast to the actor-oriented view of transfer. Here, the aim is to try and understand how students see a learning situation as being similar to a transfer task. In essence, this approach attempts to investigate what it is that students transfer from a learning situation to a transfer task. The traditional approach assumes that transfer is an all-or-nothing affair—either students transfer completely or not at all.

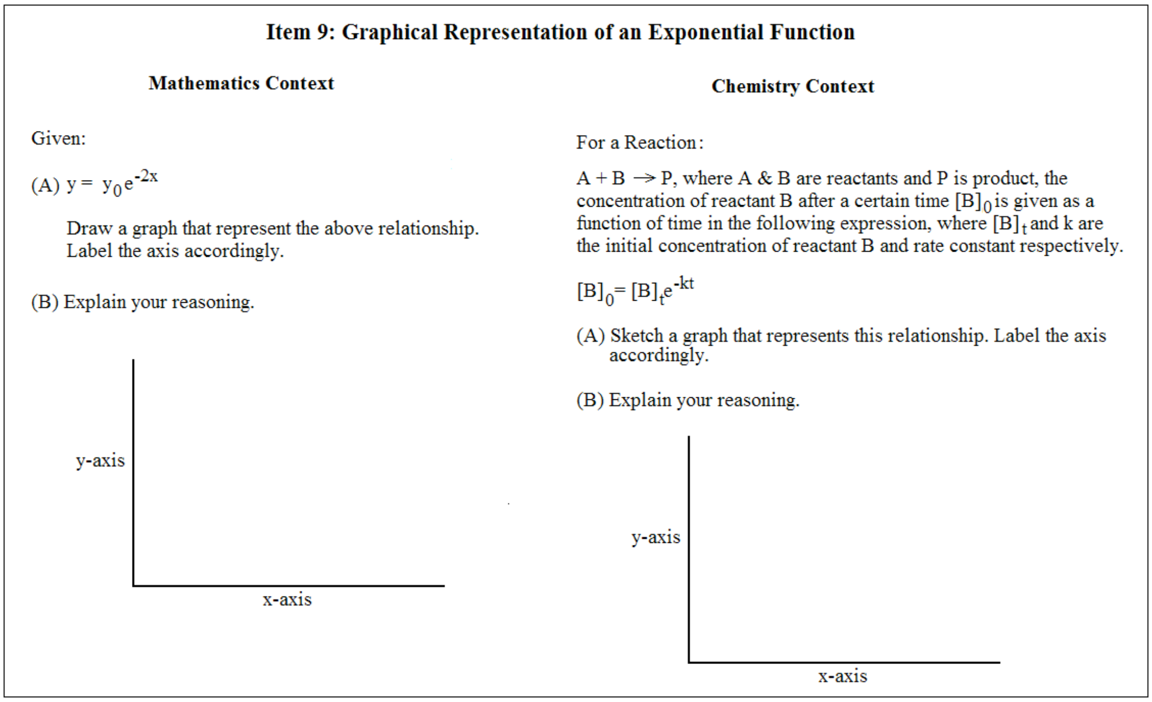
The main reason for our adoption of the traditional approach is because the research is attempting to focus on an immediate issue—namely can students transfer assumed mathematical knowledge into a chemistry context—as opposed to investigating more general questions of transfer, which is at the heart of the actor-oriented view of transfer.

Investigating whether or not students who evidenced an ability to explain their answer in a mathematics context for a particular mathematical item associated with transferring this mathematics item more than students who do not? *(Q.2(I))*, emerged from endeavouring to define procedural and conceptual understanding in the context of mathematics. Previous research has stated how: "it has long been recognised that if procedures are understood [in conceptual terms], or learned in a meaningful way, they transfer more easily to structurally similar problems" (Hiebert and Lefevre, 1986). We wanted to test such a claim. In the process of trying to define such terms as procedural and conceptual understanding, it became apparent that such terms are not absolute. Moreover, Anderson (1993) describes how conceptual problems can become procedural if students are exposed to the same type of problem repeatedly. Such difficulties in distinguishing the two types of understanding were reconciled (after the reading of various mathematics-educational theories) through the asking of *Q.2(I)* instead.

The rationale behind the asking of: Do students who show a capability to translate pertinent algebraic expressions into their graphical representation associate with transferring these algebraic mathematical items more so than students who do not? *(Q.2 (II))* originated from attempting to define procedural and conceptual understanding. Various literature such as the work by Potgieter *et al* (2007) focused not just on determining whether or not students could transfer algebraic thinking but also, where appropriate, the graphical relation of this algebraic thinking. Their reason for so doing was their viewpoint that: visualisation/ graphical representation, of algebraic thinking is a means of cultivating conceptual understanding. If this is so, then their conjecture (as was ours) that: students who possess such understanding may be more favourably disposed to transferring algebraic items more so than students who do not evidence graphical understanding could be warranted.

Diagnostic tools were designed and administered to determine the ability of a group of 30 08/09 and a group of 24, 09/10 2nd-year undergraduate students in mathematics pertinent to chemical kinetics and thermodynamics. These abilities were tested both in a mathematics context and the corresponding chemistry context. The tools were designed on the basis of students having completed a first-year calculus course (which should have equipped them with the necessary mathematical knowledge pertinent to a chemical kinetics and thermodynamics course) and a second-year chemistry module, which encompasses thermodynamics and kinetics. The items investigated can be seen in Table 1; they numbered 15 in total.

The students first completed the items in a mathematics context and subsequently in a chemistry context. An example of such an item is shown in Figure 1. Each of the items contained a Part A and insofar as was possible a Part B. The Part A allowed us to address transfer *(Q.1)*, while the Part B allowed to investigate an ability to explain mathematical understanding possibly associating with transfer *(Q.2(I))*.



Item 9: Graphical Representation of an Exponential Function

Mathematics Context

Given:

(A) $y = y_0 e^{-2x}$

Draw a graph that represent the above relationship. Label the axis accordingly.

(B) Explain your reasoning.

Chemistry Context

For a Reaction:

A + B → P, where A & B are reactants and P is product, the concentration of reactant B after a certain time $[B]_0$ is given as a function of time in the following expression, where $[B]_t$ and k are the initial concentration of reactant B and rate constant respectively.

$[B]_0 = [B]_t e^{-kt}$

(A) Sketch a graph that represents this relationship. Label the axis accordingly.

(B) Explain your reasoning.

Figure 1: The Exponential-Type Mathematical Item (Item 9) Used in Our Study

Due to the nature of our research questions, categorical statistical tests were used. For the transfer question *(Q.1)*, the items which students did and did not transfer (at the 95% confidence level) can be seen in Table 1. In investigating students' ability to explain and transfer *(Q.2(I))*, the principles of qualitative data analysis as described by Cohen, Mannion and Morrison (2000) were used. In essence, using such an approach determined whether or not students could explain their reasoning. The results with respect to such a question are also shown in Table 1.

Students who were able to answer the graphical aspect of an algebraic item (an example of which is shown in Figure 2) were looked at in order to see if they associated with answering the algebra item in a mathematics context and chemistry context, more so than students who did not *(Q.2(II))*. Again, in order to test the appearance of an association (if it so happened to appear), for significance, categorical statistical tests were used. This type of analysis was performed for each of the mathematical items, which had a graphical equivalent. The results can be seen in Table 2.

Item 8: Usage of Exponentials

Mathematics Context

Given:

$Ln\ y = c - mx$

(A) Derive an expression for y.

(B) Explain your reasoning.

Chemistry Context

A student is studying the chemical reaction:

A + B –> P, where A & B are reactants and P is the product.

After graphing the Ln of the concetration of A, obtained at different times (i.e. the graph of $[A]_t$ against time (t)), the student finds that the graph corresponds to the relation given below, showing that the rate of the reaction is 1st order with respet to A.

$Ln\ [A]_t = Ln\ [A]_0 - kt$

(A) Derive an expression for $[A]_t$

(B) Explain your reasoning.

Item 12: Graphical Representation of a Natural Logarithmic Expression

Mathematics Context

Given:

$Ln\ y = c - mx$ ***Eqn. 1***

(A) Draw a graph that represents ***Eqn. 1***
Label the axis accordingly.

(B) Explain your reasoning.

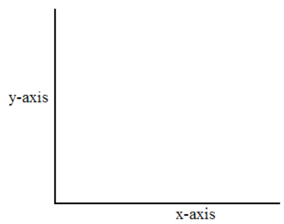


Figure 2: An Algebraic Item and Its Graphical Equivalent

RESULTS & DISCUSSION

In terms of the transfer question *(Q.1)*, it was found that of the 15 items investigated, students in the 08/09 study transferred 9 of these items. Students in the 09/10 study, transferred 4 of these items despite having been reminded of the relevant mathematics in a mathematics context. However, it should be noted that a sample size of 24 in 09/10 compared with 30 in the 08/09 may have been the reason for a reduced number of statistically-significant transferred items in 09/10.

It was found that students who evidenced an ability to explain their answer for 8 of the 11 items requiring an explanation in a mathematics context, associated with transfer *(Q.2(I))*. Similarly for these same 11 items in the 09/10 study, students who evidenced an ability to explain 8 of them, associated with transfer. When we compare the 4 items in the 09/10 study, which had a Part B with those same items in the 08/09 study, which did not have a Part B, we find that: students who evidenced an ability to explain 3 of these 4 items in the 09/10 study associated with transferring them.

Lastly, it was found that for the 3 algebraic-type mathematical items, which had a graphical equivalent in the 08/09 study: students who answered the graphical equivalent in a mathematics context did not associate with transfer *(Q.2(II))*. A similar result occurred for the 09/10 study.

Table 1: Mathematical Items which Students Did or Did not Transfer; in Addition Mathematical Items which Students Transferred or Did not Transfer after Evidencing an Ability to Explain their Answer in a Mathematics Context.

Item Number	**Mathematical Item**	**Transfer Question**		**Factors Question: Ability to Explain & Transfer**	
		08/09 n = 30	*09/10 n = 24*	*08/09 n = 30*	*09/10 n = 24*
1	Calculation of Slope.	0.8	0.2	0.2	0.036
2	Sketching of Line with Positive Slope.	0.019	0.5	**Not Tested**	0.082
3	Sketching of Line with Positive Slope.	0.005	0.5	**Not Tested**	0.019
4	Sketching of Line with Negative Slope.	0.002	0.1	**Not Tested**	0.042
5	Generating an Expression for Derivative.	0.064	0.004	**Not Tested**	0.002
6	Generating an Expression for Derivative.	0.042	0.02	0.042	9.4E-05
7	Interpreting Derivative.	0.3	0.7	3.3E-05	1.2E-05
8	Algebraic Usage of Exponentials.	9.5E-06	0.3	9.5E-06	0.5
9	Graphical Representation of an Exponential Function.	0.3	1	1	1
10	Proportionality.	0.008	0.3	2.2E-07	3.1E-05
11	Algebraic Usage of Natural Logarithms.	0.004	0.055	0.004	0.023
12	Graphical Representation of Natural Logarithmic Expression.	0.3	0.1	0.3	0.72
13	Algebraic Evaluation of an Integral.	0.064	0.035	0.023	0.018
14	Graphical Representation of an Integral.	0.039	0.2	0.039	0.028
15	Graphical Representation of a Function.	0.031	0.2	0.031	0.034

CONCLUSION

The difficulties students appear to have with certain elements of mathematics in a chemistry context, may not be due to difficulties in transfer; instead the problem with transfer in some instances may be due to not possessing the necessary mathematical knowledge in a mathematics context. Furthermore, an ability to explain one's reasoning in a mathematics context, is a factor that associates with transfer; being able to graphically represent certain mathematical items appears not to be. Because of the former finding, it is the reason for informing the design of an inquiry-based curriculum that encourages students to explain their reasoning.

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A quiet revolution: large-scale curriculum change to embed enquiry-based maths teaching into an undergraduate physics programme

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Two years ago, at SMEC2008, I presented a talk that detailed the first steps we were taking to address our 'maths problem': the well-documented decline of mathematical abilities of entrant undergraduates into science programmes across (and indeed well beyond) the UK and Ireland. The intervening two years have seen rapid and seismic changes in the nature of the maths provision to first and second year students on Physics programmes at Edinburgh. This talk will present details of these changes and their impact, on students, staff and at an institutional level.

I will set out the philosophy and processes of change, underpinning our complete restructuring of our maths courses for years 1 and 2 physics undergraduates. I will detail the practicalities of what we have done, which has included enlisting the effort of almost half the academic staff in the department to contribute to the delivery of first year maths teaching. I will present quantitative data that evidences significant learning gains, as measured by student attainment on isomorphic pre- and post-course diagnostic tests of mathematical skills.

As a process of educational change, this has been far from plain sailing. I will present details of lessons learned and implications for the future. The talk will be of relevance not only to coalface practitioners, delivering and supporting enquiry-based learning, but also to those with responsibility for curriculum design and development.

Fostering Positive Attitudes towards Mathematical Problem Solving in the Primary School utilising Constructivist Methods: Lessons from Practice

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This study took place in the classrooms of 6 primary teachers as they endeavoured to implement constructivist teaching strategies during mathematical problem solving lessons with senior grade primary school pupils. Although it may influence teaching, constructivism is a theory of learning and not a theory of teaching (Wolffe and McMullen, 1996). It is an epistemology, a learning theory that offers an explanation of how we learn. The challenge therefore is translating this theory of learning into one that is usable for teaching. Emergent constructivist theory suggests that humans generate knowledge from their experiences and interactions with one another (Matthews, 2000). In a constructivist classroom, the learner should play an active role in the learning process in an environment designed to support and challenge him/her. Learning activities in constructivist settings are characterised by active engagement, inquiry, problem solving and collaboration with others. Constructivist principles are woven into many curricula worldwide, yet the implications for classroom teaching are still evolving. Using Polya's (1945) widely known strategy for exploring mathematical problems, teachers endeavoured to challenge children to solve complex mathematical problems in collaborative learning situations. Teachers who chose appropriate mathematical problems of relevance and interest to students and their capabilities, and who adopted facilitative roles employing open ended higher level questioning techniques, laid solid foundations for effective constructivist explorations.

INTRODUCTION

Irish primary teachers have been engaged in reform in Irish primary classrooms for the past ten years. We know a lot about teaching and learning in the primary school and our curriculum has undergone reform and evaluation (NCCA, 2008), but to what extent is this knowledge and reform impacting upon teaching practices within the primary mathematics classroom? Various reports and research conducted since 1999 have revealed that Irish primary students can perform basic mathematical skills quite well and that they know their mathematical facts, but, at second level, 15 year old students compare poorly with other countries in relation to higher level mathematical processes such as reasoning, analysing, solving problems, and analysing solutions (Eivers, Shiel and Cunningham, 2007; Mullis, Martin, Beaton, Gonzalez, Kelly and Smith, 1997; Surgenor, Shiel, Close and Millar, 2006). This is typical of students who have come through an education system that places significant emphasis on direct instruction and less emphasis on alternative forms of instruction. Gash (1993) reported that even though constructivist principles underpinned the curriculum introduced in primary schools in 1971, teachers continued to utilise didactic and teacher directed methods of teaching. An examination of teaching practices, of teachers' approaches to the teaching of mathematical problem and in particular their teaching and exploration of higher level mathematical processes is required to realise the necessary changes that must be made to practice for real reform to happen.

MATHEMATICAL PROBLEM SOLVING AND CONSTRUCTIVISM

It is quite difficult to draw a distinction between the teaching of mathematical problem solving from a constructivist perspective and engaging children in mathematical problem solving as espoused by the Irish Mathematics Curriculum (Government of Ireland, 1999). Literature suggests that doing mathematics or problem solving is 'reaching the stage at which one is producing more of that stuff by oneself or in collaboration with others' (Scheonfeld, 1994) which, in itself, is innately constructivist. To elaborate, Schoenfeld (1994:58) suggests that although the result of doing mathematics may be 'a pristine gem presented in elegant clarity', the 'path that leads to that polished product is most often anything but pristine, anything but a straightforward chain of logic from premises to conclusions' (Schoenfeld, 1994: 58). This path is problem solving; in doing mathematics, children engage in processes, such as reasoning, justifying and explaining, before reaching mathematical conclusions. This path is inherently constructivist because in problem solving by testing ideas, examining hypotheses and formulating solutions students are truly engaged in learning from a constructivist perspective. They are constructing understandings, generating knowledge often in the company of others. Many mathematical problems are considered too big for individuals to solve in isolation and this necessitates collaborative work which is an important aspect of learning from an emergent constructivist perspective. Mathematical problem solving cannot be construed merely as knowledge to be received and learned. The very essence of problem solving is the process of making sense of particular phenomena.

Francisco and Maher (2005), in a longitudinal study investigating the conditions for promoting reasoning in problem solving, state that 'providing students with the opportunity to work on complex tasks as opposed to simple tasks is crucial for stimulating their mathematical reasoning (Francisco and Maher, 2005:731). This is why problem solving plays a central role in current curricula including the Primary Mathematics Curriculum (Government of Ireland 1999a; 1999b) and the Principles and Standards of School Mathematics (NCTM, 2000). Curricular perspectives on mathematical problem solving reflect, very much, the notion that mathematics is about sense making (Schoenfeld, 1994). Current curricula suggest that students should be engaged in solving mathematical problems. For example, Principles and Standards for School Mathematics explains that 'students should have frequent opportunities to formulate, grapple with and solve complex problems that require a significant amount of effort and should then be encouraged to reflect on their thinking' (NCTM, 2000: 52). The Primary Curriculum (Government of Ireland , 1999a: 35) states that problem solving experiences should develop in children 'the ability to plan, take risks, learn from trial and error, check and evaluate solutions and think logically. According to the mathematics curriculum, Government of Ireland, 1999a; 1999b), discussion and acceptance of the points of view of others are central to the development of problem solving strategies.

TEACHING MATHEMATICAL PROBLEM SOLVING FROM A CONSTRUCTIVIST PERSPECTIVE

Windschitl (1999) has derived the key features of constructivist classrooms from the emergent perspective view of constructivism. Critically, they connect what is known about how people learn and the classroom conditions that optimize opportunities to learn in meaningful ways. These conditions can be cross-referenced with current literature (Schoenfeld, 1992) to illustrate appropriate teaching of mathematical problem solving.

- Teachers elicit students' ideas and experiences in relation to key topics, then fashion learning situations that help students elaborate on or restructure their current knowledge.

- Students are given frequent opportunities to engage in complex meaningful, problem based activities.
- Teachers provide students with a variety of information resources as well as the tools (technological and conceptual) necessary to mediate learning.
- Students work collaboratively and are given support to engage in task-oriented dialogue with one another.
- Teachers make their own thinking processes explicit to learners and encourage students to do the same through dialogue, writing, drawings or other representations.
- Students are routinely asked to apply knowledge in diverse and authentic contexts, to explain ideas, interpret texts, predict phenomena, and construct arguments based on evidence, rather than to focus exclusively on the acquisition of pre-determined right answers.
- Teachers encourage students' reflective and autonomous thinking in conjunction with the conditions listed above.
- Teachers employ a variety of assessment strategies to understand how students' ideas are evolving and to give feedback on the processes as well as the products of their thinking.

In summary, teachers must engage in listening exercises to identify a student's ideas and experiences so that in turn he/she can devise appropriate learning situations and make available appropriate tools and resources which might be required for use by the students. Students should engage with one another in problem solving situations; designing, testing, debating and reflecting upon situations to reach appropriate conclusions. Particular emphasis is placed on extension activities that arise out of constructivist learning situations to validate, extend, refine and predict the usefulness of the learning exercise in future situations.

METHOD

Problem representation strategies are needed to process linguistic and numerical information, comprehend and integrate the information, form internal representations in memory, and develop solution plans (Noddings, 1985). The most significant strategy was initially developed by John Dewey. His model of the problem-solving procedure may be described in four, five or six stages (Dewey, 1933). Polya (1945) further revised such a procedure that has four key stages – understand the problem, devise a plan, solve the problem and look back. The stages are typical of a socio constructivist learning environment in which ideas and strategies are shared with significant levels of experimentation and interaction.

The primary objective was to examine the engagement of students in learning mathematical problem-solving from a constructivist perspective. Utilising case study to achieve this, the researcher followed teachers as they implemented constructivist learning theory in their mathematical problem solving classes. Research participants designed and developed templates for a mathematical problem-solving lesson, utilising Polya's (1945) four stage procedure as an initial starting point, from a constructivist perspective before going on to apply this template to their own situations and teach a series of mathematical problem-solving lessons. Their progress and achievements were monitored by the researcher throughout a full school term culminating in a series of semi-structured interviews. Student responses to these mathematical problem-solving lessons were also collected and students engaged in group interviews with the researcher.

RESULTS

Teachers used Polya's format (1945) but conducted the exercises in a thoroughly traditional fashion. Teachers were helping children to arrive at answers and it is clear from these episodes that, although the teacher's involvement with students resulted in the achievement of answers, student understanding of the answers and the techniques used to get them were limited. This was particularly evident in Joe's case. Cuban (1984) explained that many teachers construct hybrids of particular progressive practices grafted on to what they ordinarily do in classrooms (Cohen, 1990; Cuban, 1984). The case of Joe was particularly interesting, even though it was clear he believed that the employment of mathematical problem-solving and the development of independent problem solvers should be the primary goals of mathematics lessons, his teaching of mathematical problem solving was very evidently didactic, and thus prevented the pupils from developing this autonomy. His interactions, particularly his questioning strategies, with pupils and his provision of direction as they solved problems bore little resemblance to a constructivist approach. Joe's interactions with students were quite different from what Gallimore and Tharp (1989) and Draper (2002) explain are more appropriate to organising learning for students from a constructivist perspective. According to Gallimore and Tharp (1989) and Draper (2002), students must be enabled to read, write, speak, compute, reason and manipulate both verbal and visual mathematical symbols and concepts. To achieve this, the teacher should use an elaborate set of strategies including questioning, inferring, designing, predicting and facilitating.

Teachers' own school experiences significantly influence their approach to teaching (Lortie, 1975). This became particularly evident in those that recalled enjoyable and, in their view, appropriate teaching practices. Both Susan and Tomás recalled their mathematical experiences at primary level and both experienced very different forms of instruction. Susan, who was taught in classrooms employing very traditional methodologies, holds such practices in high esteem and continues to identify with and utilise such approaches in her classroom. These practices include having children learn basic mathematical facts through rote memorisation and paying particular attention to the teaching of the operations. Susan did, however, incorporate elements of a constructivist approach to mathematical problem-solving into her didactic approach to mathematics following engagement with professional development, but her fervently held beliefs about what constitutes appropriate mathematics teaching were not changed in any significant way. Tomás' only significant recollection of mathematics at primary level was one that involved mathematical problem-solving at fourth class level. Tomás, having experienced success in problem-solving at primary level, identified with having children approach mathematical problems from a constructivist perspective, and elements of his teaching of mathematics were clearly constructivist even prior to engaging with professional development. Even those participants, whose mathematical experiences, in their opinion, were not in anyway significant found value in methods of instruction of former teachers. Hence, these teachers clearly implemented these methods in some format in their own mathematics classrooms. Interestingly, Emily, who experienced corporal punishment at primary level during mathematics class when she failed to answer mental mathematics questions, uses the same procedure for examining students' mental mathematics in her own classroom today. Emily lines up her students and asks them a series of questions very quickly and if these questions are not answered the student is asked to sit down, and so it continues until one member of the class is left standing.

CONCLUSION

Teachers face many dilemmas in the adoption of a constructivist approach to teaching, not least in finding a balance between individual and group learning and the definition of appropriate constructivist instruction. These dilemmas were prevalent as teachers grappled with constructivism and its inherent link with mathematical problem solving and the implications for the mathematics classroom from the inception to the conclusion of the project. The most profound challenges for teachers are: to make personal sense of constructivism, to re-orientate the culture of the classroom to accommodate constructivist philosophy, and to deal with conservatism that works against teaching for understanding (Purple & Shapiro, 1995). Teaching from a constructivist perspective proved engaging for students and teachers when both the roles and responsibilities of everybody in the classroom were explicit. Students were successful in their mathematical problem-solving interactions when they were presented with mathematical problems that reflected their current level of understanding yet were challenging, and when they followed the four-stage procedure set out in advance for problem-solving. Teachers who chose appropriate mathematical problems of relevance and interest to students and their capabilities, and who adopted facilitative roles employing open ended higher level questioning techniques, laid solid foundations for effective constructivist explorations. There is a fine balance to be struck in achieving this as different individuals' social and cultural contexts differ; people's understandings and meanings will, therefore, be different (Airsian & Walsh, 1997). Students' construction of both strategies and solutions surprised individual students and teachers and initiated rich debate and interesting strategies of solution in those classrooms.

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The role of critical reflection and analysis in inquiry-based learning using video-based experiences: implications for mathematics teacher education

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This paper will report on the implications for teacher education programmes as we move towards a more inquiry-based approach to teaching and learning mathematics. There is need to review the training of our mathematics teachers to complement the new 'Project Maths' initiative. This study adopts an inquiry approach to teaching through the use of video-recordings and critical analysis and reflection. 29 pre-service secondary school mathematics teachers were individually video-taped teaching a mathematics class to mature students at the University of Limerick (UL). Rowland's (2008) Knowledge Quartet was the framework used for the observation and reflection of this teaching. The study offers insight into pre-service mathematics teachers' subject content knowledge, as well as their pedagogical content knowledge, both of which will impact on their ability to adopt an inquiry-based approach to teaching (Lee, 1995). The findings are discussed and implications for mathematics teacher educators are highlighted.

INTRODUCTION

The need for reform of mathematics in Ireland is highlighted each year by the low uptake of Higher Level mathematics (16% of total cohort in 2010) and by the large failure rate of mathematics at Leaving Certificate. Recent PhD work by the author (ML) suggests that first year pre-service mathematics teachers (studying Physical Education and Mathematics at UL) have a fragmented, disjointed view of mathematics and the approaches that they adopt to learning mathematics are mainly of a procedural nature. This study was undertaken in order to critically assess, reflect and develop pre-service mathematics teachers' subject content knowledge in particular, as well as their pedagogical content knowledge through the use of video-based experiences. This research is predominantly concerned with subject matter knowledge which Shulman (1986) clarified as knowledge of the content of the discipline such as facts and concepts. He described pedagogical content knowledge as the manner in which a teacher can represent the subject in a way that others can comprehend and an understanding of what makes the learning of the subject easy or difficult.

The video-based experiences in this study, and the critical analysis and reflection of such experiences, offered a novel inquiry approach to teaching and learning for the pre-service mathematics teachers. According to Towers (2010), it is important that pre-service teachers experience inquiry approaches to teaching and learning if they are expected to implement the same in their classrooms. In addition, the method of inquiry provided the pre-service teachers with analytical skills necessary to reflect on their own teaching and continue inquiry about practice. The importance of teachers learning through analysing teaching is emphasised by Hiebert, Morris, Berk & Jansen (2007). There is also much evidence from the literature that suggests analysing video lessons has a positive impact on pre-service teachers. Alsawaie & Alghazo (2010) concluded from their study that video-based experiences increased pre-service teachers' knowledge about problems in practice, developed their sensitivity toward student learning and lead to them to think in depth about efficient instructional strategies.

The new 'Project Maths' syllabus places much greater emphasis on student understanding of mathematics concepts, with increased use of contexts and applications that will enable students to relate mathematics to everyday experience. Mathematics teacher educators and their pedagogy classes are paramount to the success, or not, of this move towards a more constructivist approach to teaching and learning. This paper details the research conducted from January to May 2010 with pre-service mathematics teachers. An analysis of the data gathered is presented and the findings are discussed.

METHODOLOGY

This research was guided by the literature and provided supporting theoretical frameworks and methodologies for investigating pre-service mathematics teachers' subject content knowledge and to a lesser extent, their pedagogical content knowledge. The theoretical framework employed is now discussed.

Theoretical Framework

Rowland, Huckstep & Thwaites' (2005) Knowledge Quartet (KQ) was the framework upon which this study was conducted. Rowland and his colleagues devised this framework for the observation and review of mathematics teaching. It consists of four units: foundation; transformation; connection and contingency. Each unit is subdivided into smaller codes of which there are 17 in total. Rowland (2008) describes foundation as trainees' knowledge, beliefs and understanding acquired in preparation for their role in the classroom. Transformation concerns "knowledge-in-action as demonstrated both in the planning to teach and in the act of teaching itself" (Rowland, 2008, p.289). Connection, the third category, links together choices and decisions for the more discrete parts of mathematical content. It includes making connections between concepts and procedures as well as sequencing of subject matter. The final category, contingency, incorporates the pre-service teachers' ability to respond to students' ideas and think on one's feet.

RESEARCH DESIGN

The research was carried out in two main stages:

Stage One

- Authors watched and compared findings from three extracts from TIMSS video study and analysed them according to the KQ.
- Pre-service teachers were provided with a twenty minute lecture and discussion of the KQ. They then observed and analysed one extract from the TIMSS video study. This was done individually firstly, following by paired and whole class discussion.
- Pre-service teachers had one further workshop where they again observed and reflected on a thirty minute extract from another TIMSS video and in pairs/groups they discussed what they had observed and reported on based on the KQ.

Stage Two

- The pre-service mathematics teachers were split into pairs for teaching a fifty minute support tutorial (twenty five minutes each) to mature students.
- Each pre-service teacher was required to teach a support tutorial and reflect on it once provided with the DVD of the lesson. They were also required to attend two other lessons to observe and reflect on their peers' teaching. The KQ formed the basis for all observation and reflection.
- The author also attended all support tutorials and observed and reflected on each teaching session.

Research Sample

The sample included 29 pre-service secondary school mathematics teachers at UL. These are third year Physical Education and Mathematics students who will commence their final teaching practice placements in September 2010. They also had a mathematics pedagogy module from January 2010 to May 2010 taught by one of the researchers (OL), so access to the sample was not a problem. Olivia Gill is also manager of the Mathematics Learning Centre in UL and assigns tutors for all support tutorials. This provided us with the sample to teach – mature students studying an access certificate course designed to refresh students skills in areas such as basic mathematics and statistics.

Data Collection and Data Analysis

Prior to data collection, consent was obtained from all mature students and pre-service teachers for recording the lessons. The students were informed that all data was anonymous and that it would be stored securely for the authors' use only. 15 lessons were recorded and DVDs developed of each lesson. Each pre-service teacher was given the DVD of their teaching only. The authors also had a copy of the DVD of each lesson.

This paper reports on the researchers' analysis of the 29 pre-service teachers' teaching. The author attended each lesson and at a later date she again reflected on all video-recordings in more detail. Again, the KQ and the codes designed by Rowland et al. (2005) was the framework for this analysis. On completion of this stage of analysis, the author (ML) used a grounded theory approach or constant comparative method (Glasser & Strauss, 1967) to determine the main themes that emerged. The themes coming from the data were compared by the two researchers for consistency. The findings are now presented and discussed.

FINDINGS AND DISCUSSION

The findings are presented under the four main categories: foundation, transformation, connection and contingency and their subcategories.

Foundation

The depth of mathematical knowledge demonstrated by the pre-service teachers was poor with only six teachers displaying a good depth of knowledge. In general, the pre-service teachers relied on procedural knowledge (19 out of 29), described by Skemp (1978) as instrumental understanding or knowing the 'how' rather than knowing the 'why'. For example, one pre-service teacher did not relate to students' method for calculating the median as it differed from her method. She was confused stating that "5.5 is the median because it is the right middle number. I don't know why the formula isn't working". Developing subject matter knowledge is essential for these pre-service teachers since improvements in particular kinds of subject matter competence contribute to better analysis of practice thus improve teaching (Hiebert et al., 2007). There was also poor use of mathematics language and terminology identified throughout. 25 out of the 29 pre-service teachers frequently used poor mathematical language or failed to introduce terminologies in their teaching. One such example is where a pre-service teacher was teaching probability and never once mentioned the terms 'independent events' or 'mutually exclusive' despite her lesson being based on both of these concepts.

Transformation

The first code under this section is how the mathematics is communicated to the learner. Mixed themes emerged from here with 8 out of the 29 categorised as good transformers of knowledge, 14 categorised as poor transformers of knowledge and 7 as average. This was determined by the way in which the teacher transformed his or her own meanings and descriptions of the content and if it was carried out in a way that enabled students to learn. An example of this was where one pre-service teacher transformed the knowledge of probability in a very effective way. She showed a clip from You Tube to begin the lesson demonstrating how probability can be related to insurance and the way in which she explained concepts suggested that she was teaching for understanding. Carpenter & Lehrer (1999) outlined many benefits of teaching for understanding such as students are more likely to be able to apply that knowledge to solve new and unfamiliar problems as well as the fact that understanding mathematics can ultimately influence a student's view about the subject.

The pre-service teachers were provided with the subject matter in the form of tutorial sheets with specific questions to follow. However, the pre-service teachers were given scope and encouraged to provide their own examples and vary their teaching strategies throughout the lesson. Use of real-life examples was minimal. 5 out of the 29 pre-service teachers used real-life examples more than once in the lesson, while 7 out of the 29 made one attempt to put some concepts in context, and the remaining 17 used no real-life application at all. The importance of putting the mathematics in context cannot be underestimated. As Boaler (1994) explains, teaching in context motivates students and builds their confidence and interest in mathematics so long as a realistic view of mathematics is given which makes sense both in the classroom and in the real world. There was some varied use of demonstrations and analogies but often these were incorporated in the lesson to little effect.

Connection

The main theme to emerge from this category in terms of making connections between concepts or procedures was that many of the pre-service teachers lacked the knowledge to do just that. Many of the topics were presented in a disjointed way with little or no connection between the concepts or between the concepts and the procedure. An example is the introduction of the terms 'sample variance' and 'standard deviation' by a pre-service teacher with no link made between the two terms and the focus solely on how to do the calculations. Ball, Lubienski & Mewborn (2001, p. 433) report on the lack of understanding of the mathematical knowledge necessary to teach well. They claim that this "insufficient understanding has meant inadequate opportunities for teachers to develop the requisite mathematical knowledge and the ability to use it in practice".

Sequencing of subject matter is another code within this category but as students were provided with tutorial sheets prior to the lesson the code was less relevant to this study. It was interesting to note however, that only four of the 29 pre-service teachers re-ordered the sequence of exercises or topics according to what they felt would most benefit the students' learning. There were only 8 incidents observed where the pre-service teachers anticipated difficulties their students may have with a particular concept.

Contingency

The final category in the KQ is contingency which is determined by the pre-service teachers' ability to think on his or her feet, respond to the students and deviate from the lesson where he or she feels it would be beneficial for one or all learners. These three codes are discussed together since they are all very much interlinked. The main findings emerging from this category were that most pre-service teachers (21 out of the 29) appeared to lack the content knowledge necessary to interpret students' questions and misconceptions and to confidently deviate from the lesson plan to explain such misconceptions. For example, in a lesson on Poisson distribution a student was clearly confused about looking up the tables for $P(X \geq 7)$ when asked for $P(X > 6)$. The pre-service teacher appeared uncomfortable with the question and chose to ignore it. The importance of subject content knowledge has been reported many times throughout this paper.

In other incidents, some pre-service teachers appeared to lack interest or lack the motivation to teach for understanding in their response to students' questions (3 out of 29). One would expect to find that all teachers who choose mathematics teaching as a career to have positive feelings towards the subject and confidence in their ability to teach mathematics. Research shows however, that this is not always the case. Pre-service teachers often bring fragmented conceptions and negative attitudes towards mathematics to university (e.g. Townsend & Wilton, 2003). On a positive note, there was some evidence of good responses and ability to deviate from lesson plan where appropriate and beneficial for students (6 out of the 29).

CONCLUSIONS AND IMPLICATIONS

The above findings suggest that many pre-service mathematics teachers may not have sufficient subject matter knowledge to implement inquiry-based learning effectively. With the introduction of 'Project Maths' and the move towards a more constructivist approach to teaching and learning, it is essential that our pre-service mathematics teachers are prepared to teach in such a way. There is much onus on mathematics teacher educators to develop pre-service teachers' ability to adopt a more inquiry-based approach to their teaching and instil confidence among them to move away from the traditional approach which they may be accustomed to. Video-based experiences are one way of doing so. They offer a challenge to teacher educators to harness the evidence from such experiences in a way that creates awareness among pre-service teachers of the need for a change in approaches to teaching mathematics. In addition, video-based experiences provide trainee teachers with the opportunity to critically reflect on their subject content knowledge and pedagogical content knowledge. Findings in relation to the pre-service teachers' self-reflection reports will be reported at a later date.

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Distributed Cognition: Scientific Investigations of primary school children in duo context

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A sample of 530 sixth-grade students were initially administered the Raven's Progressive Matrices (RPM) and based on their performance a smaller sample of 120 students was selected. These students were assigned in sixty dyads and were instructed to interact with a device and investigate its functioning. The students were explicitly instructed to think aloud before and after any experiment with the device, to keep a record of their observations and to jointly decide how to proceed with their investigations. At the end of the investigation, each dyad was required to report its final conclusions concerning the functioning of the device. This procedure was based on Klahr and Dunbar's (1988) study, who conceptualized scientific investigation as a dual search, a search in a space of hypotheses and a search in a space of experiments. The results showed that the students spent most of the time during the investigation working competitively and based on the Degree of Collaboration, each investigation could be divided in four different stages. In addition, the results of the study clearly demonstrated primary school students' limitations in terms of cognitive abilities, i.e., control of variables, combinatorial reasoning, verification bias or in terms of reporting their experimental data and using their records as an external memory system.

INTRODUCTION

Resent science reform efforts advocate the development of students' scientific reasoning. According to Zimmerman (2007), scientific reasoning includes the thinking and reasoning skills involved in inquiry, such as experimentation, evidence evaluation, inference, recording and interpreting data and many others. Klahr and Dunbar (1988) considered scientific reasoning as problem solving involving search in two coordinated spaces: the hypothesis space and the experimental space. The hypothesis space represents all possible hypotheses, and the experiment space represents all experiments that can be conducted. Prior knowledge and experimental results guide the search in the hypothesis space, while a current hypothesis guides the search in the experiment space. Another main component in the model is the evaluation of evidence, by which it is decided whether the cumulative evidence justifies acceptance, rejection, or continued consideration of the current hypothesis.

Distributed cognition is a theory that moves the boundary of cognition from the heads of individuals and considers the "joint cognitive system" as the unit of analysis (Hutchins, 1995). It focuses on the interactions between people, between people and their environment, and between people and artifacts that are created and manipulated in the course of doing work, and it emphasizes information flow and information transformation.

The present study was based on the Klahr and Dunbar model (1998) and took into account the notions of distributed cognition and joint cognitive system and attempted to evaluate and compare the performance of the components (social and material dimensions) of the distributed cognitive system. The study also focused on the underlying cognitive processes operating when primary school children conduct investigations and on identifying factors that may hinder or support the optimal functioning of a joint cognitive system taking into consideration both its social and material dimensions.

METHODOLOGY

A sample of 530 sixth-grade students were initially administered the Raven's Progressive Matrices (RPM) and, based on their performance, a smaller sample of 120 students was selected. These students were assigned in 60 dyads, where 20 dyads consisted of students who had high performance on RPM H-H, 20 other dyads consisted of students who had low performance on RPM L-L, and the remaining 20 dyads consisted of one student having high and another student having low performance on RPM H-L. These dyads were instructed to interact with a device and investigate its functioning. The device consisted of a wooden box with eight light bulbs in a line and five switches in another line underneath. The bulbs and the switches were connected in a hidden circuit inside the box, while a red button beneath the switches was to test which lamp(s) was (were) lit. In the circuit, one of the switches was connected as a general switch, while another switch was a dummy one. The students were explicitly instructed to think aloud prior and after any experiment with the device, and to keep a record of their experiments and the consequent results. The students had to jointly decide how to proceed with their investigations. At the end of the investigation, the students were required to report about their final conclusions concerning the functioning of the device.

RESULTS

Each investigation was divided into interaction sequences representing units of dialogue. Based on the interaction sequences, two types of interaction sequences were distinguished: "collaborative" or "competitive." The "Degree of Collaboration" for each dyad was then calculated. Operationally, the "Degree of Collaboration" was defined as the number of collaborative interaction sequences, divided by the total number of the interaction sequences in an investigation. The mean of the Degree of Collaboration for H-H dyads was 0.263 (SD= 0.154), for H-L dyads was 0.113 (SD= 0.113), and for L-L dyads was 0.069 (SD= 0.068), respectively. A one-way ANOVA analysis results indicated that there was a significant difference in the Degree of Collaboration among the three types of dyads [$F(2,57)=15.072$, $p=0.000$]. Post hoc comparisons using a Scheffe test showed that the mean of the Degree of Collaboration for H-H dyads was significantly higher than the mean of the Degree of Collaboration for the other two types of dyads ($p<0.05$). The findings indicated that students in H-H dyads collaborated to a higher degree than those who were paired in L-H and L-L dyads.

Based on the Degree of Collaboration, each investigation was divided in four different stages. In Stage 1 (Initial Investigation), the pupils worked competitively, in Stage 2 (Intermediate Investigation), the pupils began efforts to collaborate and to take into consideration each other's opinion and in Stage 3 (Collaborative Investigation), the pupils managed to collaborate continuously. At the end of investigation, and after the students reported their final conclusions concerning the functioning of the device, the researcher prompted the students to re-examine their data and draw any additional conclusions. This part of the investigation was considered as a fourth and separate stage (Collective Review).

The majority of the investigations (n=38) included only the stage of Initial Investigation. Ten investigations included two stages (Initial and Intermediate Investigation) and only 12 other investigations included three stages (Initial, Intermediate and Collaborative Investigation). Finally, in 9 out of 60 investigations, the students managed to take advantage of the stage of Collective Review. The majority of H-H dyads (n=11) included three stages (Initial, Intermediate and Collaborative Investigation), indicating that these students managed to collaborate during the investigation. On the contrary, the vast majority of the H-L (n=15) and H-H (n=16) dyads, respectively, included only the stage of Initial Investigation, indicating that these students were working competitively throughout the whole investigation.

Thirty dyads identified the general switch (GS). Especially, 17 H-H dyads, 12 L-H dyads and only one L-L dyad succeeded to identify the GS. Only 8 H-H dyads gave the GS the right name and explained how it worked. Besides, only 20 dyads identified the "dummy" switch (DS). The majority of these dyads (*n*=14) was H-H type. On the contrary, only 6 L-H dyads and no L-L dyad managed to solve the problem of the DS. The vast majority (*n*=18) comprehended that the particular switch was not connected to the electric circuit and supported that "it doesn't work," "it is useless," or "it is a dummy."

The students of 52 dyads preferred to perform experiments that would generate a result or would make a lamp light, based on their hypotheses. This tendency is known as confirmation bias. The remaining 8 dyads employed a negative-test strategy, that is, they performed experiments that could disconfirm their hypotheses.

Deep analysis of the investigations revealed that the students did not take full advantage of their external memory system. Almost all students belonging in H-H dyads (*n*=18) and a large proportion of students belonging in H-L dyads (*n*=12) took advantage of the experimental results: (a) to identify one or both special switches (general and "dummy" switch), (b) to identify experiments that they had not executed before and, (c) to avoid the execution of repeated experiments. On the contrary, the students in L-L dyads often trusted their memory to obtain the information needed for testing their hypotheses.

Each dyad conducted a number of experiments during the investigation. The mean number of performed experiments for H-H dyads was 21.10 (SD=5.29), for H-L dyads was 24.05 (SD=6.41) and for L-L dyads was 31.10 (SD=6.89), respectively. A one-way ANOVA indicated that there was a significant difference in the number of performed experiments among the three types of dyads [$F(2,57)=13.591$, $p=0.000$]. Scheffe post hoc analysis showed that H-H and L-H dyads performed fewer experiments than L-L dyads ($p<0.05$).

Despite the fact that the students recorded their experimental results, almost all dyads performed some identical experiments (same combinations of switches). The mean number of repeated experiments for H-H dyads was 2.05 (SD=2.37), for H-L dyads was 3.90 (SD=3.55) and for L-L dyads was 9.25 (SD=4.67), respectively. A one-way ANOVA indicated that there was a significant difference in the number of repeated experiments among the three types of dyads [$F(2,57)=20.957$, $p=0.000$]. Scheffe post hoc analysis also indicated that H-H and L-H dyads performed fewer identical experiments than L-L dyads ($p<0.05$).

The dyads' ability to control variables was also examined. A dyad was considered to employ the control of variables strategy when in two successive experiments they moved only one switch. The mean number of experimental trials in which the students employed the control of variables strategy for H-H dyads was 27.7% (SD=9.0%), for H-L dyads was 29.6% (SD=17.96%) and for L-L dyads was 16.4% (SD=10.4%), respectively. A one-way ANOVA results indicated that there was a significant difference in the control of variables among the three types of dyads [$F(2,57)=20.957$, $p=0.000$] and post hoc comparisons, using Scheffe criterion, revealed that H-H and L-H dyads employed the control of variables strategy in higher proportion of their experimental trials than L-L dyads ($p<0.05$).

Students' ability to move the switches up and down systematically was considered as a measure of their combinatorial reasoning. The students in 16 dyads exhibited limited combinatorial reasoning, because during the experimentation with the device, the students moved the switches up and down randomly. The students in 35 dyads exhibited in some degree their combinatorial reasoning and only the students in 9 dyads were able to employ a more developed combinatorial reasoning.

CONCLUSIONS

The findings of the study clearly indicate that students assigned to H-H and H-L dyads had significantly better performance, in terms of several variables (number of performed experiments, number of repeated experiments and combinatorial reasoning), than students assigned to L-L. Besides, students assigned to H-H dyads outperformed students assigned to H-L and L-L in terms of identifying the GS and the DS.

Another important conclusion was that the students spent most of the time during the investigation working competitively. Based on the Degree of Collaboration, each investigation could be divided in four different stages. Only the students assigned to H-H dyads managed to collaborate, but the collaboration was developed at the end of investigation (stage of Collaborative Investigation).

The results of the study clearly demonstrate primary school students' limitations in terms of cognitive abilities, (i.e., control of variables, combinatorial reasoning, confirmation bias) and using their records as an external memory system.

The total results of the present study suggest that the existing science curricula failed to achieve the declared objectives of science teaching.

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Lessons from Teaching Algebra by A Multi-Disciplinary Team of Algebra Cubed STEM Graduate Students

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Algebra Cubed is an educational outreach project in rural Kentucky sponsored by the (U.S.) National Science Foundation to promote educational interactions between school teachers and graduate students from the STEM fields. A goal is to impact content and pedagogy knowledge of teachers as well as cognitive and affective domains of students. In each of three years, ten STEM graduate students are trained as fellows to work in two middle schools and two high schools. We have engineered this rich interaction of fellows with teachers and students in algebra classes. Can interactions of this nature in mathematics classrooms improve teachers' understanding of content and pedagogy as well as attitude and achievement of students? Algebra Cubed is based on the premise of the theoretical framework of Wenger's "community of practice" and of Bandura's social learning theory. We used a pre-test and post-test design to measure gains of teachers in mathematical knowledge for teaching and of students in algebraic knowledge. We designed a survey questionnaire to measure changes in teachers' pedagogical understanding of critical issues in mathematics education and in students' attitude toward mathematics. Across three years, we have found (a) higher impact on students than teachers (e.g., significant improvement in algebra achievement among high school students versus no significant improvement in algebra knowledge among teachers), (b) higher impact on high school students than middle school students (e.g., significantly more appreciation of fellows as role models among high school students than middle school students), and (c) high satisfaction of fellows with their school experiences.

DESCRIPTION, RESEARCH BACKGROUND AND THEORETICAL FRAMEWORK

Algebra Cubed is an educational outreach project of the University of Kentucky, sponsored by the (U.S.) National Science Foundation to promote educational interactions between secondary school teachers and doctoral students from what is often referred to as the STEM (science, technology, engineering, and mathematics) fields. This engagement is expected to impact both content and pedagogy knowledge of teachers as well as both the cognitive and affective domains of their students. Each year of the three years of the project, ten doctoral students from the STEM fields are recruited and trained as fellows (which is how we will refer to them throughout this article) to go to work with teachers and students in two middle schools and two high schools in rural, economically depressed Kentucky, U.S.A.

Each fellow is paired with a mentor teacher who is teaching algebra to middle or high school students. This relationship is a two way street. Fellows are both assistants who help mentor teachers prepare and implement algebra lessons and colleagues who use their solid mathematical knowledge to influence mentor teachers' understanding of the content of algebra. The mentor teachers work with the fellows to build the pedagogical skills of the fellows. Furthermore, fellows interact with the students of their mentor teachers through such activities as answering questions in class, tutoring students after class, and offering homework assistance. Each fellow is required to spend 15 hours per week on the project with at least ten hours in a designated school. We have engineered this rich interaction of fellows with both teachers and students to promote teachers' mathematical knowledge of teaching and students' learning in algebra classes. A key question then is whether interactions of this nature in mathematics classrooms really improve teachers' understanding of content and fellows' of pedagogy as well as improve attitude and achievement of students.

For the teacher component, Algebra Cubed is designed based on the premise of the theoretical framework of Wenger's (1998) "community of practice" defined as "shared histories of learning" with a focus on learning as social participation and interaction (p. 86). Central to this framework is the regular professional interaction among members of a professional community that promotes constant reflection on content knowledge and classroom practice as well as constant renegotiation of what it really means to teach algebra. For the student component, Algebra Cubed is designed based on the premise of the theoretical framework of role models within a larger social learning theory (Bandura, 1977). Central to this framework is the conception that significant others inspire and motivate students to pursue higher educational and occupational goals.

RESEARCH METHOD

We employed a quasi-experimental design to examine the impact of Algebra Cubed on the teaching of teachers and the learning of students. Each year, we used a pre-test and post-test design to measure gains of teachers in their mathematical knowledge for teaching, and we designed a survey questionnaire to measure changes (through pre-survey and post-survey) in their pedagogical understanding of critical issues in mathematics education. Each year, we also used a pre-test and post-test design to measure gains of students in their algebraic knowledge, and we designed a survey questionnaire to measure changes (through pre-survey and post-survey) in their attitude toward mathematics (in particular, attitude toward learning algebra). Finally, we designed and then used each year a survey questionnaire to measure reactions of fellows (through pre-survey and post-survey) to the program.

ANALYTICAL RESULTS AND RESEARCH SIGNIFICANCE

Based on three years of data collected and analyzed, we found higher impact at the high school level than at the middle school level. Specifically, we found significant improvement in mathematics (algebra) achievement in three out of three years among high school students but significant improvement in mathematics (algebra) achievement in two out of three years among middle school students. Across each year of the three years, we found significant improvement in many more aspects of attitude toward mathematics among high school students than middle school students. Finally, across the three years, we found significantly more appreciation of doctoral students as role models among high school students than middle school students (Ma and Millman, 2008).As to mathematics teachers, there was a lack of significant impact on mathematics teachers across all three years. Indications of this phenomenon include that there was very limited change in attitudinal aspects of Algebra Cubed mentor teachers across three years and there was no significant improvement in algebra knowledge for teaching among Algebra Cubed mentor teachers across three years. However, mathematics teachers highly enjoyed working with fellows as a way of professional development across all three years.

Finally, there was valuable impact on fellows. We found that fellows were extremely satisfied with their experience as participants in the project across three years and fellows highly enjoyed working with mentor teachers across three years. In addition, the fellows who went on to university level mathematics teaching said that the ALGEBRA CUBED experience made them a far more attractive as a candidate. Anecdotally, they said that this project came up uniformly during their job interviews as they finished their doctorate.

Some questions surfaced during the three-year research on Algebra Cubed students, teachers, and fellows. Overall, this innovative outreach approach involving doctoral students in the STEM fields shows very good promises. Nevertheless, we ask the question why there was higher impact on students than teachers. We also ask the question why there was higher impact on high school students than middle school students. In addition, we question whether the duration of the intervention (one year for each fellow) is sufficient and whether the intensity of the intervention is sufficient. Even though our project was not equipped (or required) to answer these questions empirically, we believe that we have pinpointed key issues in terms of the idea of teaching algebra by a multi-disciplinary team of STEM graduate students. Thinking and investigating these issues would lead to a better design on the interaction between STEM graduate students and school teachers and students for significant improvement in teachers' teaching and students' learning.

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Retaining Weaker Students in Irish Undergraduate Science Programmes

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Due to the increase in the number of students seeking third level education, it is true to say that it has resulted in many students choosing science programmes who may not necessarily have an adequate foundation in science. This study is an attempt to increase retention amongst weaker students in undergraduate science programmes.

An intervention programme was designed for three groups of students, who have previously been identified as weak. This programme was piloted in the academic year 08/09. The positive results from the pilot, led to the expansion of this programme into a larger scale study, which began in the academic year 09/10. This revised programme lasted 10 weeks, consisting of tutorials in basic chemistry; online resources were also made available to students.

The tutorials consisted of various strategies including peer learning and assessment, problem based learning and the use of concept questions. *A pre- and post- diagnostic test of chemical concepts and misconceptions was designed and administered in the first and last tutorial session*. Student's *performance in both the pre- and post diagnostic tests was measured. The pre- diagnostic concept tests were used to design the intervention programme in order to meet the students' specific needs and address their weaknesses.*

The results of the intervention programme were positive. The examination results of students who undertook this programme were better than those in previous years. However, while the results are encouraging, poor attendance in both the main module and in the intervention programme will be accounted for in the results.

INTRODUCTION

In recent years in Ireland there has been an increasing problem with students dropping out during their third level education, particularly in science–based courses. The Irish government's expansion policy on education has resulted in much higher numbers pursuing higher education than ever before, with over 60% of school leavers progressing to third level education in 2009 (Forfás Expert Group on Future Skills Needs, 2009).While the large numbers entering higher education are seen as a socially progressive move, it does lead to the problem of a very diverse group of students in higher education with a wider spread of academic ability. (Childs & Sheehan, 2009; Darmody & Fleming, 2009). Unless these weaker students are supported and given the time and help they need, they are at risk of non-completion of their third level studies. It has been noted that more 'fine-grained' approaches are needed to tackle 'student underperformance, student persistence, retention and academic success'(Moore, 2004).

This study is a follow-up of work done by Hayes and Childs (2009) on the development of a pilot intervention programme for weak chemistry students.

LITERATURE REVIEW

As mentioned above, the diversity in the student population in recent times calls for a more varied approach to teaching and learning. Cottrell (2000) agrees that: 'student intakes today are more likely to have higher proportions of students who learn best if they are offered alternative ways of studying'.

Misconceptions in chemistry are widespread among students at all levels. The literature reports on a wide range of areas in chemistry where students misunderstand the chemistry content that they are taught due to misconceptions or alternative conceptions which hinder learning. Misconceptions can act as 'barriers' for meaningful learning and must therefore be addressed (Taber, 2000). Childs and Sheehan (2009) have reported on areas of difficulty in chemistry in Irish students and their persistence throughout their chemistry education, from second level to third level. Their study indicates that 'performance at higher levels is being significantly affected by a failure to master core ideas earlier in their chemistry education'. To enhance the students' learning experience, other teaching and learning techniques need to be explored. In today's teaching climate, it is important to identify at-risk students and create a supportive learning environment. By teaching smarter, rather than teaching harder, students are given a better opportunity to succeed (Perkins, 2007). There are a number of ways that this can be achieved, and some are described below.

Chemistry is seen as a challenging and difficult subject by many third level students especially if the student has no prior experience of the subject. Chemistry needs to be understood at several levels: the observational level (macro level), the molecular level (sub-micro level) and the symbolic and process level (Johnstone, 1982). Failure by students to realise that chemistry involves all three aspects can often lead to the formation of misconceptions. In order to help students to overcome these misconceptions, models, diagrams and computer animations can play an important role in developing students' understanding of difficult chemical topics. It is important that students are helped to move from the macro to the micro, from the concrete to the abstract, for example by using physical models. The use of such models and also real examples allows the learner to visualise areas of chemistry which are often abstract and concept-laden (Childs, 2009).

METHODOLOGY

A pilot programme was run in The University of Limerick for one semester of second year in 2008-09 (Hayes and Childs, 2009). Based on the success of this pilot programme, an expanded study has been implemented in 2009-10, using a similar approach but starting in first year. The pilot study involved two groups of students previously identified as weak. These particular groups of students have been identified as weak due to the following reasons: they have studied little or no chemistry Leaving Certificate; their overall academic background is weak with low entry points; they showed a weak performance in previous third level chemistry examinations. The pilot intervention was a 9 week programme covering basic chemistry concepts, run in the first semester of second year. A pre- and post- diagnostic test of chemical concepts and misconceptions was designed and administered in the first and last session. The pre-test results were used to design the course to meet the specific needs of the students.

This expanded study involves a longer intervention programme running over two semesters and starting in the second semester of first year. The programme was developed for the same two groups of students Group A and Group B as well as a third group Group C, all of which have been identified as weak for the reasons given above. The intervention programme was advertised through class emails, and by the chemistry lecturer of the module they were taking at the time. The students were encouraged to attend by the lecturer but attendance was voluntary. A pre- and post- diagnostic test of chemical concepts and misconceptions were administered in the first tutorial session with the students. The pre- diagnostic tests were used to design the content of the intervention programme to meet the students' specific needs.

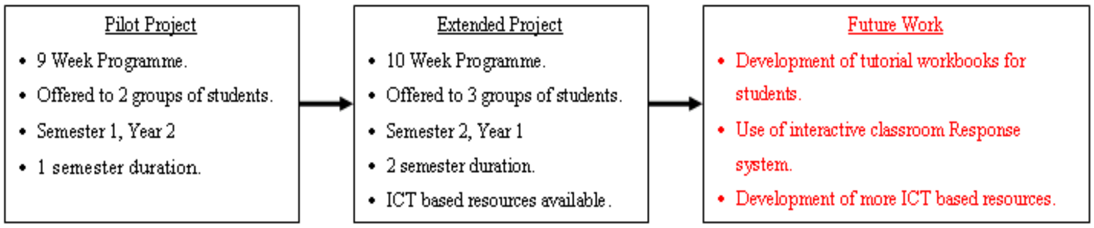

Figure 1: Project outline.

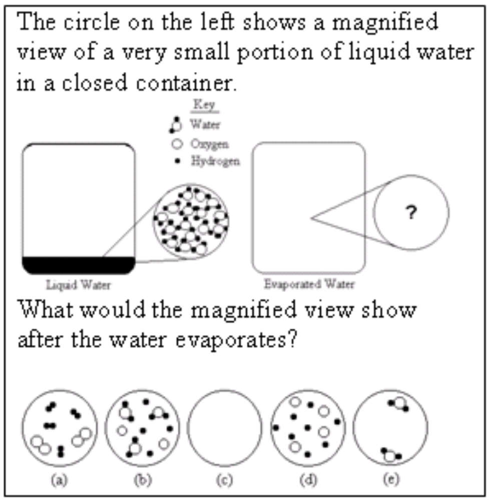

Figure 2: Diagnostic test sample question.

RESULTS & DISCUSSION:

Pilot Project: Pre- and Post-Diagnostic Test Results

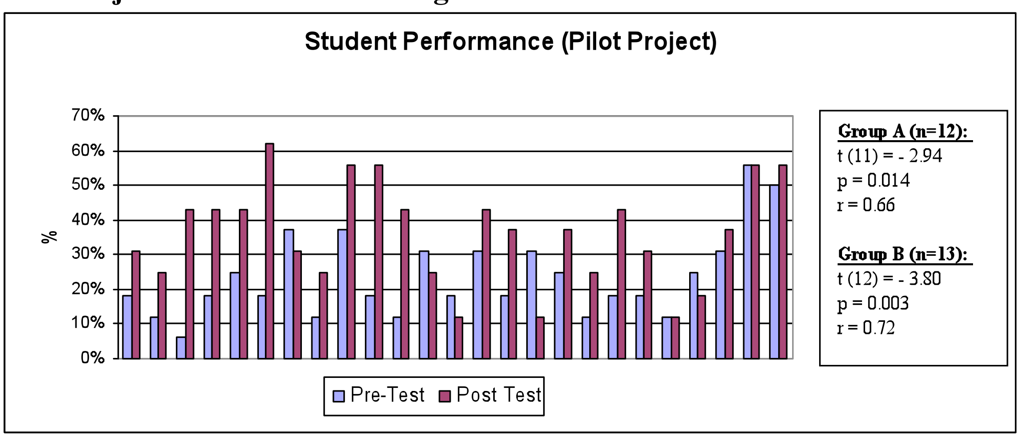

Figure 3: Performance of students who took both pre- & post- diagnostic tests.

There was a significant difference between pre- and post-diagnostic test results for both groups (see Figure 3.) On average participants in Group A experienced significantly higher results in the post-concept test after the intervention programme ($M = 39.08$, $SE = 4.62$) than in the pre-concept test ($M = 29.73$, $SE = 4.17$, $t(11) = -2.94$, $p = 0.014$, $r = 0.66$). Participants in Group B also experienced significantly higher results in the post-concept test, after the intervention programme ($M = 41.28$, $SE = 4.49$) than in the pre-concept test ($M = 22.05$, $SE = 2.86$, $t(12) = -3.80$, $p = 0.003$, $r = 0.72$).

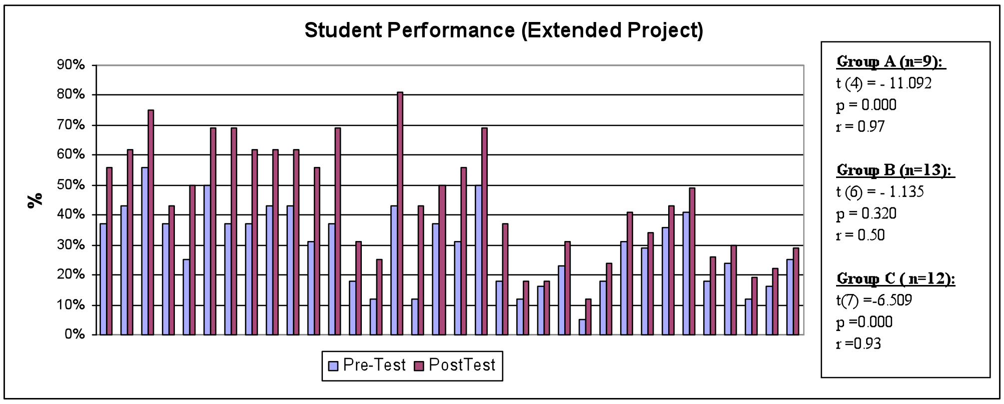

Figure 4: Performance of students who took both pre- & post- diagnostic tests.

As shown in Figure 4, group A experienced significantly higher results in the post-diagnostic test after taking part in the intervention programme (M=64.147, SE=1.89) than in the pre-diagnostic test (M=39.71,SE=2.32). Group A had the highest attendance rate at the Intervention Programme, attending 72% of the tutorials. Group B experienced higher results in the post-diagnostic test after taking part in the intervention programme (M=48.20,SE=11.96) than in the pre-diagnostic test (M=39.60, SE=5.04). However it was not significant for this group. A possible reason for this is that Group B showed the lowest attendance rate for the Intervention Programme, attending only 59% of the tutorials. Group C also experienced significantly higher results in the post-diagnostic test after taking part in the intervention programme (M=49.00, SE=6.75) than in the pre-diagnostic test (M=27.63, SE=5.19). Group C attended 68% of the Intervention Programme tutorials.

Influence of the Intervention Programme on Students' Performance in the Chemistry Module Examination

In the chemistry module that students were studying at the time of the Intervention Programme, students in all three groups experienced, on average, slightly higher marks in the written part of their exam than those who did not take part in the Intervention Programme. Figure 5 shows that the mean grade of all students who participated in the intervention programme was better than those who did not. However, this is only significant for one group, Group A. This may be due to the fact that Group A showed the highest attendance rate at the intervention tutorials.

FRIDAY AM - 2

<u>Extended Project:</u> Pre- and Post-Diagnostic Test Results

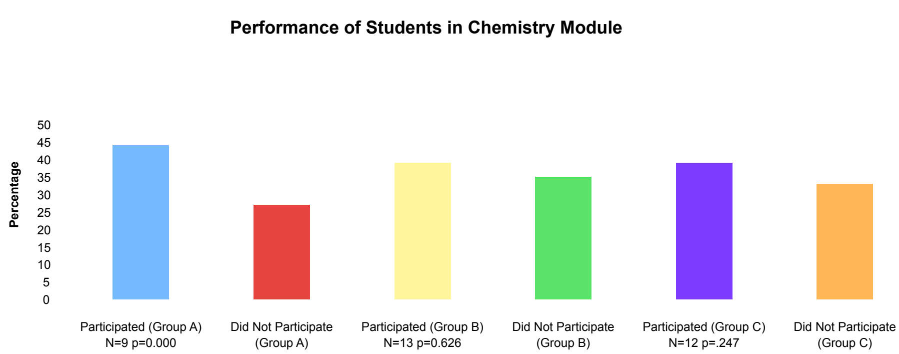

Figure 5: Comparison of Results in Chemistry Module.

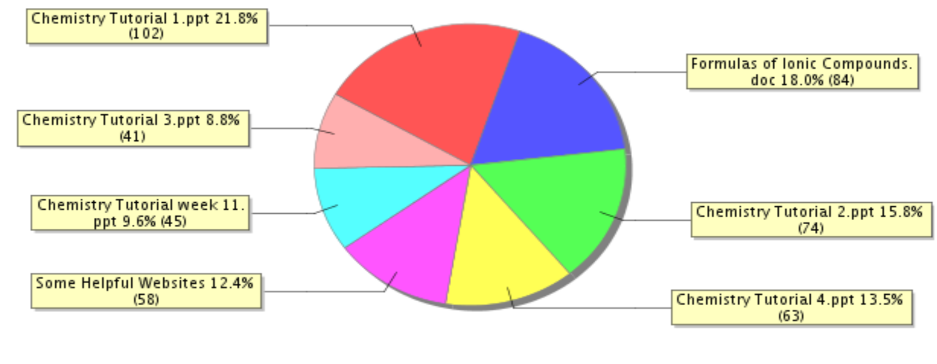

Figure 6: Student usage of some of the resources made available on website.

Interaction of Students with Web-Based Resources

In total 669 visits were made to the intervention web site during the 10 week Intervention Programme. Figure 6 shows a pie chart of the students' usage of some of the resources that were made available to the students on the website. It is clear from the chart that students made use of the PowerPoint presentations which were used each week during the face-to-face tutorials. These presentations included visual animations and also examples that the students worked through during the tutorials, as well as elements of formative assessment.

CONCLUSIONS:

Overall, the results of this Intervention programme are positive. It is clear from the results that taking part in the programme positively influenced students' performance in a number of ways. All of the students who completed both a pre- and post-diagnostic tests at the beginning and the end of the 10 week programme achieved higher grades in the post-test. This shows that the tutorials and web-based resources may have been successful in targeting students' specific difficulties and misconceptions in certain areas. It is also evident that students who undertook the intervention programme performed better in their written examination for the accompanying chemistry module. Web resources were accessed by students frequently throughout the course of the 10 week programme proving that this additional teaching and learning support was of benefit to students. While these positive results are encouraging, this Intervention Programme was optional and so poor and inconsistent attendance does affect the results. Many of the students who participated in the intervention programme could not be assessed as they did not complete both the pre- and post-diagnostic tests. The improvements noticed may also be due to the self-selected nature of the sample. The more motivated students may have availed of the intervention programme rather than the weakest students.

FUTURE PLANS:

This expanded version of the Intervention Programme intends to run over two semesters. In September 2010 phase two of the programme will begin. For this phase, it is intended that student workbooks will be developed which will be used during the tutorials. An interactive classroom response system using clickers will be used leading to more formative assessment taking place. Also more ICT based tools will be made available to students which will enhance the teaching and learning experiences of the students.As well as this, research will be carried out in the area of student motivation. If students' motivation can be increased; the problem of poor and inconsistent attendance may be improved. A NAIRTL grant has been received for the development of resources for this expanded intervention project.

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Friday Afternoon Session,
17^{th} September 2010

The Fibonacci Project: Large scale dissemination of inquiry based science and mathematics education

Workshop Facilitators: Tina Jarvis, Cliona Murphy[2] and Colette Murphy[3]

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The Fibonacci Project is a development of two projects that were identified in the EU Rocard (2007) report as being particularly successful in improving practice in the teaching and learning of mathematics and science in schools across Europe. These projects were: ***Pollen & Seed Cities for Science:*** a science project that used a community approach to support European schools in raising standards in investigative science; ***SINUS-TRANSFER*** a mathematics and science project based in Germany, focused on disseminating good practice between schools.

The Fibonacci Project is an inquiry-based science and mathematics education programme, which aims to help develop an integrated strategy for scientific literacy and awareness for primary and post-primary schools across Europe. The main goals of the project are to bring about change in the way science and mathematics is being taught throughout Europe and to increase scientific literacy in younger generations. The Fibonacci consortium includes 25 members from 21 EU countries.

In the first part of this workshop an overview of the Fibonacci Project will be provided. This overview will be followed by three short presentations facilitated by partners from 3 of the 25 members of the consortium, representing an example of the developing collaborations within the Fibonacci Project.

The first workshop/ presentation entitled *Realistic links between science and one or more other subjects* will focus on creative cross-disciplinary investigative activities in science that were trialled in the City of Leicester over the past 3 years. Issues regarding: the advantages of employing cross-disciplinary approaches; the importance of planning; strategies of linking different subjects and; challenges of using cross- disciplinary approaches will be considered. Specific examples of cross-disciplinary approaches to science and literacy and science and mathematics will be presented.

Educational research literature indicates that when explicit approaches to teaching about Nature of Science are employed while implementing science curricula, teachers are: more confident and enthusiastic about teaching science; employ more hands- on inquiry-based approaches and; afford their pupils more opportunities for discussion and reflection in science class (Murphy, Murphy and Kilfeather, 2010: Murphy, 2008; Murphy, Kilfeather and Murphy, 2007; Mc Comas et al, 1998; Driver et al 1996).

Furthermore, it would appear that pupils who engage with activities that relate to different aspects of NoS reveal more interest in school science. (Murphy et al, 2010). The second workshop in this series, *The Teaching about Nature of Science*, will provide participants with the opportunity to engage with generic and scientific activities that address different aspects of NoS, including scientific inquiry and science as a human activity. Exemplars from classroom practice in the recent Building Expertise in Science Teaching (BEST) Project, funded by the National Academy for Research in Teaching and Learning (NAIRTL) will be provided.

The final workshop, *Creative ways of teaching science investigation*, will include innovative approaches to inquiry-based science which have emerged from recent school development projects (NAPSTA-New Approaches to Primary Science Teaching and Assessment, BASICS-Books And Stories in Children's Science, and DREAMS- Digitally Resources Engaging And Motivating Science) funded by the AstraZeneca Science Teaching Trust. Ideas for creative and curious science provide opportunities for nursery, primary and secondary teachers to link science with Numeracy, Literacy and ICT using creative, novel and exciting science teaching approaches based on stories, role-play, thinking time, minds-on science, drama and digital technology.

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Constructing Knowledge and Skills in the Physics Laboratory

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CHANGING PHYSICS LABS

This workshop aims to give the participant a flavour of major structural changes we have made to our first year undergraduate physics labs. However, as the labs commence at upper secondary school level, the workshop should be of interest to teachers science teachers, too. The main reason for change was simply this: most students did not have a useful learning experience, nor did they enjoy the labs.

STUDENT PROFILE

The student cohort we are dealing with have chosen to study a science other than physics, and take 3 hours of algebra-based physics lectures, a one-hour tutorial taken by 30 students at a time in which typical end-of-chapter-problems are solved, and a 2.5 hour lab session taken by 70 students at a time. A survey among nearly 400 students, spread over three years, revealed that roughly 70% of students taking the labs have studied physics only as part of a general Science subject at lower secondary level (called "Junior Certificate Science" in Ireland, typical student age 12 to 15. Only 25% would have studied physics in a two-year higher secondary level program, with the remaining 5% having different or unknown educational backgrounds. From these data one likely source of student dissatisfaction emerged: the starting level of the labs should be more or less that of the starting level of an upper secondary physics course, whereas a lot of physics knowledge was assumed within the older labs.

AIMS AND OBJECTIVES

In the new set-up, we help build students build up a "tool kit" of experimental skills and tackle conceptual problems in the course of seven experiments, after which they are ready to carry our quasi-independent investigations in the last two weeks. Starting from quite tightly guided inquiry based labs with little procedural autonomy, students are given less and less guidance as their skills base grows until they are able to carry out simple investigations with equipment they are familiar with. The labs are set up as an exploration environment, in which students continually make and test hypotheses. In doing so, we challenge their preconceptions, while they simultaneously develop different measurement and evaluation skills and means of representing their data. None of the labs are designed to verify a known formula. We avoided the use complicated pieces of equipment, as students need to understand what equipment they use. Pivotal in our approach is that we wished for our students to:

1. engage with physics laboratories and enjoy them;
2. develop general scientific skills such as hypothesis testing, control of variables, graphing and graph interpretation, tabulation, drawing conclusions and extracting mathematical relationships from observed data;
3. clarify conceptual difficulties based on their observations in the laboratory;
4. be able to carry out quasi-independent investigations.

STUDENT ATTITUDES TOWARDS LABS

When probing students' attitudes to labs at structured interviews, it came as no surprise that their views are strongly coloured by the structures they have encountered. While the students we interviewed generally agreed that labs were useful in some way or form, the advantages many of them gave were that doing the labs helped them memorise the theory. In the students' eyes, the quality of their experiment is strongly correlated with the closeness of their result to the pre-determined value, and not to the skills they picked up along the way. They are used to experiments "not working" and teachers showing the experiment and its expected outcomes beforehand.

IMPLEMENTATION

By contrast, the first seven labs serve, in part, to build up a skills base. We have split the skills into two categories: manipulative and representation skills on the one hand, and reasoning and investigative skills on the other. The former include graphing, tabulation, scientific notation, unit conversion, report writing; the latter consist of interpretation of graphs, control of variables, qualitative hypothesis testing, drawing inferences from data and establishing physical and mathematical relationships from experimental data, and metacognitive skills.

At the same time, almost all of the labs are based on the development of one concept as an experiment is carried out. Higher order comprehension questions were set to give students the opportunities to show understanding and also to give students some time to exercise some independent thinking outside the bounds of the followed procedures. The conceptual development was verified using a pretest/post-test method.

The new set-up of the labs required an almost complete change of equipment. We avoided the use any black boxes, to the extent that students would explore the principles behind even such a simple device as a commercial spring balance (newtonmeter) before they could use it.

THE WORKSHOP

In this workshop, we will give a brief overview of the ideas behind the new labs, but the main focus is on participants carrying out excerpted laboratory exercises.

Promoting Equity through Problem Solving: Results from Two Decades of Mathematics Instructional Reform in the United States

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On sabbatical leave from the Department of Curriculum and Instruction, University of Illinois at Urbana-Champaign

Over the past two decades, reformers in the United States have promoted new standards for mathematics instruction that involve more problem solving, classroom discourse, and conceptual understanding. There are substantial similarities between the goals of the U.S. reforms and Project Maths in Ireland. After two decades, the U.S. reforms appear to enhance overall achievement, but controversies about the reforms persist, and their impact on equity is less clear. Despite the need for more meaningful instruction for marginalized students, research has revealed some ways in which problem-centered instruction might pose unintended barriers for these students. This presentation highlights research on U.S. student achievement, instruction, and equity over the past two decades of reform, and will highlight ways in which educational leaders can enhance mathematics instruction and equity while avoiding potential pitfalls.

INTRODUCTION

The past two decades have been a time of exciting and contentious mathematics education reform in the United States. Although I am new to studying Irish education, it seems that this is also an exciting time of mathematics education reforms here in Ireland, with the rolling out of Project Maths.

I am here in Ireland as a Fulbright Scholar, and I came, in part, to study the mathematics education reforms here. I am struck by the similarities in the goals of recent reforms in the U.S. and Project Maths in Ireland. Yet, the social and political context is substantially different, and I am curious how things might play out similarly or differently.

Despite the importance of every subject—including science—in educating well-rounded individuals, mathematics education—at least in the United States—tends to be a gatekeeper for high-status careers (Campbell, 1989). Hence, mathematics is particularly important for traditionally disadvantaged students, as mathematics can provide a ladder of upward socio-economic mobility. However, students from low-income and ethnic minority families in the United States have been more likely to receive less meaningful, memorization-oriented mathematics instruction than higher-income students (Anyon, 1981). The National Council of Teachers of Mathematics (NCTM, 2000) in the U.S. recognized this disparity in the late 1980s and for the past 20 years has been striving to reform instruction so that all students can learn mathematics in more meaningful, engaging ways.

In this paper, I briefly take stock of the NCTM reforms in the U.S. and the ways they are similar to Project Maths in Ireland. I then discuss trends in achievement since the start of the NCTM reforms and discuss why, despite positive results, criticisms continue to plague reformers' efforts. Given U.S. reformers' emphasis on enhancing equity, I then consider the impact of such reforms on traditionally under-served groups, and ways to increase equitable outcomes.

GOALS OF THE NCTM REFORMS IN THE UNITED STATES

Beginning in 1989 and continuing into the past decade, NCTM has promoted new standards for mathematics instruction that involve less memorization and practice of procedures and more student inquiry and sense-making. Through its various standards documents (NCTM, 1989; 1991; 2000), NCTM has called for more engaging, meaningful mathematics instruction, which includes more "real-world" problem solving, more mathematics discussion in classrooms, and more balance among five mathematics strands: number/operations, statistics/probability, measurement, geometry, and algebra/functions. One important distinction NCTM makes is the use of problem solving as a means of teaching and learning mathematics, as opposed to an end in itself (Lubienski, 1999). That is, instead of a traditional textbook lesson that begins with examples and then asks students to solve similar problems using a given procedure, NCTM envisions lessons centered around carefully crafted problems that are designed so that students grapple with key mathematical ideas as they solve them. Ideally, a skillful teacher guides the students as they work on the problems and facilitates discussion that helps students recognize and connect the key, intended ideas.

NCTM REFORMS IN COMPARISON TO PROJECT MATHS

Much of the above description of the NCTM reforms might sound familiar to those who know about Project Maths here in Ireland. Both NCTM and Project Maths share similar mathematical and instructional goals— increasing emphasis on problem solving, student sense making, and a balanced emphasis across various strands of mathematics, which include number, geometry, probability/statistics, algebra and functions (National Council of Curriculum and Assessment, 2005; NCTM, 2000). Even the rationale for the reforms have key similarities. That is, in both Ireland and the U.S. there have been concerns about international test score rankings and the need for mathematically literate workers, and these concerns have been used as a way to fuel the fire for reform among policy makers and the public.

However, despite these many similarities, there are intriguing differences in the Irish and U.S. approaches to improve mathematics education. The most striking difference is that there appears to be a more coherent structure and support for Project Maths at the federal level, with Ireland's National Council of Curriculum and Assessment being part of the Irish government's education infrastructure. In contrast, NCTM as an organization of teachers has no power to implement their standards, no federal funding for teacher professional development or curriculum reform—in short, no governmental or legal authority whatsoever.

The leaders of NCTM are primarily U.S. mathematics teacher leaders and teacher educators. In the 1980s they came to remarkable agreement on both the shortcomings of traditional instruction and an alternative vision for mathematics teaching and learning. Subsequently, they published their *Standards* documents and promoted them at conferences and other modest means available to them (NCTM, 1989; 1991; 2000). Despite the lack of NCTM's authority, the *Standards* have made a widespread impact that has trickled throughout various parts of the elementary and secondary education system. For example, the NCTM Standards have influenced the school curricular standards of most of the 50 states, prompted new curriculum development efforts, and shaped many standardized tests used throughout the U.S.

However, NCTM's efforts were not without critics, and there have been other conflicting reform efforts. This is not surprising, as education reform in the fifty states tends to be a hodge podge of efforts, with various city, state and national bodies working to reform schooling in one way or another. The most influential reform to co-exist with NCTM's efforts was George W. Bush's No Child Left Behind Act of 2001, emphasizing testing and accountability. If the tests used to measure progress for No Child Left Behind were well-aligned with NCTM's efforts, one might view these two reforms as compatible. However, each of the 50 states has been allowed to choose its own test to measure progress, and there is great variation in the form and content of the mathematics tests used.

As one who has studied public and private school differences in U.S. education (Lubienski & Lubienski, 2006; Lubienski, Lubienski & Crane, 2008), it is intriguing to me that although religion is intertwined with Irish public schooling in a way that it is not in the U.S., the resulting system in Ireland appears more—not less—unified. The NCTM mathematics reform movement stands in great contrast to the situation that exists—at least on paper— here in Ireland, where there is a government-affiliated body making a coherent plan for developing and implementing Project Maths, with alignment of curricula, assessments, and teacher professional development.

It is too soon to tell whether Project Maths will be implemented throughout Ireland as intended. Studies of math reform in the U.S. indicate that it is easier for teachers to make "surface changes" in instruction, such as the use of new manipulatives, than it is to make fundamental shifts toward student sense-making in the classroom (Ball, 1990; Cohen, 1990). But it is possible for deep instructional changes to occur, and there is evidence to suggest that teacher professional development is most effective when it focuses on increasing teachers' understanding of students' thinking about mathematics, and connects with the curriculum and assessments that teachers actually use (Cohen & Hill, 2001; Hill, Rowan & Ball, 2005). So it will be interesting to see what develops here in Ireland over the next few years.

U.S. REFORMS: THE IMPACT AND CONTINUING CONTROVERSIES

Given the similarities in the aims of the NCTM reforms and Project Maths, it is worth taking stock of the effects of the NCTM reforms in the U.S. over the past two decades. Clearly, how one judges the reforms' impact depends upon which measures are used. Still, evidence from schools that have used new, reform-oriented curricula has generally been encouraging, with students outscoring control groups on a variety of measures and in a variety of contexts (e.g., Riordan & Noyce, 2001; Schoenfeld, 2002; Senk & Thompson, 2003). The gains tend to appear particularly impressive when examined over multiple years, as students who understand the mathematics they are taught tend to retain more of it over the summer (Senk & Thompson, 2003). Scores on the National Assessment of Educational Progress (NAEP), which became aligned with the NCTM Standards in 1990, have shown fairly steady progress in mathematics since that time. It is particularly noteworthy that scores in mathematics have increased substantially since 1990 for every group—rich, poor, black, white, male, female (National Center for Education Statistics, 2009). It is also noteworthy that scores have not increased in reading, which is the other subject in which there has been much national attention.

However, there has continued to be heated debate about mathematics instruction throughout the past two decades. Some critics of reform have pointed to the fact that scores on NAEP's Long-Term-Trend (LTT) mathematics test remained flat during the 1990s, after a period of growth in previous decades (Loveless & Diperna, 2000). However, this special form of NAEP has consisted of the same set of questions since

1973. Given its traditional nature, many reformers consider it good news that the LTT results have remained stable, as other, more conceptually-focused mathematical goals have been achieved, as measured by the Main NAEP.

Other criticism has come from those who interpret the NCTM Standards as suggesting that teachers should sit back and relax while children play with mathematical "toys" and rely on calculators. That is clearly not the intent of the Standards, but it only takes a few instances of poorly implemented reform-oriented lessons in order to fuel parents' fears. Some criticism also stems from the U.S. public's perception that mathematics IS computation, and so any use of calculators in the classroom means that children are no longer learning math.

Part of NCTM's political problem began with its initial version of curriculum standards in 1989, in which they included a list of topics that should receive increased and decreased attention. The list of topics to be deemphasized included dozens of topics, including long division and the use of factoring to solve equations (NCTM, 1989). The most recent version of the NCTM Standards (NCTM, 2000) contains no such list because readers tended to interpret "decreased attention" as "eliminate," thereby fueling critics' fires.

Hence, despite the fact that the vast majority of mathematics education scholars and leaders have been strong supporters of the reforms, they have consistently had difficulty influencing the opinion of a public with deep-seated traditional views of mathematics teaching and learning. This is especially true at the secondary level, where parents want their children to learn mathematics in accordance with the wishes of university mathematicians, and the support among that group has been mixed at best. There have been extreme anti-reform groups that have fanned the flame of resistance among mathematicians and parents (e.g., see mathematicallycorrect.com for one primary example of such a group). The fact that the in-depth problem solving promoted by NCTM is actually closer to genuine mathematical activity than rote practice of rules has tended to be overlooked, amid cries that rigorous mathematics has been "watered down" in order to make it more engaging and accessible.

Indeed, if one's goal is to prepare the next generation of mathematicians, then abstract symbol manipulation is arguably more important than if one's goal is to prepare everyday citizens to make good shopping, voting, and health-related decisions. Hence, U.S. reformers have had dilemmas over the years, particularly given their slogan of mathematical power for *all* students.

U.S. REFORMS AND EQUITY

Have the U.S. reforms helped promote equity? The answer to this question is unclear. Some have argued that an increase in scores for all groups means that greater equity is achieved (Franco, Sztajn & Ortigão, 2007). However, I would argue that although general improvement in scores is impressive, we must pay attention to the disparities in outcomes between various groups in order to judge whether equity is being achieved.

Before drawing conclusions about the reforms' impact, it is important to note that reforms are probably not implemented equitably across student groups. In the U.S. each city's school district can choose which curriculum to use, out of the dozens available on the market. There is evidence that traditionally marginalized students continue to receive more rote-oriented instruction, as has been the history in the U.S. For example, Low-SES and ethnic/racial minority students in the U.S. remain substantially more likely than their more advantaged peers to agree with the statement, "Learning mathematics is mostly memorizing facts." This traditional view of mathematics is strongly negatively correlated with achievement, even after controlling for SES and race (Lubienski, 2006).

In terms of NAEP scores, immense SES- and race-related achievement disparities persist in the U.S. and have not consistently shown improvement over the past two decades (Lubienski & Crockett, 2007). Some of these gaps are roughly one standard deviation in size, which in statistical terms is considered a very large effect. However, again, not all students are actually receiving reform-oriented instruction in equal doses, so implications of these trends are unclear.

Although my primary focus in this paper is SES and race/ethnicity, it is worth noting that reform-oriented mathematics instruction does not seem to have narrowed the small gender gaps that persist in the U.S. Males continue to outscore females in mathematics by a small margin (.1 standard deviations) in both elementary and secondary school. (McGraw, Lubienski, & Strutchens, 2006; Robinson & Lubienski, in press). NAEP score differences are, of course, only one glimpse of inequities in educational outcomes; if one considers disparities in later wages, for example, the gender gap appears much worse.

Still, in the past decade, there has been some closure of race- and SES-related gaps, but the greatest point of closure seems to coincide with the launching of the George W. Bush's No Child Left Behind (NCLB) Act of 2001. This federal law essentially demands that each school have more and more students pass a test each year or else be closed down. Despite the many downsides to the NCLB Act, one of the requirements that might enhance equity is the requirement that schools publicly report their results by student subgroup, thereby revealing each school's disparities by race/ethnicity and SES. Although the Act seemed long on ideals and short on support for schools to meet these goals, NAEP trend data reveal significant gap closures immediately after the act went into effect (National Center of Education Statistics, 2009). However, although NCLB pertains to both mathematics and reading, this gap closure occurred only in mathematics. Additionally, when talking with teachers in the trenches, one wonders whether gains produced from NCLB are, in fact, real advances in mathematics learning, or if teachers are simply teaching test-taking skills to students. Moreover, a recent study revealed that, amid presures to improve scores, over half of teachers surveyed admitted to some form of "cheating" when administering the test (e.g., providing hints to students or allowing extra time) (Amrein-Beardsley, Berliner, & Rideau, 2010).

Hence, in terms of large-scale, national data, it is not clear whether the NCTM reforms have helped promote equity. It might seem surprising that equity would not be achieved by instructional methods and curricula that are designed with the goal of better reaching all students. In order to understand some potential pitfalls in the implementation of NCTM-oriented instruction, I turn now to some earlier, qualitative research I conducted with low- and high-SES students. I also make connections to related studies conducted in the U.S., England, and elsewhere. This research suggests some reasons why teachers and their students might struggle when implementing reform-oriented instruction in low-SES contexts. By discussing these potential challenges, I hope to increase the chances that such challenges can be overcome.

One Study of Low- And High-SES Students' Experiences With Reform

At the start of the U.S. reform movement in the early 1990s, I was a graduate student helping develop an NCTM-aligned mathematics curriculum, entitled the Connected Mathematics Project (Lappan, Fey, Fitzgerald, Friel, & Phillips, 2006). I piloted draft versions of this curriculum with low- and high- SES 6th and 7th graders (students aged 11-13) over the course of two years (Lubienski, 2000a; 2000b). This curriculum was centered around a "launch, explore, summarize" lesson model, where a teacher would launch a problem with the class, guide students while they explore the problem, and then lead a summarizing discussion.

When teaching with this curriculum, I found that not all students shared my enthusiasm for it, and some reactions fell along class. The low-SES students seemed the most resistant to learning mathematics through problem solving and discussion. Higher-SES students possessed the confidence to make sense of the mathematics for themselves, as intended; in contrast, more lower-SES students—especially females—seemed uncomfortable with the ambiguity and would tend to ask the teacher to just "explain how to do it." While most higher-SES students said they enjoyed class discussions about conflicting mathematical ideas, more lower-SES students said they did not find discussions helpful because they were unsure which ideas were right or wrong.

Additionally, whereas the high-SES students usually noticed that the curriculum revisited the same mathematical ideas in various story contexts, the low-SES students would often become engaged with the real-world aspects of the problems, missing the mathematical point intended by the curriculum's authors. For example, one problem asked which of three movie popcorn containers was the "best buy," given their particular dimensions and prices. One bright, working-class student named Rose had no trouble finding the volumes of the various containers, which were shaped as a cone, a cylinder, and a rectangular prism. However, while answering the question about which was the best buy, she concluded that "It depends on how much popcorn you want." Although Rose's approach was actually more sensible in the context of the problem than the unit-price approach, she missed the intended experience of comparing ratios.

As another example, in a fractions problem that involved sharing a pizza, lower-SES students considered many real world factors, such as whether each student would arrive at the pizza parlor on time and whether some students might be hungrier than others. In general, the lower-SES students in this study were more likely to use common-sense reasoning in mathematics class. Although their approaches were often very sensible in terms of real-world constraints, these students were at a disadvantage when they missed the mathematical point of the problems. (Lubienski, 2000b)

Other Studies on Social Class and Approaches to Learning

A similar pattern was noted in England, where researchers found that low-SES students tend to take the contexts of national exam questions more seriously than the test makers intended (Cooper & Dunne, 2000). Though such generalizations about low-SES students run the risk of being wrongly interpreted as negatively stereotyping or "blaming" students (and their families) for their struggles in school, two issues are worth further exploration.

First, upper-class students might arrive at school with more of an orientation toward decontextualized meanings, which could ultimately make it easier for them abstract mathematical principles while exploring contextualized problems. Bernstein (1975) and Holland (1981) argued that lower-SES families have fewer opportunities to venture beyond local environments, and tend to have more context-dependent orientations to meaning. For example, Holland (1981) found that middle-class children tended to categorize pictures in terms of trans-situational properties (e.g., grouping foods together that were made from milk or came from the sea), whereas working-class children tended to categorize pictures in terms of more personalized, context-dependent meanings (e.g., grouping foods that are eaten at Grandma's house). Both Bernstein and Holland concluded, not that children could not think differently, but that they had been raised with a particular orientation.

Second, higher-SES students might be more confident in their problem solving abilities and more comfortable with less structured and directive forms of teaching. For example, scholars have noted that working-class jobs tend to require conformity to externally imposed routines, while middle-class occupations allow for more autonomy and intellectual work. Similarly, studies on child rearing have found that working-class parents tend to be more overtly directive with their children, often showing or telling the children how to do things. In contrast, middle-class parents use more questioning and playfulness, guiding their children's problem solving through questions that focus attention on the general principles underlying problems (Heath, 1983).

Clearly, these distinctions do not hold true for every family or society. Since most of the research discussed above was conducted in the U.S. and England, the extent to which such patterns may hold in Ireland and elsewhere is an open question. Still, the evidence suggests that particular instructional methods can be more or less comfortable for students from different social classes. The conclusion from this research is not that children should necessarily receive instruction that matches their home environment. Indeed, one could argue that low-SES students are *most* in need of mathematics instruction that emphasizes questioning and problem solving. In fact, some research suggests that reform-oriented instruction can be particularly beneficial for lower-SES students, particularly when teachers carefully help students engage in problem-centered learning (Boaler, 2002).

My research and that of others suggests that mathematics teachers and reformers must pay attention to children's orientations toward learning, particularly when changing the culture of the mathematics classroom for traditionally under-served students. We also need to pay attention to whether reforms, even those that appear to be beneficial, might actually increase the gap between low- and high-SES students, as was found in a large-scale study of reform-oriented teaching in Brazil (Franco, Sztajn & Ortigão, 2007).

WAYS TO PROMOTE EQUITY AMID MATHEMATICS EDUCATION REFORM

Implications of the research surveyed above are not uniform across various countries and contexts. However, the following points may be helpful as educators in various locations strive to more effectively teach mathematics to their low-SES students.

Help Students Understand Rich Mathematics Problems and Discussions

One of the main features of reform-oriented curricula in the U.S. is their problem-centered structure. The research reviewed above suggests that teachers need to take extra care to ensure that their students—especially low-SES students—learn what is intended from such problems. This care can involve a series of written focusing questions to guide students' attention during problem solving, the teacher explicitly highlighting and recording key, mathematical ideas as they arise in discussion, and journal prompts requiring students to record key definitions and formulae at the end of a lesson (e.g., see Lubienski & Stilwell, 2003).

Some students might resist learning through problem solving and discussion, preferring to apply rules given by the teacher or text. Teachers might need to wean students away from their dependence on explicit instructions and to clearly explain the students' role in a problem-centered classroom. Yet giving students the ability to make sense of mathematical ideas for themselves and to apply mathematics to important problems is a goal worth striving for—one that has been restricted to high-SES students for too long, at least in the U.S. context.

Protect Low-SES Students' Interests

The sayings, "the rich get richer and the poor get poorer" and "those who have, gets" are commonly used when describing unintended consequences of education reform in the U.S. That is, the children with the most advantages tend to disproportionately benefit from education reform, particularly when such reforms are targeted toward "all students." In the United States, part of this phenomenon is due to the fact that high-SES parents look out for the interests of their own children, making sure that they have access to the best schools, teachers and courses (McGrath & Kuriloff, 1999). According to Lareau (1987), low-SES parents are less likely than high-SES parents to know the unwritten rules of schools, including ways in which parents can lobby for their children's interests. In a study of the ways in which secondary school students and their parents chose between a reform-oriented and more traditional mathematics course sequence in high school (Lubienski, 2004), I found that low-SES parents were less likely to talk to a teacher about the course options, but were more likely than middle-class parents to base their decisions on teachers' advice. Hence, one conclusion is that teachers' time is well-spent when talking with lower-SES parents.

Although the specifics vary by cultural context, the fact that many low-SES parents have felt unsuccessful in school means that educators need to work at nurturing relationships with these parents. In order to promote equity during times of instructional reform, schools should be sure to advise low-SES students and their parents about the written and unwritten rules of schooling, including the ways in which early mathematics and other course placements can affect their children's future career options.

Monitor Outcomes to Ensure Equitable Benefits From Reforms

One pattern evident in NAEP data is that low-SES and minority students in the U.S. continue to perform worse on non-routine problems (Lubienski & Crockett, 2007). For example, the vast majority of 4th- and 8th-grade students from all race and class groups correctly answered basic computation problems, such as 238 + 462 = __. In contrast, there were large race and class-related disparities on computation problems with extraneous information or multiple steps. This pattern of achievement suggests that low-SES students may, at best, be receiving a watered-down version of reform-oriented instruction, given that one major goal of NCTM is for students to be able to reason through non-routine problems.

If we are truly committed to equal outcomes, it will take more than a blanket reform approach providing the same instructional resources for all students – some students will need more focused attention to level the educational playing field. In virtually all countries, there are political and social factors perpetuating class- and race-based inequities, and many of these lie well beyond the control of schools. However, education can be a key to dismantling the cycle of poverty, and there are steps that educators can and should take to increase low-SES students' learning and retention in schools. My hope is that this paper highlights some ways in which mathematics education reformers and educators can enhance mathematics instruction and equity while avoiding dangerous pitfalls during reform implementation.

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