ESTABLISH | SMEC 2012

Teaching at the heart of learning

Dublin City University, Ireland
7th – 9th June 2012

Hosted by the
Centre for the Advancement of Science and Mathematics Teaching and Learning

WELCOME ADDRESS

We, the organising committee of SMEC 2012 and ESTABLISH, would like to welcome you to Dublin City University for this joint conference entitled *Teaching at the heart of learning*.

SMEC 2012 is the fifth in a series of biennial international Science and Mathematics Education Conferences to be hosted by CASTeL – the Centre for the Advancement of Science and Mathematics Teaching and Learning. The purpose of this conference series is to provide an international platform for teachers and educators to discuss practices and share their experiences in the teaching and learning of mathematics and science. Previous conferences have focused on themes such as Inquiry-based learning: Facilitating authentic learning experiences in science and mathematics; Sciences serving science; and explored the interconnections between teaching and learning of mathematics and science.

ESTABLISH is a four-year European project focused on the dissemination and use of inquiry teaching methods for science with second level students (age 12-18 years) by creating authentic learning environments and involving the stakeholders in driving change in the classroom.

ACKNOWLEDGMENTS

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THE MANY REASONS WE TEACH SCIENCE AND WHAT EVERYONE SHOULD KNOW ABOUT HOW IT WORKS[†]

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There is little argument that a rich introduction to science is a worthy element of the educational experience for all students. Indeed, starting in the late nineteen century, the school curriculum has featured increasing numbers of science classes for K-12 learners with specialized classes including electives and advanced placement experiences for those with the highest levels of interest and ability. Of course, this expansion of the science curriculum is very good news but comes with a striking warning.

Much of the focus in science classes from the preK years through college does little to reveal to students how science functions. The vast majority of science learning goals feature traditional science content. The end result of scientific investigations is augmented by the learning of scattered science process skills, the tools of research scientists. The content that is generally missing from science instruction relates to a discussion of the ways and means by which knowledge is generated and validated, a domain commonly called the “nature of science” or NOS. Even though state science standards have an increasing number of targets related to NOS, few science classes and even fewer textbooks include much focus on what should be one of the most important instructional goals, the nature of the discipline itself. Without such a background, it is impossible for students to effectively contribute as a critic, connoisseur or creator of science—the three major ways in which any student might make use of his or her science knowledge.

First, let us consider “creator” as a rationale for the study of science as a career goal. This is certainly the most common reason provided for why we have our students study science in school. Students and teachers alike accept that one of the major reasons for studying science is that much of the knowledge transmitted may someday relate to an occupation in a science related field. In other words, students may, in the future become creators of new scientific knowledge themselves in research or engineering or at least, may use such knowledge in an allied science field such as medicine or technology. Unfortunately, if students make the decision that they will not pursue a career in the sciences they may too quickly conclude that there is no reason at all for them to worry about science learning. This faulty conclusion gives rise to another reason for the study of science, that of the connoisseur.

Connoisseurship is related to an avocational focus in a subject. I often ask my graduate students in science education to go to a bookstore with a large magazine section and examine the number of periodicals that focus on science-related subjects. The number of such works is surprising as are the number of handbooks on bird and plant identification and trade books on various elements of science for non-professionals. This exercise can be repeated at home by looking at the number of science themed television shows on air

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[†] Previously published as: W.F. McComas. (2010). Educating Science Critics, Connoisseurs and Creators: What Gifted Students Must Know about How Science Functions. *Gifted Education Communicator,* Fall 2010.

and the science museums and nature centres that attract countless individuals annually. It turns out that science is intrinsically interesting to many people, well beyond the population of those who use science in their daily jobs. Those who have some non-professional interest in science, its products and processes, are connoisseurs. How sad it would be if school science did not adequately prepare or whet the interest of such future science connoisseurs.

Finally, we come to the critic as a rationale for the teaching of science. Every school subject should enable students to carefully analyze and make judgments about that discipline. This is particularly true in science where our current students will be the consumers and voters of tomorrow. Almost daily one can see an advertisement for a product that makes scientific-sounding claims for its effectiveness or a news report of some health-related finding based on research and testing. We want our students to be able to critique such claims and render conclusions based on their knowledge of what counts as science and what is in reality pseudoscience or worse. There are aisles in any pharmacy featuring products that would likely not be for sale if only consumers could recognize the faulty claims for effectiveness made in their advertisements.

Consider, too, the issue of citizenship more broadly. Most everyone will be asked to vote on issues that have scientific foundations. We will all be asked to evaluate candidates' claims and positions on science-related issues. Many of us may sit on juries where verdicts can only be rendered accurately by those who understand science, its methods, and its limitations. Students of all abilities may assume the roles of creator, critic and/or connoisseur of science as they take on their adult responsibilities, but gifted students are among the most likely to recognize and seize the opportunities that these roles offer.

No matter which role a student finds personally rewarding, each will require that the student gain an enhanced understanding of the nature of the discipline. Therefore, it is logical to consider what we should be teaching regarding that nature. Fortunately, science educators have been thinking about this issue for many years and are now converging on a proposed list of "nature of science" topics that should be included throughout the science curriculum. Such a list of NOS content will be considered next by focusing on nine NOS elements organized into three clusters related to *science as a process, science as a human activity*, and *the questions addressed by science*. The proposed elements within these three clusters are not definitive; there may be other NOS topics worthy of inclusion in the curriculum, but the conclusion among science educators is that topics such as these must be featured in science instruction if students are to understand how science works.

SCIENCE AS A PROCESS

Science relies on empirical evidence.

One hallmark of science is that no matter who is offering a conclusion—scientist or amateur— there must be evidence to back up the claim. Furthermore, that evidence must be "sharable," in that the fleeting glimpse of something interesting may be compelling but it can't be conclusive until others have had a chance to see it and evaluate it. The various sightings of "Bigfoot" come to mind here. There may be some huge secretive humanoid wandering about the remote reaches of the planet, but there is simply no conclusive evidence for such a creature. We may wish that Bigfoot exists but wishing does not make it true. Students must understand both the necessity for and nature of scientific evidence if they are to appreciate how scientific claims are made and evaluated.

There is no single step-wise scientific method.

A pervasive, but false, notion is that there is a six-step method by which work in science is conducted. Many teachers suggest that all scientists start their research endeavours by defining the problem, going to the library, formulating a hypothesis, designing an experiment, proposing a conclusion, and reporting results. This method does serve as a good model for how a problem may be tackled, but does not represent the way in which all science is done. Unfortunately, science educators who offered up such a research method in textbooks appearing in the mid-twentieth century are the source of this incorrect idea. Scientists themselves would be surprised to hear that they all share such a common mode of investigation and would be fascinated to learn that students believe that scientists all conduct classic experiments.

A review of the work of researchers such as Jane Goodall, who fifty years ago began her detailed observations of the chimpanzees in western Tanzania, clearly disproves the notion of a step-by-step experimental method. Goodall's science is just as rigorous—and just as empirical—as that of other scientists but without experiments. Of course scientists do share a number of tools that might be called methods including careful data collection and reasoning with both inductive and deductive means, but science cannot be reduced to any particular set of shared steps. In fact, the idiosyncratic ways in which scientists work result in a strong creative element in science that we will hear about in a subsequent section.

Laws and theories are distinct kinds of scientific knowledge.

Another particularly pernicious idea is the supposed continuum from hypothesis to theory to law with laws being the pinnacle of scientific knowledge. This notion is reflected in the unfortunate expression—usually directed at evolution—that it is *only* a theory. The clear implication is that something is worth believing when it is raised above theory status.

All of this is false despite the fact that this continuum is commonly taught in schools. This section could be book length in order to discuss all of the details it contains but perhaps if we stick with the definitions, this will make sense. Let us start with the definitions of law and theory before moving on to the problem with hypothesis. Laws are patterns or generalizations about something in nature and can be used to predict the appearance of another example of that pattern. *A theory is the explanation for why a law operates as it does*.

For instance, if an air-filled balloon is put in a hot place it will expand—that's the law. The kinetic molecular theory of matter suggests that air is composed of tiny particles that behave like billiard balls that become more active as temperature rises and push against each other causing expansion—that's the theory. Even scientists fail to use the terms "law" and "theory" in the most accurate and appropriate fashion so it is always best not to worry about the label given by science—law or theory— and look at what the idea does rather than what it is called. Laws generalize and theories explain.

To turn quickly to the idea of the hypothesis we find the term used mostly to represent a trial idea. Many teachers define it as an educated guess. That's fine, but an educated guess about what? A hypothesis that is designed to provide an explanation (i.e. a "baby" theory) might best be called an explanatory hypothesis. A hypothesis that is designed to suggest a pattern or relationship (i.e. a "baby" law) should be labelled a generalizing hypothesis. Adding to the confusion is the fact that many teachers use the term hypothesis when referring to a prediction. In these cases, it would be best just to use the label "prediction." There is so much potential confusion regarding the term hypothesis with its three distinct meanings that I have long wondered if we wouldn't be better off without it.

Laws, theories and hypotheses are related, but they are most certainly not the same. Laws and theories, once they are supported with evidence and accepted by the scientific community are equally valuable and important kinds of scientific knowledge. Therefore, waiting for a theory to become a law is a fool's game.

SCIENCE AS A HUMAN ACTIVITY

Science is a creative process.
In a study completed some years ago, researcher Sheila Tobias asked bright liberal art students why they did not want to take advanced physics; she was told that science was not very creative and the students were not particularly interested in learning only about what others had done. These students were correct about one thing: science instruction often does not show the creative side of science even through science itself most certainly is. In school science, we don't do a very good job sharing that reality and giving students first hand opportunities to see it. Science is a creative endeavour beginning with the selection of research problems and the highly individualistic methods applied to the solutions of those problems. Sometimes it may seem that science is more like art than science.

Science has a subjective component.
Like the creative component, subjectivity is a highly human characteristic. Different scientists—even when looking at the same data—may "see" and respond to different things because of their prior experiences and expectations. This may mean that some individual scientists may make a profound discovery because they "know" what they are looking for (and looking at) while others may miss an important discovery because they are not "ready" to see and appreciate what the data suggest. At the end of the process of discovery and publication, the community of scientists decides what counts as valid and reliable scientific knowledge.

There are historical, cultural, political, and social influences on science.
A final "human" element of science can also be one of the most contentious. Although anyone of any culture can do science, the rules of the game of science are international. To say this in a different way, no matter what is contributed to the domain of science, it will be evaluated using the same criteria. The needs and priorities of various groups and nations do dictate what is worthy of study (and funding) but science is science. One does not win a Nobel Prize (or even add something to textbooks and journals) in categories of nation or culture but on the quality of the research.

Because of this, a potentially problematic issue in school science is that the vast majority of scientists studied are whites of European descent. One means for addressing this issue is to acknowledge it head on by describing the history of science and the rules of the game while using as many diverse examples as possible. Ultimately, the way to address this situation is to ensure that all students have the skills necessary to make scientific contributions thus writing a new history of science to inspire future learners.

THE QUESTIONS ADDRESSED BY SCIENCE

Scientific knowledge is durable, self-correcting, but ultimately tentative.
The methods of science do ensure a high degree of validity and reliability in the conclusions offered at the end of a period of research. However, it is impossible to know that any particular law or theory will last for all time—particularly when new information

and evidence are discovered in the future. Some have suggested that this inherent limitation of science means that we should hold no special reverence for scientific conclusions resulting in an “anything goes” view of the natural world, but that would be counterproductive. The conclusions of science have been tested and debated and, where necessary, updated and modified. Still, science is one of the most secure ways to know about the patterns in nature and the explanations of those patterns.

Science cannot answer all questions.
A complete view of the nature of science includes the realization that the tools and methods of science cannot shed light on every question of human interest; there are limits to the questions that can be investigated using scientific means. Questions in morality, aesthetics, and faith fall outside the lens of science and are often the domain of philosophy and religion, two other institutions that mankind has looked to for guidance.

Of course, it is possible to determine what percentage of the population expresses a preference for a particular work of art or music, but it is unreasonable to expect that science could fully explain why such opinions exist. Likewise when humans want to know something of the afterlife, science cannot provide much guidance. Science, philosophy, and religion play vital, but distinct, roles in human affairs, and asking a question of the wrong authority has suggested that a war exists between these unique ways of knowing.

Science and technology impact each other but they are not the same.
In the minds of many, science and technology are synonyms but it would be more accurate to consider them two sides of the same coin. Science is the pursuit of pure knowledge while technology represents the ways to solve a particular problem. Of course, these two pursuits interact frequently, but they are not the same. In the quest to explore nature (otherwise characterized as science) technology is frequently applied. As work proceeds toward the development of some useful product (often characterized as technology) scientific principles are frequently applied. Most scientists apply technology and many technologists apply science as they engage in their work. Occasionally, individuals work almost exclusively in one domain or the other.

Consider the case of Einstein and Edison. Edison was clearly a technologist. His statement, “Anything that won’t sell, I don’t want to invent. Its sale is proof of utility, and utility is success,” is testament to the focus of his endeavours. In fact, had Edison applied scientific principles more regularly he might have invented the filament for the light bulb without having to go through one thousand trials of materials that were not useful in that regard. Contrasting Edison, we find Einstein who was not interested in products and, as a theoretical physicist, did few experiments (which might have made use of technology) to verify his predictions.

The distinction between science and technology is certainly not the most important in the nature of science but one that has interesting ramifications for research work in the modern world.

FINAL THOUGHTS

The nine elements of the nature of science discussed here should be the starting points for a more complete discussion of science in classrooms across the nation. It is not enough to tell students of the products and discoveries of science; we must assist students—particularly those of the highest abilities and interest—in achieving a complete understanding of the foundation of science itself. Science is a “game” that anyone can play but only if the shared rules are understood and followed. The nature of science, represented here by nine basic ideas, is a kind of handbook of those rules. When students appreciate the rules of science they will become better critics in evaluating the products of science, more passionate connoisseurs of science, and more effective creators as they apply science in the pursuit of new knowledge as practitioners of science.

"WHICH ENERGY SOURCE IS THE BEST?" - TEACHING RENEWABLE ENERGY

Martin Lindner, Louise Bindel, Stephan Domschke and Melanie Meinl

Biology and Geography Education, Martin-Luther-University,
Halle-Wittenberg, Germany.

THU 15.00 - 16.20

Along with the growing energy hunger around the world, the search for alternative energy sources is vital. Several sources have been developed into mass production in the last decade, like biogas, wind-power, solar energy or fuel cells.

The workshop for the students starts with the simple and purposely simplifying question "Which Energy Source is the Best?" This problem should involve students in finding questions, tasks and experiments to do research on it. The workshop presents various experiments useful to examine the science behind the energy sources, to step deeper into science methods and to combine experiment, measuring, calculating, argumentation and finally the evaluation on the results with respect to the problem. We suppose this is true IBSE teaching.

The material and the way of learning were tested in two summer camps. The results have been evaluated with scientific methods and will be presented together with the experiments. They show a good acceptance and a change of attitude towards science even for participants not familiar with science.

During the workshop you will learn nice and appropriate experiments dealing with energy sources. Some of them are new experimental kits and all of them are easy to do. Especially for science teachers not having their focus on Physics and Technical Education this might be a chance to familiarize with this approach.

POLYMERS AROUND US

Petr Šmejkal and Hana Čtrnáctová

Charles University Prague, Czech Republic.

This workshop will focus on investigating the properties of polymers, to understand their wide usage and their importance for contemporary life. This workshop will use inquiry-based approaches to identify the polymers in a variety of products and to probe the polymers structural properties. Participants will get to examine how such properties change following chemical reactions, such as solvent solubility and flame testing, while also being challenged with developing a strategy to manage the disposal of polymer waste. This workshop is particularly focused on chemistry techniques, and will take place in a laboratory setting.

REFERENCES

Establish project, available on <www.establish-fp7.eu>

INTEGRATION OF ICT IN IBSE

Ewa Kedzierska, Vincent Dorenbos, Ton Ellermeijer and Ron Vonk

Foundation CMA, The Netherlands.

The integration of ICT in Science Education has proved to be very effective to enable Inquiry-Based Education and also to make links to more professional and industrial activities.

Teachers and students are provided with powerful tools for data-acquisition with sensors and from videos (*e.g.* automatic point tracking and perspective correction), for analyzing data and for modeling (computational science). This helps them to perform more realistic research-kind of projects.

In the ESTABLISH project Teaching and Learning Units have been developed in which the ICT environment Coach for Science Education is applied.

In the workshop participants will be introduced to Coach and Establish applications, and will have hands-on experience.

APPROPRIATE SETTINGS AND SUPPORTS FOR THIRD-LEVEL DIAGNOSTIC TESTING IN MATHEMATICS

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Mathematical diagnostic tests are issued to first year students by many third level institutions, including Dublin City University and the National University of Ireland Maynooth. The aim of such tests is to provide staff and students with an immediate picture of which mathematical concepts are well-known to the student. The tests are also a mechanism through which students who are struggling are made immediately aware of a wide range of follow-up initiatives, which are provided by the respective Mathematics Learning Support Centres. A common questionnaire was issued to students in both institutions to ascertain their attitudes towards diagnostic testing. In this paper, we present an overview of the role of the diagnostic test in both institutions, look at the mathematical backgrounds of the students tested, and present their views on the purpose of the test and the environment in which they took it. We also investigate their views on the subsequent feedback they received and the supports available to them. Finally, we look at the changes that both institutions have made as a result of this questionnaire.

INTRODUCTION

The activities and entities collectively described as *mathematics support* now comprise a mature feature of the third level landscape both internationally and within Ireland (Gill et al., 2008, Perkin & Croft, 2004). The concept of providing additional support in mathematics to third level students has arisen in response to a well-established and evidence-based recognition of the mathematical under-preparedness of new undergraduates (Gill & O'Donoghue, 2007, OECD, 2003). In both Dublin City University (DCU) and the National University of Ireland Maynooth (NUIM), as is the case in many other institutions, mathematics support is coordinated by a dedicated unit: the Maths Learning Centre (MLC) in DCU (http://www4.dcu.ie/maths/mlc/index.shtml) and the Mathematics Support Centre (MSC) in NUIM (http://supportcentre.maths.nuim.ie/).

Many universities have adopted a policy of issuing diagnostic tests in mathematics to incoming first year students to identify (for both staff and students) the areas of main weakness. Considerable research is available on the provision of diagnostic tests, e.g. Ní Fhloinn (2009) and Gillard et al. (2010). This testing policy is a means to an end:

> Diagnostic testing should be seen as part of a two-stage process. Prompt and effective follow-up is essential to deal with both individual weaknesses and those of the whole cohort. (Savage *et al*, 2000; p. iii)

Thus in both DCU and NUIM, diagnostic testing is followed-up by the provision of extra support mechanisms delivered early in the academic year by the mathematics support centres. Students identified by the test as being at-risk of failing their mathematics courses are encouraged in different ways to avail of this additional support. In DCU students are advised to attend refresher sessions on basic mathematics during the first two weeks of semester and to make frequent use of the MLC during the year. In NUIM students are assigned to an online mathematics proficiency course and accompanying workshop. They are also encouraged to avail of the MSC as regularly as they can. The impact that these supports can have on students is well documented, *e.g.* Dowling and Nolan (2006), Pell and Croft (2008), Mac an Bhaird *et al* (2009) and Lee *et al* (2007).

Given the significant investment of time and resources in diagnostic testing and the associated follow-up activities, it is important to gauge the effectiveness of this approach. Key aspects of this effectiveness relate to students' attitudes to testing and follow-up. Thus with a view to building up an accurate picture of these attitudes, a common questionnaire was issued to first year DCU and NUIM students midway through the first semester in the academic year 2009-10. We report here on two aspects of students' attitudes, opinions and knowledge of the diagnostic testing and the follow-up supports. We consider the questionnaire responses relating to the following issues:

- What opinions do students have in relation to practical aspects of the implementation of the diagnostic test (timing, location, announcement of the test)?
- What views do students have on the additional supports provided following the diagnostic test?

These are important questions for staff involved in the provision of mathematics support. In this paper, we will describe the structure and delivery of the questionnaire and we provide a brief profile of the students who completed the questionnaire. We then present the results relating to the two research questions above, and give our conclusions about these results. Other aspects of the questionnaire responses will be reported on elsewhere, including the basics of student opinion on diagnostic testing – is it a good idea? – and student opinion on the overall feedback and related follow-up mechanisms (Ní Fhloinn *et al*, 2012).

METHODOLOGY

The questionnaire we report on was devised by members of the Irish Mathematics Learning Support Network committee (the first two authors and Dr Olivia Fitzmaurice (née Gill)). (See http://supportcentre.maths.nuim.ie/mathsnetwork/). The survey was anonymous, and comprised of 20 questions. The first seven questions relate to the profile of the student respondent and the remaining questions relate to opinion of diagnostic testing and follow-up.

The questionnaire was issued to first-year students in DCU and NUIM midway through the first semester of 2009/10. In DCU, the questionnaire was issued in paper-based form during mathematics lectures, resulting in 663 responses. In NUIM, the questionnaire was issued online via Moodle, resulting in 205 responses. Two paper-based questionnaires had already been issued in class to this first year cohort and it was not possible to get further class time to issue an additional questionnaire. The authors are aware of the restrictions of issuing an online questionnaire, and that the respondents may not be from a representative sample of the students who sat the diagnostic test. However, as we will see, the results from the online questionnaire are by and large very similar to the paper-based feedback, so we feel that their inclusion is valid. Where differences arose, they will be discussed.

RESULTS

Profiling questions

For completeness, we briefly review the first seven (profiling) questions on the questionnaire. These asked students to indicate their degree programme (Q1), mathematics module (Q2), gender (Q3), leaving certificate level (Q4) and result (Q5) in mathematics, the time at which they switched from Higher Level mathematics to Ordinary Level in Leaving Certificate (if they did so) (Q6) and whether or not they were a mature student (Q7).

Respondents from DCU came from a large variety of programmes in business, computing, education, engineering and science, studying one of five different mathematics modules. Respondents from NUIM were studying (at least) one of four different modules and came from two different programmes, mathematical studies in arts and finance, and mathematics for science. There were 867 respondents in total (414 female, 451 male; 2 did not indicate their gender). 53 respondents identified themselves as mature students. 363 students responded that they took higher level mathematics at Leaving Certificate, 469 took Ordinary Level, 20 students responded 'other' to this question and 13 students did not respond. Students who started Higher Level Mathematics for Leaving Certificate and changed to Ordinary Level were asked to indicate when they changed. 93 Stated before Christmas in fifth year, 54 before the end of fifth year, 99 before Christmas in sixth year and 76 after the mock exams in sixth year. We will not consider results or level selection further here.

Opinion questions

The remaining questions (8-20) focused on students' opinion of certain important aspects of the diagnostic test itself. In this section we report specifically on the questions which consider the test setting, the length and timing of the test, and the feedback and supports made available after the test.

We were interested in whether students thought that the venue played an important role in the test. Students were asked if they felt that the room where they took the test was suitable. In DCU, the diagnostic test takes place during an introductory session to the MLC in Orientation Week. Although students are allocated a specific time to attend based on their class-group, a significant portion attend at an alternative time if it suits them better. This has led to overcrowding issues in some sessions. As a result, 24% of respondents in DCU did not feel that the room was entirely suitable, with students citing the lack of space and the large number of students present as negative factors, *e.g.*

> No it was too small and people had to sit on the floor.

> No, too many people in there - I couldn't really concentrate on the test.

By comparison, only 12% of respondents in NUIM (where the test took place during one of their mathematics lectures in week one) were not fully happy with the room, citing similar issues to those raised in DCU. However, the majority of responses concerning the venue were positive, *e.g.*

> The atmosphere wasn't as serious because there were so many students and the room was so big. Which was a good thing.

Interestingly some comments, from both the positive and negative categories mentioned cheating, some saying that the venue made it easier to cheat (this was a negative comment), while others said it was harder to cheat (a positive comment). So, overall the venues used do not appear to have an unduly negative impact on students and indeed some students stated that the venue was not important.

General questions about the timing of the test and the length of time available were also asked. Students were asked if they felt that the timing of the test was suitable: 71% of the 713 responses were positive. Students in both institutions are not told in advance about the diagnostic test as we feel that this will give a much clearer picture of the material that is known or unknown to them. However, as the tests are not all conducted at the same time for different modules, it is inevitable that some level of information about the test will emerge in advance. Despite this, 75% of respondents said they did not know about the test beforehand; 20% found out about the test from other students and 5% from a staff member. Students were also asked if they were given sufficient time to complete the test: 90% of respondents felt that they were.

One of the main reasons that both institutions issue diagnostic tests is to make students aware of the various supports that are in place should they need them. Students who obtain below a certain predetermined mark in the test are deemed to be “at-risk” and are advised to avail of various support mechanisms. It is made clear to them that this advice is based on their performance in the diagnostic test. Students were asked if they had been advised to avail of additional supports based on their results and 30% of respondents said that they had. 17 of 381 students in DCU and 32 of 126 students in NUIM who said they were *not* advised to seek support said that they did avail of some. However, in DCU only 60 out of 165 respondents who were advised to attend said that they actually did so while in NUIM this figure was 43 out of the 58 respondents advised. (We note that overall 291 DCU students and 224 NUIM students were advised to avail of support; not all of these students completed the survey.) This is one of the most concerning outcomes of this survey, and highlights a very important issue: how do we promote and maintain high levels of engagement in students who have been identified as needing to avail of mathematics support? Our interpretation of the difference in the respondents’ reporting of their uptake is that it relates to the difference in the mode of delivery of the survey in the two institutions: paper-based in DCU and online in NUIM.

Students were also asked to comment on the supports available to them after the diagnostic test. There were 367 comments and the breakdown is contained in Table 1. Responses were categorized as positive, negative, mixed, information comment and don’t know. *Positive comments* comprise those indicating a positive opinion on supports available to students after the diagnostic test; *negative comments* express a negative opinion. Responses categorized as *mixed* including both positive and negative opinions. Some students interpreted the question as asking for factual details about available supports: these comments described some of the supports available but gave no additional opinion and are categorized as *information comments.* A number of students responded *don’t know* or equivalent to the question and are categorized thus. These open-ended responses were categorized using the general inductive approach of Thomas (2006).

Table 1: Responses to Q16: “Please comment on the support available to students after the diagnostic test.” See text for description of the categories.

Response Category	DCU	NUIM
Positive	141	109
Negative	6	5
Mixed	6	-
Information Comment	95	8
Don’t Know	16	1
Total	264	123

THU 15.00 - 16.20

The majority (68%) of the 387 comments were positive which is very encouraging for both institutions. Considering all the responses, only 17 were *don't knows*, so most students (who responded) are clearly aware of the supports available. However this perspective must be tempered by the fact that 480 students (out of 867) did not respond to the question. Among the positive comments we find:

> The support was huge after the test. people's confidence levels weren't high when we started our maths course, and even after the test. but as we all attended the maths support centre, and workshop, we could understand things a lot better and people are more able to work out the problems in their homework.

> There is excellent help available to students through the support offered by the MLC.

The negative comments mostly referred to problems with the room where follow-up support sessions were held (too small), issues with tutors (e.g. not enough), timing of supports being unsuitable, or, in the case of a single NUIM student, problems with access to the online course.

Given that the respective student groups completed a common questionnaire, there is a surprising disparity between the proportion of DCU and NUIM students who gave an *information comment* response to the question. The information comments from DCU students seem to come principally from students who were not categorized as being at-risk and did not avail of support.

CONCLUSIONS

The main aim of the parts of the questionnaire presented in this paper was to determine if the diagnostic tests issued in both institutions are delivered in an appropriate manner, and if students feel that the follow up is sufficient. The majority of the feedback is positive and constructive, and this is very encouraging. In general, most students appear happy with the location, timing and lengths of the tests. This is consistent with the feedback we present in Ní Fhloinn et al. (2012) which shows that the students are typically very positive about diagnostic testing, its purpose and the potential benefit for both staff and students. This complementary study also shows that students have a good level of knowledge of the purposes of diagnostic test.

The evidence here also confirms that the supports available in both institutions are well advertised and known to the students who responded. This would suggest that the issuing of a diagnostic test to identify areas of weakness and to promote the supports in place works. However, it is also clear that a significant number of students who were advised to avail of support do not do so. This is a well documented concern which is reported elsewhere, e.g. Mac an Bhaird et al. (2009) and Pell and Croft (2008). This raises the question of how institutions can increase the engagement levels of 'at-risk' students with non-compulsory supports that are in place and that we know can benefit them. This issue is captured very well by the following comment from a student:

> The supports are there, it is up to the student to avail of them. I feel at a disadvantage as it is so long since I sat the leaving cert, so maybe I push myself that little bit more.

One possible method is to introduce a monitoring scheme as described in Burke et al. (2012). This scheme was introduced in 2010-11 in NUIM, and students who were not showing appropriate levels of engagement were contacted and advised to change their behaviour. The engagement levels of the students contacted increased significantly.

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MATHEMATICAL MODELLING IN CHEMISTRY LESSONS

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In chemistry it is often necessary to apply mathematical terms, methods and scientific paradigms in order to explain chemical phenomena (Höner, 1996). Furthermore, a mathematical analysis of chemical processes can help to facilitate and deepen the understanding of the underlying chemistry (Harisch, 1979). That is why avoiding mathematical views in chemistry lessons might result in students having difficulties in developing an adequate understanding of chemistry. However, it is still unclear to what extent mathematical modelling is actually implemented in chemistry lessons at all.

Based on a detailed model of the process of mathematical modelling in chemistry, an analysis of the curricula of German upper secondary chemistry concerning the actual situation of mathematical content has been done. Hence, a study regarding problems with mathematical modelling in chemistry has been developed. Herein, tasks with incremental learning aids are used as diagnostic tool in order to analyse pupils' problems within the process of mathematical modelling in detail. In the presentation, an example of using tasks of this type will be shown and first experiences will be reported.

FRAMEWORK

Considering the acquisition of problem solving skills in chemistry, it seems reasonable to introduce tasks which aim at problem solving by using mathematical models (Beck *et al*, 2010). Mathematical modelling in chemistry lessons demands the transfer and usage of mathematical knowledge in new and significant situations and thus can support the comprehension of the terms that were modelled and foster problem solving skills (Borneleit *et al*, 2001). However, it is known that students have difficulties with connecting aspects of mathematics and chemistry (Potgieter *et al*, 2008). But problems with mathematical modelling in chemistry lessons have not been examined, classified or even solved yet.

The following quotation points out the definition of mathematical modelling, which is used in didactics of mathematics: "We talk about modelling when pupils consciously justify or choose mathematical descriptions, a model and its assumptions, and when they validate the efficiency or the limit of the chosen model on the basis of the interpreted results." (Büchter and Leuders, 2005) This means mathematical modelling includes a whole process of mathematization as well as interpretation.

This process of mathematical modelling can be described by a model according to Blum & Leiß (2006), which helps explaining teaching-, learning-, and thinking processes (Borromeo Ferri, 2007). Adapting this model to the process of mathematical modelling in chemistry lessons, leads to the following model (Schmidt and Di Fuccia, 2012).

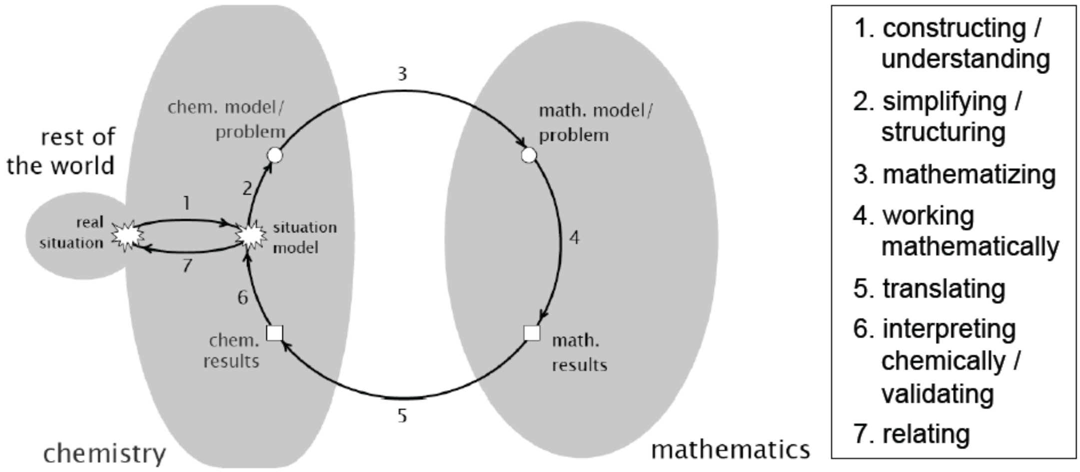

Figure 1: The process of mathematical modelling in chemistry lessons.

Going trough the process means starting with a situation in the real world. Pupils have to construct and to understand the problem or task and they have to simplify and to structure the problem in order to obtain a chemical model, such as reaction equations or laws and resultants of chemistry. In the next step, pupils have to choose mathematical terms or methods in order to describe the problem mathematically and to obtain a mathematical model, e.g. a function or an equation. In step 4, being in the world of mathematics, pupils have to calculate to get mathematical results. Afterwards, they have to translate these results from a chemical point of view and they have to ask themselves whether these results are useful or not. Finally, they have to relate their results to the starting situation.

The detailed description of the process of mathematical modelling allows a classification of students' difficulties with mathematical modelling. More precisely, it becomes possible to specify at which individual step in the modelling process students face problems and which consequences this might have on understanding chemical phenomena.

Research questions

1. *In which contexts* should mathematical modelling be taught in chemistry lessons according to the curriculum?
2. *How* is mathematical modelling taught in chemistry lessons?
3. Do issue-specific or general problems occur when pupils pass through *modelling processes*? For instance:
   - Do pupils use mathematical models?
   - Are pupils able to transfer and apply competences acquired in maths class in chemistry settings?

METHODOLOGY

1. In order to identify *in which contexts* mathematical modelling should be taught in chemistry lessons, the current German curricula of upper secondary chemistry have been analysed since there is only rarely reliable information available from research in this area at the moment.
2. The following approaches are to provide a multidimensional insight into *how* such issues are taught in everyday chemistry lessons:

- An inspection of different textbooks, which is currently been done, serves to get more details about the way the curricular guidelines are interpreted with respect to the mathematization of chemical concepts.
- A qualitative analysis of the tasks of the centralised final exams for the subject chemistry will be done. It can be assumed that these tasks reflect which assignments or rather subject areas are currently deployed in chemistry lessons in secondary education.

3. In order to analyse the *process of mathematical modelling* in detail, tasks with incremental / stepwise learning aids (Schmidt-Weigand, Hänze, 2009) will be used as diagnostic tool in order to identify students' difficulties at each step of the process of mathematical modelling.

   Up to now, tasks with incremental learning aids are known almost exclusively as learning tasks: Incremental learning aids allow students to deal with complex tasks or problems and they are predestinated for tasks aiming at application and transfer of content. Moreover, the aids are suitable for problems showing a linear structure, typical for mathematical tasks in chemistry lessons. As these learning aids may be designed in respect of the single steps of the modelling process, tasks with incremental learning aids allow a clear distinction of the individual steps in the modelling process and can be designed as diagnostic tool to differentiate between chemical, mathematical as well as learning and procedural strategies. In this way, it can be determined whether the occurring problems during the modelling process are linked to a specific step of the process or to topic-specific difficulties. In particular, it can be examined whether and respectively to what extent students are able to apply and transfer competences acquired in maths class in chemistry lessons.

   First experiences with designing such tasks have shown that the aids have to be arranged in a different way than it is known from tasks with incremental learning aids as learning tasks. When designing tasks with incremental learning aids as learning tasks, the aids are structured in the following manner: In the first part of one aid a hint is given or a question is posed. In the second part of the aid the answer to this question is given directly. When designing these aids as diagnostic tool, we additionally differentiate between aids, which give a hint at the next step of the modelling process in general, and subsequent aids, which concretise the next step in the cycle and its realisation. In this way, each resulting aid covers a smaller part of reasoning within the modelling process, so that each single step in reasoning of the process is reproduced. Using tasks with incremental learning aids allows pupils to pass the whole process of mathematical modelling and researchers to diagnose pupils' problems in a more detailed way.

   Within the study, tasks with incremental learning aids will be used to carry out a video study in which pupils have to work on a task of mathematical modelling in a laboratory situation.

   Finally, additional loud thinking or interviews will help validating the results of using tasks with incremental learning aids.

PRELIMINARY RESULTS

By analysing the current curricula of upper secondary chemistry, topics were identified, which rely on a mathematization of chemical issues. The comparison of the curricular guidelines of the 16 federal states of Germany indicated that these guidelines differ enormously:

4. The curricula of the single federal states differ in respect of the topics that require a mathematical analysis of chemical phenomena. For instance, half of all states request a quantitative analysis of an organic compound according to Liebig / Meyer, while the other half doesn't demand this topic.
5. The curricula of the single federal states differ in respect of the depth of mathematization, in particular:
   - Mathematical views are more extensive in advanced courses than in basic courses in all federal states. For example, the Henderson-Hasselbalch equation has to be taught only in advanced courses but not in basic courses in almost every federal state of Germany.
   - The curricula differ in the recommendations of how mathematical modelling should be implemented in class. For example, one keyword that can be found in all curricula is "the law of mass action". However, only in few curricula the derivation of that mathematical model is explicitly recommended. This means that dealing with the law of mass action is mandatory while the derivation is not.

   A closer look at the identified points, where a mathematization of a chemical topic is possible, indicates that in 32.8% of all these points an explicit recommendation of how it should be taught is included. A closer look at these explicit recommendations reveals that in 82.8% a calculation or numeric example is demanded and only in 17.2% a derivation is mandatory.

Overall, two different types of using mathematics in chemistry lessons in the current German curricula of upper secondary chemistry can be identified:

6. Calculating and applying, which means finding results by using given mathematical terms, methods, tools and models (such as functions, graphs, geometric figures and coordinates)
7. Derivations of chemical laws and resultants, which can be described mathematically by using mathematical terms, methods, tools or models.

The keyword "mathematical modelling", which comprises the whole process of explaining facts and data by using mathematics can't be found explicitly in the current German curricula. This means, that mathematical modelling as understood in the model above isn't mandatory according to the curriculum, but it is feasible.

In order to get an insight into how the curricula are usually interpreted, the analyses of different textbooks and of the tasks of the centralised final exams are done right now. The results of these analyses as well as first experiences with using tasks with incremental learning aids will be published soon.

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PRIMARY MATHEMATICS TEACHER EDUCATION: TEACHING AT THE HEART OF LEARNING

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In this presentation we use the theme of teaching at the heart of learning to illustrate the opportunities for pre-service teacher learning. The presentation reports on the outcomes of classroom based inquiry in primary level mathematics education. The research involved pre-service primary teachers and teacher educators collaborating with classroom teachers and primary principals in two incubator schools in Limerick city. We found that engaging pre-service teachers in the design, implementation and evaluation of mathematics study lessons provides a vehicle for better understanding of the complexity of mathematics teaching at the primary level. The process highlights the need for strong subject matter knowledge, understandings of developmental and learning trajectories, the developmental nature of mathematics learning, appropriate pedagogical strategies and representations, insights into pupil responses and misconceptions, and the organization of classroom structures to support learning. Pre-service teachers reported that engaging in the process of looking at teaching had a more profound impact on their learning than their previous experiences of traditional mathematics teacher education modules.

INTRODUCTION

While national and international studies agree that many factors affect the standard of mathematics education, there is general consensus that the teacher is the most significant resource i.e. high quality teaching is vital (OECD, 2005; EGFSN, 2008). Effective mathematics teaching is a complex endeavour requiring knowledge about the subject matter of mathematics, the theory of mathematics, the way students learn, and effective pedagogy in mathematics (Beaton *et al*, 1996). Primary mathematics teacher educators face the challenging task of facilitating pre-service primary teachers to develop this range of knowledge domains. Within the Irish context factors exist which pose obstacles toward the development of the range of skills and dispositions which contribute towards good mathematics teaching. While the limited time available for mathematics education during pre-service preparation is a constraint, pre-service primary teachers' experiences and beliefs relating to mathematics also affect their openness to and interpretation of approaches and methodologies presented in the mathematics methodology courses. The *apprenticeship of observation* (Lortie, 1973) that prospective primary teachers experience i.e. traditional didactic approaches focused on rote learning of mathematics, result in limited personal experiences of methodologies they are expected to model (Hourigan, 2009) and lead to beliefs about mathematics that are debilitating and narrow (Szydlik *et al*, 2003). It is evident that the task of initial teacher training is onerous. It has been established that where 'traditional' experiences are not challenged in the course of initial teacher education, pre-service primary teachers have been found to 'teach as taught' (Becker and Settler, 1996; Smith and Sutherland, 2003; NCCA, 2006). In fact, there is a strong case to suggest that mathematics teacher education courses are a 'weak intervention' in affecting pre-service primary teachers' knowledge, beliefs and attitudes (Nesbitt Vacc & Bright, 1994; Feiman-Nemser, 2001; Shiel *et al*, 2006). Moreover, there is evidence to suggest that the effects of university teacher education are 'washed out' by school experience (Zeichner and Tabachnick, 1981).

It is possible to challenge and transform pre-service primary teachers' attitudes and beliefs (Peard, 2007) through the provision of opportunities to reflect (Ambrose, 2004) upon and critique prospective teachers' own experiences with mathematics. Supporting this proposed approach, Kahan (1992: p.77) cited in Szydlik *et al* (2003: p.255) asserts

> If a program is to promote growth among novices, it must challenge them to make their pre-existing personal beliefs explicit; it must challenge the adequacy of those beliefs; and it must give novices extended opportunities to examine, elaborate, and integrate new information into their existing belief systems. In short, pre-service teachers need opportunities to make knowledge their own.

It was with this in mind that the mathematics education area decided in 2006 to make 'Japanese Lesson Study' a core component of the curriculum specialisation elective taken by pre-service primary teachers in their final year of study. It was intended that the process of engaging in classroom based inquiry, guided by the Lesson study structure, would promote reflection upon critical components of mathematics teaching and facilitate participating pre-service primary teachers to *'learn'* from the act of *'teaching'*.

METHODOLOGY

Participants

While each year since 2006, 20-25 prospective teachers completed Japanese Lesson study, this paper focuses on the Spring 2010 cohort of 21 final year pre-service primary teachers who studied mathematics education during the concluding semester of their teacher education program. These participants had completed their mathematics education courses (three semesters) and all teaching practice requirements (at junior, middle and senior grades) and self selected into mathematics education as a cognate area of study. Seven students were male; the remainder were female. Two students were international Erasmus students.

Lesson Study

All pre-service primary teachers, and three mathematics educators, engaged in *Japanese Lesson Study* (Fernandez and Yoshida, 2004; Lewis, 2002; Lewis and Tsuchida, 1998). Lesson Study is an approach for studying teaching that utilizes detailed analyses of classroom lessons. Lesson study was used in this study to facilitate the examination of both the planning of lessons and the implementation of those lessons in primary classrooms and thus provided an avenue to design tools and sequences of instruction to support the development of algebraic reasoning with primary children.

The research was conducted over a 12-week semester. Participants were organized into groups of 5-6 to work collaboratively on the design and implementation of a study lesson. Four groups were formed and requested to design a lesson to engage primary level children in learning specific algebraic concept i.e. growing patterns, equality, functions, variables. All of the selected algebraic concepts, with the exception of variables, received little or no explicit mention in the Primary School Mathematics Curriculum (Government of Ireland, 1999). Initially the pre-service teachers associated the latter three concepts with their secondary school mathematics experiences.

The first phase of Lesson Study involved the *research and preparation* of a study lesson involving researching algebraic topics and the construction of a detailed lesson plan. The *implementation* stage involved one pre-service teacher teaching the lesson in a primary classroom while the other group members and the researchers, observed and evaluated classroom activity and student learning. Group members then *reflected on and improved* the original lesson design through discussing their classroom observations and modifying the lesson design in line with their observations. The *second implementation* stage involved re teaching the lesson with a second class of primary students and *reflecting* upon observations. The second implementation was videotaped. The cycle concluded with in-class presentations of the outcomes of each of the four lesson study groups.

Data collection and analysis

The primary method of inquiry was collective case study (Stake 1995). The principal data collection technique was participant observation; the researchers were closely involved with the work of each group throughout the cycle. Data collection methods were closely intertwined with and ran concurrent with the lesson study cycle. Detailed description of the data collection tools and methods in addition to the data analytic strategies are outlined in Leavy (2010).

RESULTS

In this paper we are reporting specifically on the impact of Lesson Study on pre-service teachers' knowledge of algebra and beliefs about mathematics. This paper reports on two collective case studies – the reflections of participants in the 'Equality' and 'Growing Pattern' groups. As part of the Lesson study process, participants were required to partake in ongoing reflection throughout. More formally as part of the course assessment structure they were requested to complete structured reflections in response to prompts namely 'What I learned about algebra' and 'What I learned about teaching algebra'. Insights were also gained from group presentations at the end of semester (representing the final stage of the lesson study cycle) as well as anonymous course evaluations.

Reflection – Participants' Perceptions of Effect of Lesson Study Participation

On analyzing the responses, a number of common themes emerged. Analysis of the responses facilitated the researchers in drawing conclusions regarding the perceived effects of the participation. Due to the space limitation of the paper, it is only possible here to provide a 'taste' of findings.

<u>Benefits of Collaboration</u>

A number of the groups made reference to the fact that they had benefited from the opportunity to work as part of a group, *i.e.*, engaging in collaboration (Hiebert, 1999). The following excerpts provide some insight into the reported benefits as perceived by the pre-service teachers:

> Working collaboratively in groups gave us the opportunity to benefit from each other's ideas and differing perspectives… (Growing Pattern group presentation)
>
> I learned and heard lots of ideas I certainly wouldn't have thought of if I was planning the lesson on my own. (Equality group: Geraldine)

In the course evaluation, one student also categorised *'Sharing each others ideas and work'* as a **'strength'** of the course.

<u>The Nature of Algebra and Mathematics</u>

Analysis of the data suggested that participants' beliefs regarding the nature of algebra had changed over the Lesson study cycles, e.g.

> I purposefully avoided teaching algebra in any of my teaching practices being under the illusion that it was too complex, abstract and unimportant and not a broad enough topic. After carrying out the lesson study, I found that this was not the case. (Equality group: Tony)

A number of students reported that the experience had also affected their beliefs regarding the nature of mathematics generally:

> The lesson study has taught me that mathematics is not just a whole lot of rules that children must learn in order for them to progress in life. (Growing Pattern group: Roy)

<u>Mathematics Subject matter knowledge (SMK)</u>

The majority of participants reported that engaging in classroom based inquiry made them aware that their SMK was weak and revealed the nature of their misconceptions:

> …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)

Participants reported that partaking in the lesson study developed their personal SMK.

> My own understanding of algebra has most definitely improved throughout the course of our Lesson Study Project….Before this, my knowledge was poor but now I am able to understand the background knowledge needed… (Equality group: Sophie)

> I am glad to say that after completion of this lesson study assignment my concept of algebra has been vastly broadened. (Growing Pattern group: Ciara).

The development of 'deeper' understanding was reflected in the fact that a number of students focused on relationships within and between various areas of mathematics:

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

> I also developed the understanding that in many cases algebraic reasoning is integrated with arithmetic. (Growing Pattern group: Donal)

<u>Increased awareness of the benefits of specific teaching methodologies/strategies</u>

While some students acknowledge the need for a variety of methodologies, *e.g.*

> I have also learned the importance of using many teaching techniques which teaching algebra … (Growing Patterns group: Donal),

all students reported that they had gained insight into the benefits of specific teaching methodologies in the course of completing the lesson study project, *e.g.*

> We learned the importance of working out problems with concrete materials before moving onto written problems, the value of story as a teaching method, the importance of incorporating images and colour into your materials, how to keep interest and motivation levels up by changing methodologies… (Equality group: Mia).

The experience also developed general pedagogical skills and decision making:

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

Many also reported developing appropriate questioning techniques:

> 'I think the main thing we learned…was to keep questioning as open-ended as possible…' (Growing Pattern group: Donal)

> 'I have realised that the child's responses should act as a catalyst for learning…' (Growing Patterns group: Ciara).

CONCLUSIONS

The data arising from this study emphasize the value of classroom based inquiry in supporting pre-service teachers in translating the theories presented in traditional lecture-style pedagogy courses to classroom based pedagogical practices. The benefits of 'looking at teaching' ranged from the development of general pedagogical skills (i.e. the management of learning, development of questioning skills) to revealing mathematical misconceptions and generating new understandings relating to subject matter knowledge (in this case, in algebra). While participants repeatedly acknowledged that completing lesson study was labour-intensive, consensus existed that the benefits far outweighed the demands:

> I feel lesson study while time consuming, its benefits are rich in facilitating teachers learning…' (Growing Pattern group: Donal).

In support of such sentiments one student wrote on the course evaluation:

> Hard work!! But totally worth it.

The extent of the reported impact was quite remarkable from a number of students:

> Finally, I would like to say that this lesson study experience has honestly taught me more about the art of teaching than any other activity I have undertaken in the last three years in Mary I… (Equality group: Mia)

Despite having had pedagogy sessions previously on the respective algebra concepts students reported that participation in lesson study facilitated real understanding:

> …I am so glad I got to experience this before leaving college ad I more than likely would have left with the wrong impression of algebra. (Growing Pattern group: Meg).

Examining 'real' teaching provided in-depth opportunities for active learning. Another feature common to lesson study that supported the development of understandings was the opportunity to emphasize how children learn (Fennema *et al*, 1996). Lesson study served as the vehicle wherein participants learned from engaging in and observing teaching, in contrast to traditional pedagogy courses where we just talk about teaching.

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OUT-OF-FIELD MATHEMATICS TEACHERS: PROFESSIONAL DEVELOPMENT AS A RESPONSE

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THU 15.00 - 16.20

Out-of-field mathematics teachers are just not an Irish phenomenon – the problem exists in many countries and is of major concern in Australia. Out-of-field teachers are defined by Ingersoll (2002) as those who are asked by school administrators to teach a subject that they may not be suitably qualified for. There is evidence that mathematics teachers in Australia are not suitably qualified to teach mathematics at the standard required for successful teaching and learning in the classroom. A study carried out by the Australian Council of Deans of Science (2006) raised the following concerns:

- 40% of mathematics teachers did not feel suitably qualified to teach mathematics;
- 8% of mathematics teachers had not studied any mathematics at university;
- 20% of respondents had not studied mathematics beyond first year at university;
- Teachers under 30 years of age were less likely than their older colleagues to have a major in mathematics or to have studied mathematics teaching methods.

Vale (2010: p.17) calls the current shortfall of suitably qualified mathematics teachers in Australia 'a crisis'. She explains that almost 50% of junior secondary mathematics teachers are not suitably qualified in tertiary mathematics to be teaching mathematics in the secondary classroom.

Out-of-field mathematics teachers are also of concern in Ireland. Ni Riordain and Hannigan (2009) carried out an investigation of 400 mathematics teachers across 60 schools in Ireland. Their key findings included the following:

- 48% of the respondents did not have a mathematics teaching qualification;
- Of those without a mathematics teaching qualification 35% had a BSc; 34% had a B.Commerce/Business degree and 27% had a concurrent teaching degree without mathematics;
- Older teachers (those over 35) were more likely to hold a mathematics teaching qualification (Ni Riordain and Hannigan, 2009).

The author is involved in the design and implementation of professional development for out-of-field mathematics teachers in South Australia as part of a government sponsored initiative to deal with this crisis. One would welcome the opportunity to provide information about the out-of-field situation in South Australia and professional development as an attempt at responding to this problem.

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CLASSROOM DIALOGUE

Paul Black

Department of Education, King's College London, UK.

Formative interactions, between teacher and learners, and between learners themselves, should play a central role in the learning development of pupils. After a brief introductory talk, participants in the workshop will explore, in the light of this principle, the problems and opportunities that arise in classroom dialogue. This will be done through involvement in discussions, in groups, of short transcripts of the oral exchanges between teachers and pupils in three classrooms.

SUPPORTING LANGUAGE ACQUISITION AND CONTENT-SPECIFIC SCIENCE ACCESS: UNIVERSAL DESIGN FOR LEARNING USING LEGO WEDOS TO TEACH SIMPLE MACHINES

Katie Baird[1], Aija Pocock[2], Allison Howland[2] and Stephanie Coy[2]

[1] Indiana University Purdue University, Columbus, Indiana, USA.

[2] Bartholomew Consolidate School Corporation, Columbus, Indiana, USA.

THU 16.40 - 18.00

Building on the definition of a Learning Community proposed in *Professional Learning Communities for Science Teaching: Lessons From Research and Practice* by Munday and Stiles, we embrace the following six characteristics: Focus on Learning, Collaborative Culture, Collective Inquiry, Action Orientation and Experimentation, Continuous Improvement, and Result Orientation for elementary children, pre-service and in-service educators. Learning communities were constructed with foci including Inquiry-Based Science Instruction, The Five Standards for Effective Pedagogy as defined by CREDE (Center for Research on Education, Diversity & Excellence), Teaching English as a New Language, the principles of Universal Design for Learning (Rose, Meyer, & Hitchcock, 2006), and using multimedia for instructional planning.

This presentation addresses the challenges faced by teachers of students with diverse learning needs. Typically, even if English as New Language and special education teachers are available, learning supports, particularly for language, are mostly aimed at students at the lower levels of proficiency in a pull-out setting, leaving mainstream teachers to deal with the complex learning needs of students in content areas, such as science, where the academic language demands are most challenging.

Attendees will receive a demonstration of the proposed process via construction of Lego WeDo robots and use shared language experiences in Learning Communities to simulate how English Language Learners and students with language/literacy disabilities can be supported in acquiring content-specific language along with the scientific concepts. Pilot study results evidencing empirical support for the efficacy of this intervention for all students, but particularly for English Language Learners, will also be shared.

"WHICH ENERGY SOURCE IS THE BEST?" - TEACHING RENEWABLE ENERGY (R)

Martin Lindner, Louise Bindel, Stephan Domschke and Melanie Meinl

Biology and Geography Education, Martin-Luther-University, Halle-Wittenberg, Germany.

Along with the growing energy hunger around the world, the search for alternative energy sources is vital. Several sources have been developed into mass production in the last decade, like biogas, wind-power, solar energy or fuel cells.

The workshop for the students starts with the simple and purposely simplifying question "Which Energy Source is the Best?" This problem should involve students in finding questions, tasks and experiments to do research on it. The workshop presents various experiments useful to examine the science behind the energy sources, to step deeper into science methods and to combine experiment, measuring, calculating, argumentation and finally the evaluation on the results with respect to the problem. We suppose this is true IBSE teaching.

The material and the way of learning were tested in two summer camps. The results have been evaluated with scientific methods and will be presented together with the experiments. They show a good acceptance and a change of attitude towards science even for participants not familiar with science.

During the workshop you will learn nice and appropriate experiments dealing with energy sources. Some of them are new experimental kits and all of them are easy to do. Especially for science teachers not having their focus on Physics and Technical Education this might be a chance to familiarize with this approach.

CURRENT VIEWS ON THE PRACTICAL ASSESSMENT OF SCIENCE AT JUNIOR CYCLE IN IRELAND

J. Broggy[1], R. Boyle[2], and J. Forde[2]

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

[2] University of Limerick

The revised Junior Certificate Science syllabus was first introduced in 2003 in Ireland. One of the biggest changes resulting from the revision of the syllabus was the increased emphasis placed on practical work which was "designed to help students develop an understanding of science concepts, as well as acquire the necessary science process skills" (Eivers *et al*, 2006: p.3). The syllabus has been identified as an activity based syllabus and "through a variety of investigations and experiments, students attain the specific learning outcomes, developing appropriate science process skills and a knowledge of underlying science concepts" (DES, 2003: p.3). The introduction of Coursework A and Coursework B led to the first practical assessment of science at junior cycle level in Ireland. This change was greeted with various opinions from teachers and students, which this research study set out to investigate. Two questionnaires were designed to collect data from both students and teachers. These were then administered to eight Kerry Education Service (KES) Vocational schools, targeting a total of twenty-four Junior Cycle science teachers and 531 fifth year and transition year students. It was found that overall teachers agree that practical work is an essential element of the science curriculum but they are not satisfied with the way practical work is currently assessed. The implementation of Coursework A and Coursework B adhered quite well with the recommendations in the syllabus according to students. From analysing students' attitudes, confidence and level of difficulty it was concluded that Coursework A does play some role in preparing students for the undertaking of Coursework B. Both parties participating in this research study outlined several recommendations that can be incorporated to improve the practical element in junior cycle education.

THU 16.40 - 18.00

INTRODUCTION

Education in Ireland is undergoing dramatic changes, both in its structure and delivery. The first discussions on major reform of the junior cycle commenced mid-2009 under direction from the then Minister for Education and Science, Mr. Batt O'Keeffe. From this followed the publication of the NCCA discussion paper *Innovation and Identity – Ideas for a New Junior Cycle* (2010), which was the subject of a lengthy public consultation, currently ongoing. This reform will have serious consequences for the teaching and learning of science. However, now that the new junior cycle curriculum and different assessment arrangements are being generated, we must learn lessons from what has happened in the past and ensure similar errors are not made. With this in mind it is essential that we look back at the current structure and determine what improvements can be made in order to improve the student experience. Educational change is one of those processes that have a habit of resetting itself back to how things have always been done (NCCA, 2011) so every step must be taken to avoid this from occurring with the introduction of the new curriculum. It is clear that we must look the real junior cycle classrooms and those who work in them and use this information to collect data that will in turn achieve the national aim, which is to increase the uptake and the performance of second level students in science and especially the physical sciences.

The current Junior Certificate aims to develop students in skills such as communication, experimentation, investigation and creativity together with developing students' knowledge of science and develop an appreciation and enjoyment of the subject. It was strongly believed that an increased emphasis in practical work would help students achieve all these aims. To complement this change, reform was also required in assessment procedures. For the first time in Irish education marks were awarded for practical work and 35% of a student's marks in Junior Certificate science examination are based on their performance on two practical elements of the course – Coursework A (10% of total marks), and Coursework B (25% of total marks) (Eivers *et al,* 2006: p.4).

There are many views of the role of practical work in the teaching and learning of science. It is believed that it can benefit and aid both teaching and learning. Millar identified one of the main roles of practical work in science classrooms as to demonstrate phenomena which "students are unlikely to have observed (…) in their daily lives" (Millar, 2004: p.8). He maintained that any "real event contains more information than any representation of it" and that students "get a better 'feel' for what really happens" "by doing it and observing it" (Millar, 2004: p.10). According to Wellington (1998, p.11), "practical work can illustrate phenomena but it cannot explain why they happen". In other words practical work can act as an aid to learning but not as a form of learning on its own. Roberts (2004, p.113) was of a similar opinion and said that "practical work is a means to an end; it is not an end in itself".

METHODOLOGY

In order to examine Irish students and teachers attitudes towards the current system of practice work in the science classrooms teacher and student questionnaires were developed to collect information on the following issues (Table 1).

The questionnaire was administered to all Junior Certificate science teachers (*N*=24) and Transition Year (TY) and fifth year students (*N*=531) during the academic school year 2010/2011 in the eight KES science schools. The questionnaire included both open and closed ended questions to facilitate both qualitative and quantitative responses. The timing of the research was carefully planned. It was crucial that the questionnaires were sent to the schools as early as possible in the academic year to ensure that the students' responses were not influenced by their senior cycle science experience but rather their junior cycle, which was just completed the summer previous. The time that had lapsed since the students had completed their Coursework was quite short and so the Coursework B would still be fresh in their minds allowing them to reflect on this experience for purposes of the questionnaire.

Table 1: Issues examined in both the student and teacher questionnaire.

Teacher Questionnaire	Student Questionnaire
Teacher experience	Attitude towards science
Teacher timetable	Science ability
Availability of resources	
Teaching strategies used for Coursework A	Experience of Coursework A
Teaching strategies used for Coursework B	Experience of Coursework B
Student scientific skill ability	Confidence in Science
Areas for possible improvements	Areas for improvements

RESULTS

It is important to note that the eight schools involved in this research were all vocational schools and therefore the results presented do not reflect the view of students in other types of schools. The results are also not representative of student attitudes on a national basis as the sample schools were all situated in County Kerry. The response rate for the teacher questionnaire was 62.5% (*N*=15) with the student response rate recorded at 45.2%.

Teacher Questionnaire

The teachers involved in the project varied in the number of years teaching science at junior cycle. From those who responded 20% (*N*=3) were teaching 1st year the revised syllabus for the first time, with the majority of the teachers teaching the syllabus four years or more.

As shown above in Table 1 several key issues were addressed in the questionnaire. As it is not feasible to present all of these in detail here the authors will focus specifically on two issues; development of student skills and improvements that can be introduced in practical work in junior cycle science.

Development of student experimental Skills

1. What effect does the practical work component have on the development of student experimental skills, as observed by the teacher?

One of the preliminary questions asked in the teacher questionnaire questioned whether the science teachers believed that the revised syllabus (2003) was beneficial to their students learning of science. Almost 74% of the teacher cohort believed that the syllabus and its aims provided better opportunities for student learning however the following figure (Figure 1) identifies the teachers' responses when asked to comment on their students' development of experimental skills. It is interesting to note that a high majority of the teachers believed the syllabus was beneficial for student learning yet only 20% of the teachers agree their students can present data and less than 10% of the teachers agree that their students are able to identify variables at the end of three years of junior cycle science.

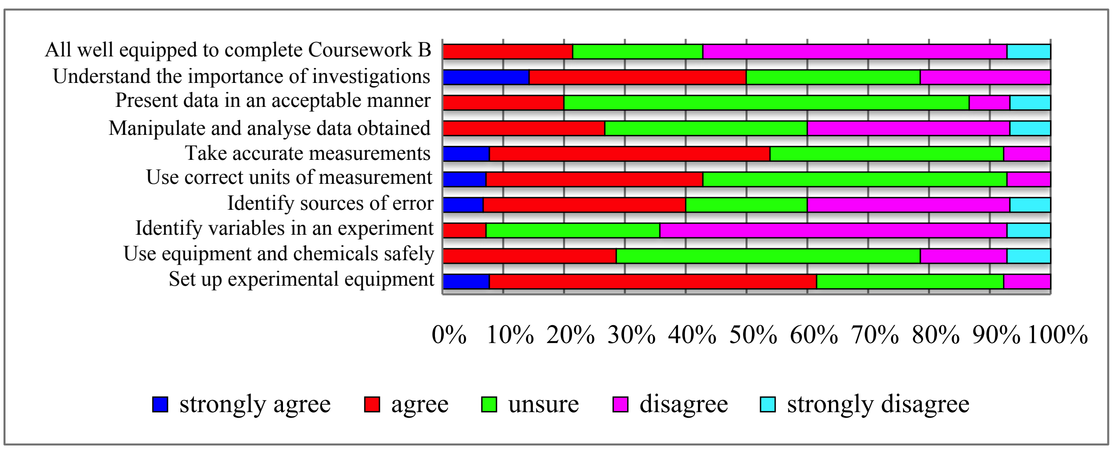


Figure 1: Teachers' opinions of the development of their students' skills at the end of Junior Cycle Science.

Improvements in Practical work in Junior Cycle Science

2. How could the Practical work component, Coursework A and Coursework B, of the Revised Junior Certificate Science syllabus be improved in the opinion of science teachers?

When the science teachers were asked to provide possible improvements to the practice of practical work in junior cycle science opinions were offered both in relation to the mandatory experiments and the practical assessment. 53.3% of the teachers felt that improvements could be made in relation to Coursework A especially in the area of monitoring of completion and the quantity. The following comments are a sample of common responses that suggest that the teachers feel the current system of completion 30 mandatory experiments does not provide opportunities for students to develop skills that they need for independent learning and lifelong learning skills.

> I fear all 30 experiments are ticked even if students don't have them all done. Could this be more heavily monitored? (Teacher 1)
>
> Challenge students to think more on how to investigate the problem. (Teacher 3)
>
> Less experiments – more time for detail. (Teacher 14)

Possibilities for the improvement of Coursework B were also provided with 73.3% of the respondents agreeing that it needed change. The majority of the comments related to improvements of the *Pro-Forma* booklet that the students must complete and submit. Similar to research carried out by Higgins (2009) the language used in the booklet was deemed not suitable for the students' ability and resulted in a large amount of time being "wasted" explaining words.

Student Questionnaire

The majority of students who responded to the questionnaire were 16 years of age and at the time of completion were enrolled in fifth year. All students have completed the Junior Certificate Revised Science exam and of the 240 respondents 62.9% did so at Higher Level and 37.1% completed the Ordinary Level exam. A wide range of grades were obtained with just over 37% awarded a B grade and 40% awarded a C grade. Similar to the teacher questionnaire two issues will be focused in detail; enjoyment of and confidence in junior cycle science and possible improvements for practical work.

Enjoyment and Confidence in Junior Cycle Science

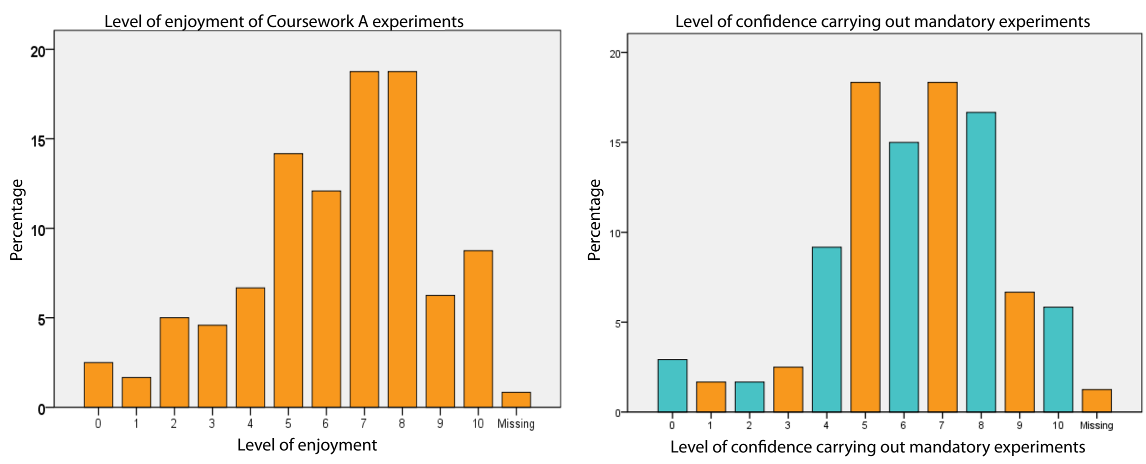


Figure 2: Students' levels of (a) enjoyment and (b) confidence in carrying out the mandatory experiments (Coursework A). [Note: 0 = did not enjoy at all; 10 = really enjoyed; 0 = no confidence; 10 = very confident].

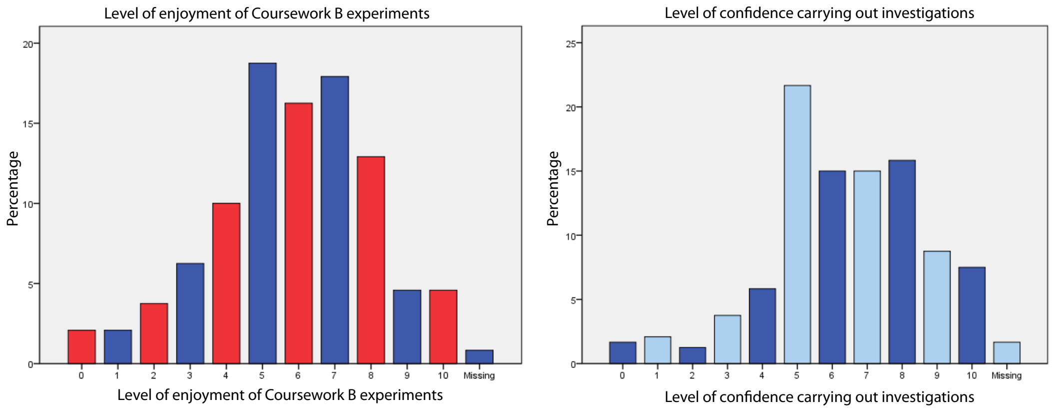
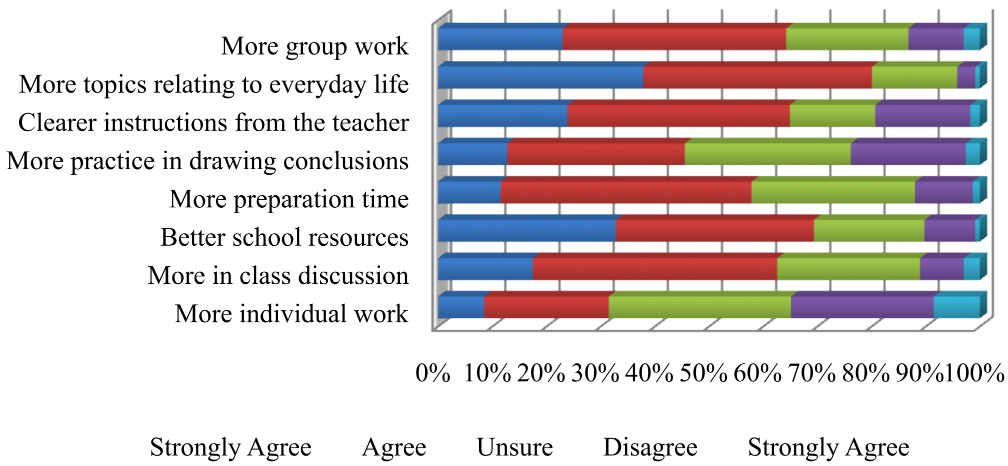


Figure 3: Students' levels of (a) enjoyment and (b) confidence in carrying out the investigations (Coursework B).

Is it clear from both Figure 2 and 3 that the students enjoyed coursework A more than Coursework B and that the students' level of confidence was much higher for Coursework A than it was for Coursework B.

Improvements in Practical work in Junior Cycle Science

Similar to the teacher questionnaire the students offered several possible solutions that they feel would help the student experience in junior cycle science (Figure 4). The students agree that more topics should be taught by relating them to everyday life together with a larger focus on group work and classroom discussion.



CONCLUSION

The above results show that both junior cycle students and teachers agree practical work is important for the development of scientific process skills. However, the current system in place, both in practice and assessment, requires improvement. It is intended that the successful completion of Coursework A will help develop skills for independent learning and scientific reasoning yet 53.3% of teachers felt that their students in the third year of study they were not equipped with the necessary skills to complete Coursework B. At a time when the current junior cycle programme is under review is it imperative that the voices of students and teachers are heard.

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INQUIRY-BASED ACTIVITIES FOR THE TOPIC PLASTIC AND PLASTIC WASTE

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In this paper we focus on presenting created inquiry-based activities for the topic *Plastic and Plastic Waste* within the Unit Polymers prepared in co-operation with the Faculty of Science of Charles' University in Prague.

Subunit 1 consists of the following activities: *Kinds of plastic packaging materials and their labelling* and *Properties of plastic materials*. Subunit 2 consists of the activity *Resolubility of waste in the environment*, *Separation of waste*, *Influence of acid rain on plastic products* and *Recycling plastics – using a project-based method*.

In the activity *Properties of plastic materials*, for example, pupils should determine the combustibility of plastic, its thermal and electrical conductivity, reaction with acids, alkalis and salt solutions. Pupils write the results into tables by which way they improve the following skills necessary for research – data collecting and recording, data processing, carrying out experiments, stating hypotheses. In groups, pupils discuss the conditions for conductivity of plastic, and compare the conditions with conductivity of other substances.

The activities were tested on the sample of 100 pupils of grammar schools and 50 pupils of basic schools. Verification revealed that the activities were very interesting for the pupils and at the same time they developed pupils' environmental awareness. That is why the activities can also be used when implementing the complex topic of environmental education in the subject of chemistry.

The pupils stated that they found the following activities the most interesting: *Properties of plastic materials* and *Kinds of plastic packaging materials and their labelling*.

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Establish project, available on http://www.establish-fp7.eu.

THE VIEWS OF PRESERVICE AND INSERVICE TEACHERS ON IBSE

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In light of the growing emphasis to implement inquiry based science education in the classroom, it is essential to make teachers more aware of the methods involved in executing inquiry effectively. Implementation of inquiry can be difficult as the vast majority of teachers have been taught themselves through more traditional direct transmission approaches and hence, may find it difficult to convert to a teaching approach they would never have used nor experienced before. Pre-service teachers are exposed to ideologies of IBSE during their teacher education programmes but in order to allow these teachers to eventually embrace inquiry as their own method of teaching, teacher educators must first become aware of their pre-service teachers current views and goals of education, views of good classroom practice and any challenges or anxieties they face. Understanding this makes teacher educators more aware to the needs of their participating teachers and in turn can allow them to provide the necessary support in order to help teachers overcome obstacles and develop on their practice. This study outlines the use of a paper and pencil teacher profiling instrument which made it possible to determine pre-service teachers' attitudes and beliefs about IBSE, teaching science and teaching science through inquiry and any concerns they may have in implementing it. Preliminary results are also provided from recently administered questionnaires to two groups of pre-service teachers outlining their current views and attitudes towards IBSE.

INTRODUCTION

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" (Linn and Davis, 2004). This is the understanding of inquiry–based science education (IBSE) that is used in the ESTABLISH FP7 funded programme (Establish, 2010).

Inquiry based teaching requires teachers to become a facilitator of learning rather than the source of all knowledge. The National Science Education Standards advocate that teachers

> create an environment in which they and students work together as active learners

and orchestrate learning so that students are engaged, focussed and challenged throughout each class (National Research Council, 1996). Posing questions and problems that are relevant to students' lives are paramount. According to Driver *et al* (1994, cited in Crawford, 2000) inquiry teachers assist the improvement of students' current knowledge by encouraging students' involvement in inquiry based activities relevant to real world phenomena and "engaging in higher level thinking and problem solving". In turn, there is a shift from teacher centred to more student centred classrooms.

The struggle both in-service and pre-service teachers have as regards changing their methods of instruction from didactic to inquiry practices can stem from deep-set personal beliefs and histories with their own education. Eick and Reed (2002) demonstrated how teacher role identities are influenced strongly by the individual's own lived experience of teachers as well as the strength of their teaching beliefs. An individual is shaped by the experiences they encounter through life, and in that sense, previous experiences with education and positive or negative teacher role models can shape the individual as a teacher themselves. Having strong beliefs about teaching, based on reflection of these past experiences, can also lead to a stronger role as a teacher in the classroom.

The difficulty for many teachers is that they themselves have been educated under concept-based programmes and this background may inhibit or slow down their shift to a more context-based method of instruction (King, Bellocchi and Ritchie, 2008). The level of inquiry used by a teacher is strongly governed by their core conceptions (Lotter, Harwood and Bonner, 2007). Addressing and understanding these conceptions can inform teacher education programmes and raise light issues may affect them while implementing inquiry.

METHODOLOGY

Many obstacles identified when implementing inquiry focus on teachers' personal beliefs, and attitudes towards teaching science as well as science knowledge. Therefore the ESTABLISH project needed to determine the following for each of the participating teachers:

- Attitude to teaching by inquiry
- Attitude to teaching science
- Views of Nature of science
- Attitude to change
- Self confidence in science knowledge
- Self confidence in teaching science through inquiry

Shedding light on pre-service teachers' views of inquiry as a methodology was deemed important and would require participants to share their understanding of inquiry, if they feel competent enough to use it in their instruction and their stance on the benefits of using IBSE. Classroom issues, related to inquiry classrooms, which may have an effect on teachers self-confidence and self-efficacy in their teaching and an effort to include questions relating to this area was paramount. It was important to cover the areas of industrial relevance and authentic experiences in science and there would also need to be a review of what pre-service teachers beliefs of "good teaching" comprised of. This was hoped to combat the fact that pre-service teachers have limited exposure to classrooms and in turn their actual classroom practice could not be determined.

A review of the literature found that no one particular widely available instrument would have been suitable to provide insight on pre-service teachers views on the multifaceted area of IBSE. However, numerous tools and instruments used for profiling teachers were researched and evaluated on their suitability and helped inform the construction of the instrument presented. These tools included TALIS, PSI-T, CLES-T, and the VNOS questionnaire and covered the areas of classroom practice, the Nature of Science and general attitudes toward inquiry teaching. A new instrument was developed for this project and it incorporated both open ended and Likert style questions.

It was hoped the nature of science could be addressed in the instrument created but a review of the research has indicated that teachers' views of NOS cannot be encapsulated using a paper and pencil instrument (Lederman, Wade and Bell, 1998).

PARTICIPANTS

Thus far two groups of pre-service teachers have been administered a questionnaire, which has subsequently been analysed. The pre-service group consists of 74 students in their second year of teacher education; 37 of whom will specialise in teaching science (two of Physics, Chemistry and Mathematics) (ST) while the other group of 37 specialise in physical education and biology teaching (PT). Both groups were based in the authors' university and had three weeks of teaching practice prior to receiving the questionnaire. The PT group had a cohort of 51% males and 49% females between the ages of 18 and 26 while the ST group consisted of 59% male and 41% female between the ages of 19 and 22.

RESULTS

In order to determine whether the questionnaire was a reliable source to gain information about the views of pre-service teachers towards IBSE it was analysed using Cronbach's alpha for internal consistency. For the PT and SE cohort the Cronbach's alpha was measured as 0.793 and 0.791 respectively suggesting that the questionnaire was sufficiently reliable.

As regards responses to questions, the pre-service teachers were largely uncertain in a number of areas concerning their views of inquiry as a methodology. Importantly, 35% were uncertain as to whether inquiry could be used with students of all capabilities. Despite this 72% of these teachers felt that students do not need to know a lot of facts to participate in inquiry activities. 55% also were uncertain as to whether it would be easy to teach the curriculum using inquiry based methods and 46% were unsure whether they will ever use inquiry and an additional 17% definitely do not want to use it as their main teaching method at all. Despite this, 96% admit they are open to trying different methodologies.

Pre-service teachers appeared unconfident and uncomfortable with delving outside the limits of their own knowledge in the classroom. 65% of teachers felt uncomfortable with teaching areas of science they had limited knowledge of and 73% admitted to being uncomfortable with asking questions where they are unsure of the answer themselves.

95% understood that good teachers should allow students to develop their own research questions and 88% believed student questions should guide their teaching overall.

When comparing both pre-service groups (see Table 1) it was found that they shared remarkably different views in a number of areas. 70% of the ST cohort believed they fully understood inquiry compared to 55% of the PT group who also had a large percentage (32%) that were uncertain. An aspect of their views of the nature of science was tested in one particular question involving the tentative nature of science. In this, 43% of PT students agreed that scientific theories were constant unchanging bodies of knowledge compared to only 24% of ST students. While overall 36% of the students felt their goal was to transfer factual knowledge, 54% of ST students disagreed with this compared to only 27% of PT students. These PT students were largely uncertain about this statement or agreed with it. In a related matter, 35% of PT student teachers also felt the need to immediately tell their own students the correct answer if a student investigation or experiment didn't go as planned. This is compared to only 16% of ST student teachers.

89% of ST students were also more confident in their ability to relate scientific concepts in the curriculum to phenomena beyond the classroom compared to 55% of PT students. Overall however, both the PT and ST cohorts were enthusiastic about the importance of relating science to industry and the phenomena in the outside world. 91% understood that good teaching involved making the relationship between industry and science explicit to their students. 89% wanted their students to know about the latest developments and applications of science and engineering.

Table 1. Examples of items from pre-service questionnaire with corresponding results.

Sample Items from Questionnaire:	PT Cohort:	ST Cohort:
I don't fully understand inquiry based science education.	55% disagreed	70% disagreed
Inquiry will never be my main teaching method.	64% uncertain or agreed	60% uncertain or agreed
Scientific theories (e.g. atomic theory) are constant unchanging bodies of knowledge.	43% agreed	27% agreed
Teaching is more effective when all students are doing the same activity at the same time.	27% agreed	55% agreed
My goal is to transfer factual knowledge to the students.	27% disagreed	54 disagreed
I can easily relate scientific concepts in the curriculum to phenomena beyond the classroom.	55% agreed	89% agreed
If a student investigation leads to an unexpected result I should always tell the student the right answer/result.	35% agreed	16% agreed
I am uncomfortable teaching areas of science I have limited knowledge of.	65% agreed overall	
I would be uncomfortable with asking questions, in my class, where I am unsure of the answer myself.	73% agreed overall	

Despite the general trend of a less inquiry oriented PT cohort, they appeared to have better classroom management skills, which are so essential to the implementation of inquiry classrooms, than their ST counterparts. 55% of ST students felt that teaching was more effective when all students were doing the same activity at the same time compared to only 25% of PT students. A similar item on the questionnaire also highlighted this trend where 35% of PT student felt they would not find it difficult to manage a classroom where each student group was doing different activities compared to only 19% of ST students.

Time constraints appear to be the most concerning factor overall for pre-service teachers in implementing inquiry. This is followed closely by classroom management issues and a lack of equipment or assistance in school laboratories.

DISCUSSION

Damnjanovic (1999) stated that in-service teachers are more open to inquiry and contemporary science instruction and have more of a grasp on evolving teaching methods than pre-service teachers. This coincides with the attitudes of the 46% ST and PT pre-service teachers who were not overly receptive towards using inquiry based teaching practices in their future teaching. Damnjanovic (1999) also found that in-service teachers disagreed more strongly than pre-service teachers to the statements that science was exact. Both the ST and PT students have had the same amount of teaching practice yet the ST group displayed better insight into science similar to an in-service teacher, understanding that science isn't beyond doubt.

Inquiry teachers must be confident in their scientific knowledge, or at the very least must be confident and comfortable with delving into areas with students that are unknown to them. Some teachers involved in the Biomind Programme in Israel (Zion, Cohen and Amir, 2007) commented in their profiling interviews that they are uncomfortable with not knowing all the answers that inquiry investigations can bring about and tend to steer students toward questions to which the teachers knows the answers to or investigations that they can expect the outcome of. Some teachers deliberately made use of "safe questions" so that the students had some faith in their knowledge as a teacher and that the students themselves began to feel some form of progress on knowing the answer. Clearly the ST and PT pre-service teachers feel a similar level of discomfort in exploring beyond the limits of their own scientific content knowledge and prefer to be primed and prepared for any question a student may ask them.

The ST students had a clearer grasp on the fact that scientific concepts could be challenged whereas PT students accepted scientific concepts as the absolute truth. That said, PT students may be more accustomed with a less structured, student focussed, activity oriented class environment given that this approach would largely be used in physical education. They showed a significantly better reaction to dealing with group work and student oriented classrooms compared to the science education students.

Meyer (2004) noted that pre-service and first year teachers were found to be far too preoccupied with covering content which also coincides with results, particularly from the PT pre-service teachers as they believe their role as a teacher is to transfer factual information to students and then explain them accordingly.

It is expected that more questionnaires will be administered and subsequently analysed in the future as part of the ESTABLISH project. Not only will these provide information on teachers around Ireland but they will also include data from other European countries. This will further inform teacher educators on the stance of pre-service teachers towards inquiry based science education today.

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INQUIRY THROUGH THE SCIENCE OF ECOLOGY

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In the study of ecology there is now major focus on the increased use of resources and on the impact of humans on the Earth. Is it possible to understand human effects on the environment without knowledge of physics, chemistry, mathematics, technology and biology? Classical biology can explain biological phenomena but modern biology must now find new innovative ways to stimulate the intelligent mind and encourage science inquisitiveness. In this inquiry designed field activities, students with diversity of interests and various backgrounds work together as a team. The scientists/students can interact and exchange their knowledge triggering their curiosity to ask and investigate questions.

Biology has moved away from a mainly descriptive approach. It is time to change the syllabus emphasis so as to reflect the curiosity of students. Sections in the curriculum should be drawing specific attention to recent advances and students must become familiar with new science applications. The input of research scientists with communication skills is needed as teachers lack knowledge about scientific advances. There is a need in educating teachers and increasing the competence and confidence of teachers in new and emerging areas of physics, chemistry and biology. More professional development for teachers is essential if they will be expected to move toward this innovative approach to teaching and assessing science in the field and in the laboratory. Consultation with scientists is required in order for the successful implementation of the experiments.

THE LEVEL OF ENVIRONMENTAL AWARENESS AMONG THE STUDENTS OF SPECIALTY CLASS TEACHER AT THE UNIVERSITY OF AL AL-BAYT AND ITS RELATIONSHIP WITH SOME VARIABLES

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The purpose of the study is to assess the environmental awareness among the students in a specialised student-teacher course at the University of Al al-Bayt (AABU) in Jordan. The relationship between the students' environmental awareness and their gender, level of study, residence, level of family income, and studying a course related to the environmental education were evaluated with a valid and reliable instrument consisting of 30 multiple choice items. The study was carried out at AABU among 163 student-enrolled in the first semester 2011/2012 at the Faculty of Educational Science. The results showed that the environmental awareness of the subjects was limited. The study did not reveal significant differences in environmental awareness attributable to gender or level of study, while it revealed significant difference attributable to the residence area (Bedouin and rural), level of family income, and participation in a taught course related to the environmental education. Based on the results of the study, it was recommended that the syllabus of schoolteacher majors must include a compulsory course in environmental education, not an elective course as in the case now.

PREPARING TEACHERS TO TEACH PHYSICS USING INQUIRY

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The Irish government's expansion policy on education has resulted in much larger numbers taking up higher education than ever before. The last ten years has seen an extensive expansion in the numbers entering higher education in Ireland, which leads to the problem of a very diverse group of students in third level education, from varied backgrounds and level of experience. This problem is very evident in pre-service teacher education programmes in the University of Limerick. As teacher knowledge is an extremely important factor which influences student learning pre-service teacher training must align and cater to the needs of the changing population, both in second and third level.

This paper reports on the recent change in practice that took place in the University of Limerick whereby third year undergraduate education students experienced teacher training which was designed to target ill-equipped physics student teachers. Upcoming changes in curriculum design at junior and senior cycle science, as outlined by the National Council for Curriculum Assessment (NCCA, 2011), support the use of Inquiry Based Science Education (IBSE) methodologies in all classrooms. IBSE is well documented in national and international research, as its use is associated with many gains including social, intellectual and mental. In light of this, an evidence-based research project was undertaken at the NCE-MSTL to help develop pre-service students' competence and confidence in teaching science through the use of IBSE.

Analysis of the data indicates that the inquiry-based approach increased the pre-service teachers' attitudes towards physics but also their confidence with regard to teaching secondary level science and physics.

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PROMOTING PHYSICS UNDERSTANDING THROUGH THE USE OF CREATIVE AND TEACHER-LED CONTINUOUS PROFESSIONAL DEVELOPMENT (CPD)

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This poster offers analysis and evaluation of a unique and immersive approach to science teachers' continuing professional development (CPD) designed and run by National Centre for Excellence in Mathematics and Science Teaching and Learning (NCE-MSTL) and the Kerry Education Service (KES) in Ireland. The three-year project began in September 2010 with the aim to develop the investigative skills of junior cycle science students, thus preparing them for their practical assessment they are met with in their third year of junior cycle education. In an attempt to 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. In order to facilitate this the teachers participating in the research received on-going training on teaching approaches suitable for Inquiry Based Learning (IBL) and were then asked to integrate the methods and strategies into their science lessons. In total eight science teachers participated in the research study and five training were provided each year. Topics covered in these training sessions include IBL lesson planning, scientific language, the teacher as a facilitator of learning, reflective practice, and cooperative learning, amongst others.

This research paper reports on one such aspect of the project and looks in detail at the training provided to the teachers to help them teach the topic of Electricity. The pre and post diagnostic tests given to the students are examined and the misconceptions held by the students (before and after instruction) are identified. The students' use of scientific language, both technical and non-technical is also discussed in this paper, thus indicating the level of proficiency of scientific language and use of everyday concepts.

MONITORING STUDENTS' ENGAGEMENT WITH MATHEMATICS AT THIRD LEVEL

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In this paper we will give an overview of a monitoring scheme that was set up in the 2010-11 academic year by the Department of Mathematics and Statistics at the National University of Ireland Maynooth. We monitored first year students' submission of assignments, their attendance at tutorials and their engagement with an online mathematics proficiency course. Students who failed to engage appropriately were contacted by the department. The contact was initially by email, but then progressed to a letter from the head of department, and onto a meeting with a member of staff for students who continued with their pattern of non-engagement. We will discuss the background to this scheme, and how the monitoring project operated. We will look at the effectiveness of the scheme by analysing its impact on students' levels and quality of engagement. In particular we will present evidence that the monitoring scheme has significantly increased levels of engagement.

INTRODUCTION

Most universities have introduced supports for first year mathematics students; these supports often take the form of small group tutorials, drop-in centres, or remedial courses. These supports are resource intensive and therefore it is sensible to investigate their effectiveness. Research on this topic has shown (Lee *et al*, 2007; Mac an Bhaird *et al*, 2009) that such supports can have a positive impact on the retention of students and on their grades. However, as highlighted in both Pell and Croft (2008) and Mac an Bhaird *et al* (2009), it is often the case that the students who are most in need of help with mathematics do not use these support systems.

There have been some studies of interventions that try to address university students' engagement levels. Richie and Hargrove (2004) report on the impact of a scheme where students with low levels of lecture attendance were contacted by telephone. When compared to students in the control group (who had similar levels of attendance but who were not contacted), students in the intervention group displayed fewer absences, better grades and a higher rate of retention into the next year. Hudson (2005) describes the implementation of a pilot 'early alert warning system' at a US university. The project monitored first year absenteeism using a web-based recording system, and students with high levels of absenteeism were subsequently contacted. Students who were contacted responded positively, and the project appears to have improved retention. Indeed, a recent report on college retention (Lotkowski *et al,* 2004) listed as one of its recommendations that colleges and universities should "Implement an early alert, assessment, and monitoring system based on…attendance records..."

In an effort to increase attendance at tutorials as well as assignment submission rates, the Department of Mathematics and Statistics at NUIM initiated a monitoring scheme in the academic year 2010/11. Students who consistently missed tutorials or failed to submit assignments were contacted by the first author via email. If the behaviour persisted, the students were sent a letter asking them to meet the course coordinator and if they still did not engage they were contacted by the head of department. In this paper, we will describe the scheme in detail. We will also evaluate the impact of the scheme by comparing

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engagement levels of students in 2010/11 with those of students in 2009/10 when no such scheme was in place.

THE MONITORING SCHEME

At the National University of Ireland Maynooth (NUIM) first year mathematics students are taught in large group lectures supported by small group tutorials. In addition, students submit assignments each week; these assignments are graded and returned in tutorials. Each tutor is responsible for keeping accurate records of assignment grades and tutorial attendance for each of their tutorial groups.

The monitor (first author) was given access to these records on a weekly basis and created her own record system containing data pertaining to all the first year students. She used this data to monitor the students' engagement with the tutorial and assignment system. Prior to the commencement of the project, the authors decided that any of the following constituted a lack of engagement with the tutorial/assignment system: a student missing two tutorials in a row; a student missing two assignments in a row; or a student missing one tutorial and one assignment in the same week. The monitor was also given access to the departmental file containing medical certificates from students that excused them from missing any tutorials or assignments, which she noted on her records. These excused absences were taken into account when looking at students' engagement with the system.

There were three levels of communication sent out by the monitor to students who were not engaging with the tutorial system; the precise details of each communication were decided upon by the authors at the start of the project. When a student was seen not to be engaging for the first time, they were sent an e-mail by the monitor. The e-mail pointed out the importance of tutorials and assignments and urged the student to address the fact that they were not engaging. It also reminded them of all the free supports available to them. If their behaviour continued, the monitor sent the student a letter from the department which again reminded them of the importance of engaging and also requested them to meet with their course co-ordinator. If, after receiving this letter, the student still did not engage, then they were sent a second, stronger letter. This letter was similar to the previous letter but written in a much stronger manner and signed by the head of department. If a student continued their pattern of non-engagement after receiving the second stronger letter, then they were not sent any further communication in that semester.

This process was repeated in semester 2 and all registered students started with a clean slate. Any communication a student may have received in semester 1 had no bearing on communications sent in semester 2. Many of the students replied to the communications that they received and either admitted to their lack of engagement and gave an explanation saying they would try to do better, or they challenged the contents of the communication. In all cases these were referred to the second author, who would reply to students' individually and stress that the monitoring scheme was for the students' benefit; he would also address any other points that the students raised. A similar monitoring scheme was implemented in order to increase engagement with a non-compulsory online mathematics proficiency course, and this is reported on in detail in Burke *et al* (2012).

RESULTS

We will consider the impact of the monitoring scheme on attendance levels and submission rates by comparing the behaviour of students in the year 2010/11 (when the scheme was in operation) to their counterparts in 2009/10 (when there was no effort to contact students who were not engaging). In 2010/11 there were 536 students registered for mathematics modules in semester 1 and 533 in semester 2. In 2009/10 the numbers were 556 in semester 1 and 519 in semester 2.

Table 1 below shows the numbers of students who were contacted in 2010/11 and the numbers who would have been contacted in 2009/10 if the scheme had been in operation.

Table 1: Highest type of correspondence received over the course of the year.

Year	No Contact	Email	First letter	Stronger Letter	Total
2009/10	291 (51.2%)	109 (19.2%)	47 (8.3%)	121 (21.3%)	568
2010/11	332 (61.1%)	121 (22.3%)	40 (7.4%)	50 (9.2%)	543

The highest level of contact is not independent of the year (chi-square test, $p<0.001$) with students in 2009/10 being more likely to have higher levels of contact from the monitor than students in 2010/11. This indicates that there were more students in 2009/10 (when the monitoring scheme was not in operation) who failed to attend tutorials or submit assignments on a regular basis.

If we compare the engagement levels of students in 2010/11 who were contacted (either by email or letter) with those of the students in 2009/10 who would have been contacted had the monitoring scheme been in place, we see that there is a significant difference between the mean number of assignments submitted in Semester 1 (t-test, $p=0.007$), and in the number of tutorials attended (t-test, $p=0.002$). In both cases, the mean is significantly higher for the 2010/11 group.

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DISCUSSION

The results presented here suggest that the monitoring scheme has had a positive impact on engagement levels. More than 20% of students in the year 2009/10 (when the scheme was not in place) displayed persistently low levels of engagement however this figure halved after the implementation of our scheme. Both the tutorial attendance and assignment submission rates increased significantly in 2010/11. It was seen in a study of engagement with an online course carried out by Burke *et al* (2012) that students who do not engage at the beginning of a course are very unlikely to change their behaviour patterns later unless some outside intervention takes place. It is our belief that monitoring schemes such as the one described here have a role to play in smoothing the transition from school to university for first year undergraduate students and in improving student retention.

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IRISH MATHEMATICS EDUCATION REFORM – A COMPLEXITY THEORY PERSPECTIVE

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This century has so far witnessed the roll out of two reform based second level mathematics syllabuses in Irish schools – the revised Junior Certificate Syllabus in 2000 and Project Maths ten years later. Both syllabuses placed a heavy emphasis on changing both the content of the mathematics syllabus and crucially, the manner in which it is taught by Irish mathematics teachers. For many mathematics teachers, the challenge of reform-based teaching has required them to change their beliefs, knowledge and practice of mathematics and ask them to 'do' maths in a new way in their classrooms.

Drawing on empirical data gathered from second-level mathematics teachers, this paper proposes to apply a complexity framework to firstly explain and describe the dynamics of a Junior Certificate mathematics classroom and secondly to conceptualise the teacher learning required to ensure the goals of reform mathematics are actualised in Irish Classrooms. The study of the interaction of multiple agents such as the teacher, school, and syllabus from a complexity framework enables us to explain the challenges inherent in a successful roll out of the latest Irish attempt at reform mathematics – Project Maths.

INQUIRY-BASED EDUCATION IN PHYSICS AT SLOVAK SECONDARY SCHOOLS

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Education in Slovakia currently faces a new curriculum reform at all basic and secondary schools from 2009. It brings great changes to the educational system. There is currently a two-level model of Slovak school control. The state curriculum defines the basic principles and goals of education while the school curriculum gives schools an opportunity to meet the interests of the particular school and its students. In science education in particular, most attention is paid to scientific inquiry with emphasis on students' active independent learning. In order to meet these goals students should carry out activities that lead to the construction of new knowledge and the development of inquiry skills that they can use in other aspects of their lives. Especially in physics education, these activities are mainly connected to a wide range of experimentation at various levels of inquiry. However, these goals require providing teachers with materials that they can use in the class to support this way of teaching and learning. Regarding this fact we accepted the offer to participate in the international FP7 project ESTABLISH. The main idea of this project is to prepare materials and train teachers in order to enhance Inquiry-based science education (IBSE). Several of the activities on the topic of Sound developed within the project have been trialled in the classroom. This contribution presents the Slovak curriculum in physics with regard to IBSE and discusses the experience gained by implementing IBSE activities in the classroom.

INTRODUCTION

In Slovakia, there were just minor changes to the science curriculum for the last decades, up to 2008. At present science education faces a new huge curriculum reform that is running at all basic and secondary schools, starting from the school year 2008/09. The reform implies many changes concerning the organization of education as well as its contents. There is currently a two-level model of Slovak school control. The state curriculum defines the basic principles and goals of education based on the general Slovak educational policy while the school curriculum gives schools an opportunity to meet the interests of the particular school and its students. In science education in particular, most attention is paid to scientific inquiry with emphasis on students' active independent learning. In order to meet these goals students should carry out activities that lead to the construction of new knowledge and the development of inquiry skills that they can use in other aspects of their lives. In physics education in particular, these activities are mainly connected to a wide range of experimentation at various levels of inquiry. Application of inquiry-based science education (IBSE) assumes a change of teachers' attitudes towards the consistent use of interactive methods in the class. "Interactive Engagement" methods as defined by Hake (1998) are methods designed at least in part to promote conceptual understanding through interactive engagement of students in heads-on (always) and hands-on (usually) activities which yield immediate feedback through discussion with peers and/or instructors.

IBSE IN THE SLOVAK PHYSICS CURRICULUM

The content of the upper secondary education for the grammar schools (ISCED 3A) [3] is divided into 7 educational areas that include: Language and Communication, Mathematics and Information, Man and Nature, Man and Society, Man and Values, Arts and Culture, Health and Movement. The subject of physics (chemistry and biology) is part of the area called Man and Nature. The main objectives in physics education are determined within 6 areas, namely The World Around Us, Communication, Science Knowledge and Ideas, Scientific Inquiry, Data Processing, and Experimentation. In each area there are concrete goals specified that should be achieved at the end of the course. The last three areas clearly identify different elements of IBSE (see Table 1).

Table 1: Elements of scientific inquiry included in the Slovak curriculum in physics.

Scientific inquiry
▪ to formulate a problem/research question that can be answered by experiment, ▪ to formulate a prediction, ▪ to test a prediction, ▪ to plan an appropriate experiment, ▪ to formulate a conclusion according to observation and experimentation, to comment on measurement errors, ▪ to formulate the validity of conclusions based upon a series of measurements, ▪ to evaluate the overall experiment including the procedures used in it.
Data processing
▪ to organize, present and evaluate data in different ways, ▪ to transform data presented in a form into another form (including calculus, tables, diagrams), ▪ to identify possible trends in data, ▪ to create predictions based upon data, ▪ to suggest conclusions based upon data, ▪ to use knowledge to explain conclusions,
Experimentation
▪ to follow written or oral instructions, ▪ to select and use safely the experimental setup, materials, technology appropriate for measurement, ▪ to carry out the experiment safely, to record data gained by observation and measurement, ▪ to use appropriate tools and technology to collect data.

HOW DO SLOVAK TEACHERS CURRENTLY TEACH PHYSICS?

From Table 1 it can be clearly seen that scientific inquiry plays an important role in the physics curriculum. But to fulfil all these requirements is not an easy task, mainly because the traditional way of teaching is deeply rooted at a school system that worked for many years on the basis of lecturing complemented with lab work, with rare use of interactive methods. The successful and consistent implementation of IBSE requires a consonance of several elements: curriculum and instructional materials, well-educated teachers, student assessment tools, a positive atmosphere, and support for IBSE at schools.

Although the curriculum is now built on the basis of IBSE elements, the reform has halved the number of compulsory lessons per 4-year study from 10 to 5. This minimum number may be increased by additional lessons; however, it depends on the status of physics at school and the willingness of the school management to support science. Another important fact is related to the availability of teaching materials for teachers as well as students to support IBSE. The reform started without these materials, so teachers were left alone without any support and help in fulfilling the reform goals. As a result teachers either prepare these materials by themselves or use old textbooks and teach the old way. But this is not just about the teaching materials. The teacher, as a key element of the educational process, needs to be aware of the methods that should change from the traditional lecture + lab work methods with emphasis on knowledge and facts towards more interactive methods that promote conceptual understanding, active learning and regular feedback and discussion. The majority of Slovak teachers are not educated in this field, and as a result not much has changed in the way they teach. They usually teach less content the same way as before. On the other hand there are a number of enthusiastic teachers who regularly educate themselves within different projects that are currently running in Slovakia and participate at in-service training courses in order to learn about the up-to-date trends. Currently there are two key projects running trying to change the science education.

PROJECTS HELP TO PROMOTE IBSE IN SLOVAKIA

Within the Slovak national project Modernization of Education at Primary and Secondary Schools (2010-13) [4] there have been instructional materials enhanced by digital technologies prepared for several subjects, including physics [5]. 543 physics teachers participate in a 5-day course aimed at the use of IBSE methods enhanced by digital technologies. The project activities are supported by an e-learning platform offering a wide selection of instructional materials that teachers can use easily.

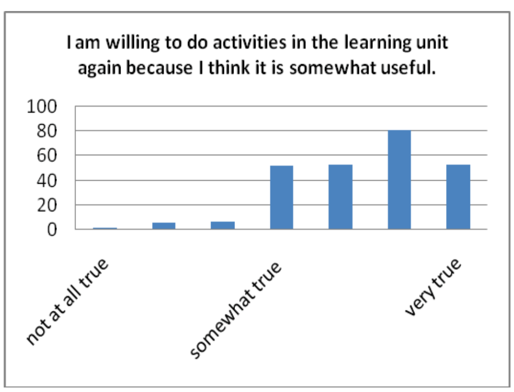
Within the FP7 project ESTABLISH (2010-13) [6], a consortium of partners from 11 European countries including Slovakia, instructional materials for teachers and students are currently being prepared. This is followed by teacher training in this field. In autumn 2011 there was an in-service physics teachers training running with 19 teachers of secondary schools who participated in a 4-day course (12 hours) to understand what and why to use IBSE in order to get familiar with the IBSE methods. Within the Sound unit there are IBSE activities designed with different levels of inquiry that teachers trained to carry out in the role of their students. Afterwards teachers were trialling at least 3 selected activities with their own students to get experience and feedback from the class.

PROJECTS HELP TO PROMOTE IBSE IN SLOVAKIA

Within the Slovak national project Modernization of education at primary and secondary schools (2010-13) (Modernizaciavzdelavania, 2012) there have been instructional materials enhanced by digital technologies prepared for several subjects, including physics (Ješková *et al*, 2010). 543 physics teachers participate in a 5-day course aimed at the use of IBSE methods enhanced by digital technologies. The project activities are supported by an e-learning platform offering a wide selection of instructional materials that are easy to use for teachers.
Within the FP7 project ESTABLISH (2010-13), a consortium of partners from 11 European countries including Slovakia, instructional materials for teachers and students are currently being prepared. The project also provides teacher training in implementing these materials. In autumn 2011 there was an in-service physics teacher-training course with 19 secondary school teachers who participated in a 4-day course (12 hours) to understand how and why to use IBSE in order to get familiar with the IBSE methods. Within the Sound unit there are IBSE activities designed with different levels of inquiry that teachers are trained to carry out in the role of their students. Thereafter the teachers trialled at least 3 selected activities with their own students to get experience and feedback from the class.

FIRST EXPERIENCE WITH IMPLEMENTATION OF IBSE ACTIVITIES

Within the Sound unit developed by ESTABLISH project there were several activities implemented in physics teaching. We present the pilot results from two classes (25 and 29 students) from two grammar schools (Kežmarok and Poprad) from the school year of 2011/12 when the following activities where tried out: Introduction to sound, Make sounds visible, How sound travels, How fast sound travels, Hearing sounds, How loud is too loud, Sound graphs, Sound signal analysis. All activities were carried out with strong emphasis on students' independent learning in groups of 2-3 supported by worksheets and digital technologies (data logging, smartphone, the programs Soundcard Scope and Audacity). After finishing all activities, students of both classes answered the questionnaire aimed at testing their attitude towards this way of teaching. We present the results of two selected question items. The results show their positive attitude towards this way of teaching (Figure 1). On the other hand, in the beginning there were some difficulties with the use of IBSE methods in terms of students' active learning. The problems appear in situations when students have to do something by themselves without exact and detailed instructions and control of the teacher. However, as lessons went on and students get more familiar with IBSE they were able to work more independently; it can be seen that the situation can be changed.



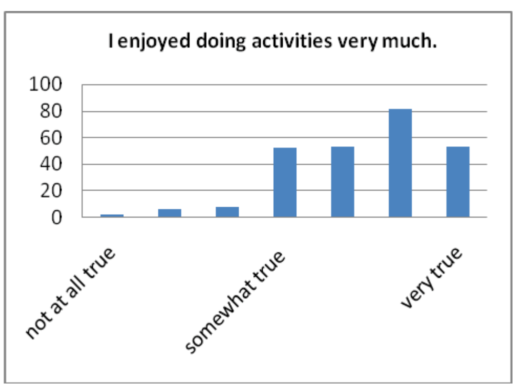


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Figure 1: Distribution of answers on two questionnaire items.

CONCLUSION

The key element of education is a well-educated teacher. The way (s)he teaches influences to a great extent the educational outcomes that include not only knowledge but also skills that students can use in their lives. For this reason much attention must be paid to the teachers' education and self-confidence in using IBSE methods. Running national and international projects can guarantee a strong support for successful IBSE implementation with an educated teacher mastering the corresponding methods.

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IMPROVING FEEDBACK IN PHYSICS TEACHING BY USING MULTIPLE-CHOICE TASKS

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Multiple-choice tasks are well-known tasks in science education. They are often used in test situations and several negative aspects have been reported in the literature. However, there are some other approaches to using this kind of tasks in physics teaching and learning than for testing the performance of learners. For example, Mie (2002) described several teaching and learning situations where multiple-choice tasks can be used easily in the classroom. The quick feedback of results and the interaction between the teacher and the whole class are two advantages of these tasks according to him. In contrast to the situation at college or university level, the empirical basis for the use of multiple-choice task in secondary level is very small. In this presentation we will report on a study with 8th grade students where multiple-choice items are used mainly in physics teaching with the primary purpose of improving the feedback.

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THE INFLUENCE OF ICT ON STUDENTS’ MOTIVATION TOWARDS PHYSICS

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In Slovakia we are currently facing a decreasing interest in science, and physics in particular. This fact results in low number of students who decide to take physics as an optional subject offered by the school curriculum at secondary level and as a consequence a decreasing number of students want to and are able to study sciences and polytechnical branches. The study analyses the situation at one of the prestigious grammar schools in Košice, Slovakia. It describes pedagogical research aimed at the implementation of interactive methods enhanced by ICT and its influence on students’ motivation towards physics. A number of different ICTs were applied in teaching (computer-based experiments and measurements, simulations and virtual experimentation, video analysis, modelling, students’ independent projects enhanced by ICT). However, it was not about ICT itself. A strong emphasis was put on the interactive methods used in the class. Within the pedagogical research that was running during two school years the hypothesis concerning the influence on students’ motivation towards physics was tested and verified. In the contribution there are the results of the research presented, analysed and discussed.

INTRODUCTION

Secondary schools in the Slovak republic have recently been facing a decreasing interest of students in Physics. Physics was not a popular course at the grammar school Šrobárova 1, Košice, Slovak republic, either. Low interest resulted in a small number of students who selected Physics as optional and graduation course.

The number of students who selected Physics as an optional course in the school years 2006/2007 to 2010/2011 fluctuated between 0-13 students, which represented 0% to 7% of the entire relevant student body. Physics as a graduation course was selected by 1-13 students, which represented 1% to 7% of the whole relevant student body.

In 2010 our grammar school was included in the national project Modernization of education at primary and secondary schools (Modernizaciavzdelavania, 2012). The main goal of the project was to introduce the teachers to effective use of different digital technologies using appropriate interactive methods in the classroom. Within the project teachers participated at in-service teacher training in order to master the interactive methods enhanced by ICT. Consequently we decided to change the current status at our school and carry out a pedagogical research and pedagogical experiment that would address the efficient use of ICT and implementation of interactive teaching methods.

Realization of the pedagogical research

The goal of the research was to change the current status of choosing the optional course for the school year 2011/2012 and graduation course for the school year 2012/2013 in favour of Physics. The following hypotheses were declared:

1. Hypothesis 1: If we implement ICT and interactive teaching methods efficiently, then we achieve a change in student interest in Physics.
2. Hypothesis 2: If we achieve change in student interest in Physics, then it results in an increased number of students selecting Physics as optional and graduation course.

In the research we focused on preparation and realization of:

1. a pedagogical experiment using ICT and interactive methods efficiently starting school year 2009/2010 to verify hypothesis 1.
2. a questionnaire in the run of the school year 2010/2011 to verify hypothesis 2.

During the research we verified the effect of the performed experiment. The research sample was represented by 145 second-grade students. The experiment was initiated in the first grade, school year 2009/2010 and continued in the second grade, school year 2010/2011.

In the second grade we administered a research questionnaire in order to find out whether efficient interactive education methods and using ICT could positively affect student interest in Physics as well as their decision to select Physics as optional and graduation course.

Performing the pedagogical experiment
The experiment was initiated in September 2009 in the first grade Physics courses. We started to use interactive teaching methods enhanced by a wide variety of ICTs in order to verify the hypotheses of our pedagogical research.

The initial motivation for the students was PowerPoint presentations done first by teachers, then by the students, about the significance of Physics related research at CERN, Switzerland. We used our experience from a field trip of Slovak teachers to CERN (UPJS, 2012). Presenting results of work done at CERN (Ješková, 2009) and its significance to humanity created an exceptional response among the students. Students themselves began to search for more information about CERN, created and gave presentations on CERN, its goals and its work, and on the development of the Universe and the Solar system.

During the experiment we used a highly efficient interactive method of computer supported laboratory measurement, the COACH system data logging. An example was the measurement of V-A characteristics of different elements. In the environment of the COACH system we performed video measurements and video analyses while teaching the students to discover and explore information. One of the examples is a video measurement and video analysis of uniformly decelerated motion of a cyclist when students worked according to the instructions in the worksheets (Ješková, 2007).

During the experiment we also used interactive lessons offered by the digital curriculum *Planet of Knowledge*, e.g. the interactive lesson on magnetic field (Planetavedomosti, 2012). *Planet of Knowledge* is an interactive educational system for different subjects with a wide variety of video recordings, simulations, interactive models and exercises, offered to support teaching. We also used interactive natural science simulations and virtual experiments to develop students' ability to search, select, examine and discover information. We used a simulation available in the Physics course book and online sources, e.g. simulations concerning electromagnetic induction designed at the University of Colorado (Colorado, 2012).

Method of dynamical modelling was introduced to students during interactive simulation of a skier motion on a ski slope (Koubek, 2007). With the help of a dynamical modelling technique students could solve rather complicated situations that require knowledge of higher mathematics. Using an appropriate computer program, the conditions of a skier's motion could be changed in order to study the real situation.

We required students to create presentations on a given topic to teach them how to present and share information.

Within the experiment we tried to make students think and work independently using interactive methods enhanced by ICT. We put much emphasis on a variety of methods and IC technologies in order to support students' active learning.

RESULTS

From November 22 to December 2, 2010 we administered a research questionnaire in order to verify the hypotheses. The questionnaire consisted of 9 multiple choice questions and was submitted by 145 students taking part in the experiment out of which 99 were girls (68.3%) and 46 were boys (31.7%).

In the questionnaire we inquired in which course interactive teaching methods and ICT are used the most. 133 students (91.7%) put Physics in first place.

Further we examined evaluation of attractiveness of Physics course and the influence of using interactive methods and ICT on student interest in Physics. 101 students (69.7%) consider the Physics course interesting, 38 students (26.2%) less interesting and 6 students consider Physics course not interesting (4.1%).

96 students (62.1%) claimed that interactive teaching methods enhanced by ICT increased their interest in Physics course, 44 students (30.3%) claimed their interest was not affected and according to 5 students (7.6%) their interest was decreased.

The following graph shows interest of students who took part in the experiment. It shows their interest in Physics as optional course in the year 2011/2012. Physics was selected by 44 students; this represents 30.3% out of all 145 students.

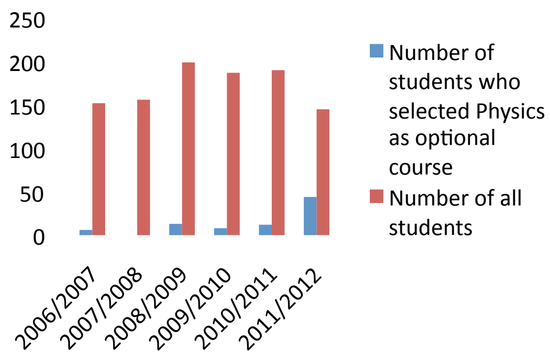

Figure 1: The graph shows number of students who selected Physics as optional course in relation to all students within six successive school years.

16 students (36.4%) claim that using interactive methods enhanced by ICT affected their interest in Physics positively, and because of it they decided to select Physics as optional course. 15 students (34.1%) selected Physics as graduation course in the school year 2012/2013 compared to 1-13 students in the previous years.

Based on the mentioned results we are able to declare that by implementing ICT and interactive methods Physics became an interesting course for the students. Interactive teaching methods enhanced by ICT are used in Physics course to their greatest extent compared to other courses and they help increase the interest of students in Physics which verifies hypothesis 1.

Changed interest in Physics resulted in increased interest in Physics as optional and graduation course. When making the decision the students were positively influenced by the fact that modern teaching methods were used, which verifies hypothesis 2.

CONCLUSION AND RECOMMENDATIONS

Currently we are able to evaluate the results of the experiment concerning the selection of optional course that has been selected by 33 students (23%) participating at the experiment. This percentage is three times higher than in the previous years.

15 out of 145 students declare their interest in physics as graduation course and this number is higher than in the school years 2006/2007 to 2010/2011.

The experiment has proven that interactive methods enhanced by ICT are an efficient tool to increase student interest and the research verifies both hypotheses. This work may well become a manual for teachers at other schools. We are pleased by the results of the research. The results demonstrate how important it is for teachers to educate themselves continuously in the area of modern teaching methods and means and their effective use in the class.

Moreover implementation of ICT into education process and efficient usage of interactive methods has helped create a big pool of students who will study Physics not as a mandatory course but solely based on their own interest. We have laid foundations for their further university study. We expect that universities will focus on further development of key competencies in the area of ICT of these future technicians, scientists and Physics teachers.

Based on the results of the performed experiment and research we advise to:

- continue the pedagogical experiment and further use interactive methods and cultivate key competencies of all students in the area of ICT

- use interactive methods enhanced by ICT as the means to increase interest in Physics as optional and graduation course
- focus on those students who selected Physics as optional course in the school years 2011/2012 in order to select Physics as graduation course in the school year 2012/2013 as well.

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SCIENCE ON STAGE TEACHER TRAINING COURSE IN SLOVAKIA

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Science on Stage (SoS) offers European teachers the opportunity to exchange successful and innovative teaching methods and materials. It is directed towards science teachers and students in Europe's primary and secondary schools. The project addresses the content and format of science teaching in European schools, seeking to improve the quality of teaching and to find new ways to stimulate students and children to take an interest in science. The National Steering Committees in the participating countries are responsible for organising national activities; they promote the overall project and are subservient to increase the teachers' interest in educational innovation. One of the way how to promote SoS activities on national level is teacher-training course for physics teachers, which is currently running in Slovakia with group of 30 physics teachers. The contribution presents the curriculum, selected activities and type of materials for teacher training course. They were selected and prepared with regard to the Inquiry-based science education (IBSE) approach by using ideas presented on Science on Stage events as well as own inventions. The strong emphasize was put on the sharing of the best school practices based on active student learning with accordance to the different level of inquiry activities.

BACKGROUND

Science on Stage (SoS) represents a European project initiated in 1999 with the aim to attract attention to science education problems associated with low scientific literacy as well as to seek solutions to the problems in European context. The project is being implemented by means of international science festivals held every other year in one of the participating countries. The festivals enable teachers, experts in education and science workers to meet in order to share experience in the area of innovative teaching methods, modernizing contents of education, popularizing sciences, and presenting current streams of scientific research, which, if transformed into teaching, should present students with the real picture of contemporary science and increase an interest in sciences among young people. The international festivals could not be held without national events that are held in all participating countries in different forms. Only the most enthusiastic of them usually participate in the festivals. Our aim is to promote the ideas and outputs of Science on stage activities among the widest possible teaching community and thus increase the impact of the events on science education in Slovakia. As a result we have prepared and been accredited a teacher training course, which from the point of view of its content represents the ideas, goals and educational activities carried out within Science on Stage events.

METHODS

It is possible to carry out the following kinds of courses within the system of continuous education in Slovakia:

- updating (20 - 60 lessons, final presentation and an interview)

- innovative (60 - 100 lessons, final presentation and an interview)
- specialization (100 - 160 lessons, defence of a thesis and an exam)
- functional (160 - 200 lessons, defence of a thesis and an exam)
- qualification (200 lessons or more, defence of a thesis and an exam)

SoS teacher training is an innovative education with the extent of 65 lessons (40 present and 25 distant) within which teachers participate at lectures given by specialists, SoS events, they carry out interactive experiment demonstrations and workshops focusing on training teachers´ skills. The distance part of the course is dedicated to studying information sources, web portals and preparing school research projects. Teachers also attend regional and national events of Science on Stage as well as visit scientific research institutions. At the end of the course teachers present their own school research project. That means that teachers design a set of activities for their students that can involve experiments, measurements, lab work or project-based activities at different level of inquiry. They design their own project and implement and trial it in the class. The most successful participants of the education have a chance to become the members of a national team at the international festival.

SCIENCE ON STAGE TEACHER TRAINING COURSE

Continuous education course content

The course syllabus consists of the following topics:

1. Introducing SoS idea – stimuli, key institutions and events, Slovakia participation in the international events.
2. Basic types of educational and popularization events characteristics – presentation in national stalls, workshop, stage presentation, excursion, importance of contact with scientific research workplace, discussion with experts, best stand presentation contest.
3. Selected educational and popularization events analysis – demonstrating a phenomenon by means of simple aids, science and technology around, innovation of learning aids and their use, computer supported measurement, pupil project, observation, measurement, scientific theatre, workshop.
4. Major Slovak scientific research workplaces – the system of scientific research workplaces in Slovakia, major workplaces in selected branches, an excursion at a scientific workplace, preparation, planning and implementation principles, excursion as an educational activity, samples of excursion pedagogical documentation.
5. School research project – aims and principles of implementation, where to look for inspiration, how to complete a project application, implementing a school research project, preparing a regional event presentation.
6. Regional and national Science on Stage Slovakia events – teachers’ participation in one of the events, presentation of a school research project, poster or oral presentation.
7. Final project presentation and interview with an interview panel.

Examples of educational activities – stand experiment

Stand experiments that teachers like presenting as demonstration experiments are particularly popular. From among a variety of ideas the following ones were presented: inductive cooker, hot air balloon model by means of a toaster, falling chimney, Archimedes’ screw and weighing air.

Figure 1: Examples of stall experiments used for teacher education (inductive cooker, Archimedes' screw).

For each of the experiments there is a short manual for teacher and a physical interpretation of the presented phenomenon. The experiments are recommended to use as interactive demonstrations in the class.

Examples of educational activities – school research project

In order to get students involved in learning as much as possible it is necessary to implement inquiry-based activities. Within the course we adopted the hierarchy of inquiry-based activities classified by the ESTABLISH project partners, namely interactive demonstration/discussion, guided discovery, guided inquiry, bounded inquiry, open inquiry. We presented examples of activities at different levels of inquiry that teachers carry out within the course, e.g. measurement of the refractive index of a liquid as a guided discovery activity, measurement of the thermal conductivity of solids as a guided inquiry type. These examples should motivate and inspire teachers to create their own activities to be designed and implemented in the class.

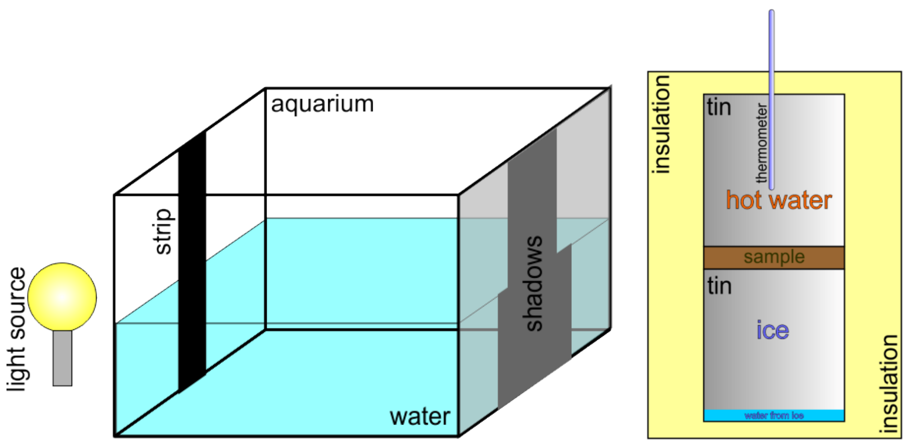

Figure 2: Measurement of liquid refraction index as an example of a guided discovery activity and measurement of substance thermal conductivity as an example of a guided inquiry activity.

Examples of educational activities – excursion

Leading European scientific workers, who by means of presenting the results of their work to teachers try to promote science among young people, take an active part in SoS events. In Slovakia, our effort is to promote science with the help of top scientific teams ranked as Excellence Centres in their research field. Teachers visited a Centre of Excellence Centre of low temperature physics, and became familiar with the possibility of observing structure by means of Atomic Force Microscope and solid state physics research and magnetism. Apart from that, teachers visited science popularization centre *The Palace of Miracles* in Budapest.

Figure 3: Excursion at the science popularization centre in Budapest (left) and scanning the structure of substances by means of Atomic force microscope (right).

Examples of educational activities – discussion with education experts

Teachers meeting significant personalities involved in science education create a wide space for experience exchange. International dimension of education issues can be a highly motivating element in the teachers' work. Within the course David Featonby from the Institute of Physics, England, gave a lecture on the physics education system and presented a *What Happens Next* workshop that was highly appreciated by teachers.

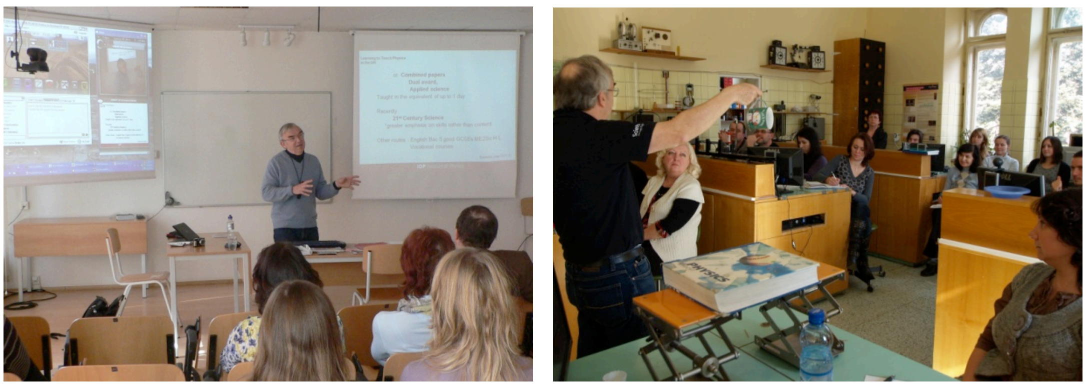

Figure 4: Lecture of David Featonby on the school system in England and What Happens Next workshop with examples of attractive physics experiments.

CONCLUSIONS AND IMPLICATIONS

The SoS teacher training course covers the characteristics of SoS events and presents a collection of ideas for different types of educational and popularization events. Currently there are 18 and 12 teachers of secondary and basic schools, respectively, involved in the course. The meetings take place at the Faculty of Science, P.J. Šafárik University in Košice; the distant learning part is organized under the LMS Moodle system. Financial support of the Slovak research and development agency is used to cover operational costs as well as to equip teachers for implementing school research projects. We are confident that after the course we will be able to find a group of other enthusiastic teachers and eager fans and supporters of SoS events.

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ESTABLISH project, available on <www.establish-fp7.eu>

INQUIRY-BASED VERSUS PROJECT-BASED METHOD OF TEACHING THE TOPIC PLASTIC

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The paper points out the significance of implementing inquiry-based activities for pupils' project work. Within the national project KEGA č . 027/2011 on the web page http://kekule.science.upjs.sk we are making accessible the digital library for doing chemistry projects of pupils. The digital library provides both teachers and pupils with educational sources needed for doing projects such as learning texts, suggested experiments on particular topics, proposals and outputs of projects and inquiry-based activities.

Plastic and plastic waste has been prepared as a pilot topic with inquiry-based activities. Project-based teaching based on implementing inquiry-based activities represents the method of teaching in which a teacher manages a pupil in a way similar to the one common in real research. The research characteristic of the teaching is manifested e.g. in the activity "Properties of plastic materials" in which pupils design experiments, formulate hypotheses, make conclusions and links with reality on their own. In these inquiry-based activities a supervised type of research is mainly used.

We have tested the digital library with inquiry-based activities in ten teachers of basic and grammar schools. The teachers claimed the library represented a useful digital aid for implementing projects. The accessible inquiry-based activities enable pupils to acquire necessary knowledge of plastic and plastic waste and at the same time develop their skills and competences stated in the State Educational Programme. According to the teachers pupils acquire more permanent knowledge and their interest in chemistry increases due to such an active approach to learning.

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“WHICH ENERGY SOURCE IS THE BEST?” - TEACHING RENEWABLE ENERGY

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The call for STEM-education comes together with the recommendation of collaboration between schools and companies, as well as academic institutions like universities or universities for applied sciences. However, everyday school situation does not make it easy to establish and keep this collaboration up and running and to make it fruitful for both sides. Research showed that a single visit in a company or an academic institution is not satisfying the needs, neither of the students nor of the visited institution. Visits should be prepared and integrated into science classroom teaching.

This presentation will show examples of fruitful and long lasting cooperation between schools and companies in Germany, and also in Finland. The approaches vary, but all are comparable in their intent to make science more relevant. We will provide data on how much students profit from the collaboration, and how the companies think about their engagement.

One aspect is the financial side of such connection. At least one example shows how much schools can also profit financially from such cooperation.

Finally, we will give tips and advice on what aspects will foster and what aspects hinder the establishment of new cooperations between schools and external partners. One example is a more playful attempt through a science competition like an egg race, including students, parents and companies.

THE PRE-SERVICE PRACTICE DURING THE MAJOR DEGREE APPRENTICESHIP PRACTICE

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National Council for Scientific and Technological Development (CNPQ)
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This study aimed to understand and analyze how undergraduate students of Biological Sciences manage student group in elementary school classes during their "practicum". Student group management (Gauthier *et al*, 1998) includes ways of solving problems related to class development, student behaviour, and learning progress, among others. The study was done with a case study and a questionnaire applied to Biological Science students of three different universities in the state of São Paulo, Brazil. Three student teachers of the course "Methodology for Teaching Biological Sciences II" from ESALQ-USP participated in the case study. Their classes for 6th grade in a public school in Piracicaba were registered and analyzed. The results showed that students have difficulty with group management in real situations, especially because they seemed to consider management as something less important than class content – which was considered the absolute priority. Five different ways of student group management were found and almost none showed co-participation teacher-student in the management process. The main tendency was heteronomy. Some disparities were noted between situations observed and answers questionnaires. Disparities indicate that attitudes previously formulated are not used in practice in many situations. The participants of this study considered "practicum" a positive experience despite their difficulties in relation to student group management.

INTRODUCTION

Nowadays one of the major concerns is improving education, for this goal, forming good teachers is indispensable. Teaching is a complex work and this challenge is even bigger with no experience, as is the case of undergraduate students. It is during the apprenticeship practice that the future teacher will acquire knowledge that makes up his reference framework for the profession (Mizukami, 1996 cited in Lopes, 2010).

Knowledge about teacher education allows learning the elements that characterize the work inside the classroom. Subject and group management (Gauthier *et al*, 1998), the basis of the analysis of this work, are two aspects of work that relate to action in the classroom in which the pre-service students must develop their own professional knowledge.

According to Doyle (1986, cited in Gauthier *et al*, 1998), group management consists of rules and provisions set to create and maintain an orderly environment conducive to both teaching and learning. Their planning is characterized by taking decisions on the selection, organization and sequence of routine activities. Class management is necessary for learning, but it is no guarantee of success. It is important to study these practices in the classroom occurring during the apprenticeship practice; both for educational research and to find tools that might delimit a reflection of undergraduate students of their role and allow them to improve themselves.

METHODOLOGY

The first part of the study contemplated a case study with observation inside the classes of three pre-service student teachers of the course "Methodology for Teaching Biological Sciences II" from "Luiz de Queiroz" College of Agriculture (ESALQ) of the University of São Paulo (USP), Brazil. The second part consisted of a questionnaire applied to Biological Science students of three different universities in the state of São Paulo, Brazil.

After the presentation of this study in the course three students accepted to participate. The case study was done in a public elementary school in the city of Piracicaba, São Paulo, Brazil, with three classes of 6th grade students. The actions related to group management were recorded in a notebook, and at the end of each class, a general impression of the class was registered. Observations were made so that the observer influenced the least possible on the classroom environment.

During a second phase a questionnaire was designed for students in undergraduate Biological Sciences courses taking internship courses (teaching practice or similar) in order to confirm the features observed in the case study and to recognize new information about how licensees deal with class management. The questionnaire was answered by students from three universities in the state of São Paulo; one of them answered the questionnaire virtually (available on the website https://spreadsheets.google.com/viewform?hl=en&pli=1&formkey=dFBCWTJ2Y3FtNm1HdTdidWVOeTJTLUE6MQ).

RESULTS

Case Study

Nineteen lessons of the three pre-service students were observed, seven of Anne, six of Clara and six of Linda[1]. In general, they were committed to their work and secure about the content to be covered in the lesson prepared. Furthermore, they were worried about group management, exchanging ideas among themselves and remembering teachings of their previous university classes. Each one led the practice in her own way, although we could point to common trends in group management.

Most of the classes happened in a different classroom, they were done in a special classroom prepared for the use of video equipment as data show and the slideshow was the most used resource. All the pre-service students taught classes about vertebrates – Reptilia, Aves and Mammalia – each one with a subject.

The forms of action of three pre-service were organized so as to form groups of five major trends of action. Here we will specify three of these groups were defined as follows:

1. Behaviourist actions to perform group management;

   The pre-service teacher uses a "prize" as a reward for good behaviour in class. Or inversely, uses punishment for behaviour seen as inadequate, saying, for example:

   > Guys, the next one speaking will be sent out of the classroom, next time I won't say anything, the person will be out of the next class in the video room! (Anne).

   These actions were seen as based on the behaviourist theories, which defend a stimulus-response as a form of behaviour control.

2. Heteronomous actions to perform group management;

   This was the most remarkable feature of the observed practice regarding group management. It was noted that the interference from other school staff is tolerated (and even desired) to maintain the organization and pace of the class (especially Linda, who almost only performed this type of management). To manage the group,

[1] The teachers' names were changed for the sake of anonymity.

one of the teachers did not interfere in the classes of the pre-service teacher while the other did, however, neither interfered with subject management.

According to Therrien & Loyola (2001), the task of teachers is a subtle balance between rules and autonomy, and that balance explicitly defines the margin of freedom and the pedagogical relationship between the components of the conception and implementation.

3. Actions aimed at maintaining or modifying the sound environment to attract attention;

For example, when the pre-service teacher, to get the attention of the class uses facial expressions, changes the tone of voice during theoretical explanation (speaks louder), or performs, for the same purpose, small movements, such as clapping, banging on the table, closing the door of the classroom.

Group management on the questionnaire

During the second phase of the research a total of 34 questionnaires were collected from the three universities, representing all the students present in class on the day of application in Universities A and C, representing approximately 28% of all students attending the course on teaching methodology of University B, which responded virtually. Respondents confirmed a predominance of expositive classes among those they ministered during the apprenticeship practice.

Here we condensed the results of the questionnaire. By analyzing the answers of the questionnaires we can recognize that students from the disciplines of teaching methodology, as well as the pre-service teachers observed in the case study, appear to be concerned with group management. In the questionnaire the pre-service teachers indicate to be more concerned with subject management when asked about their biggest preoccupation.

The pre-service questionnaires indicate the use of actions that create bonds with students and the use of subject management when students talk during class, while in the case study we had a dominance of heteronomous actions to group management – largely ceding to the help of school staff. The questionnaires also indicate that the pre-service teachers do not worry about the physical layout of the classroom, an aspect that was seen to be very important in the case study because the students were more agitated in the video room – where they were closer to each other and the environment was darker than usual – than in the regular classroom.

The questionnaire answers corroborated in one part with the results of the case study and in another part were different. This indicates some mismatch between intention and action. Possibly the action of the pre-service teachers in the case study was based on habits or routines already experienced as a student, whose strength has been a challenge to form teachers. Tardif (2002) indicates that the beliefs prior to formation course are often activated by the teachers to solve problems when they teach and the baggage of prior knowledge about teaching practices, such as beliefs, representations and uncertainties make up most of the devices introduced and the initial practice cannot change or affect them.

CONCLUSION

In both parts: case study and questionnaire, it became clear that the major concern of the pre-service teachers during the undergraduate apprenticeship practice is subject management. Thus, group management became just a discomfort inside the classroom.

The case study has indicated to us the difficulty of the pre-service teachers on the study to transform the theory viewed in their university courses into practice. The problems with group management were solved more frequently with behaviourist actions, with rewards or punishments for students (who came to sending the child to the principal or failing to complete the planned lesson) or heteronomous actions (where maintaining classroom discipline was delegated to others, for example, the student inspector). It would be necessary to develop actions that could provide new forms of teaching as a way to raise the students' education in an environment of co-responsibility for school and learning. This disparity between what was observed in practice, case study and questionnaire answers may be due to a prolonged opportunity for reflection and projection of actions allowed in answering a questionnaire, and the momentary reactions are not based on the ideal envisioned by the pre-service teachers.

It would be necessary to develop actions that could provide new forms of teaching as a way to raise the students' education in an environment of co-responsibility for school and learning as a didactic contract.

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AN ACTION RESEARCH PROJECT TO IMPROVE TEACHING AND LEARNING OF ORGANIC CHEMISTRY IN SECOND-LEVEL SCHOOLS

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In 2010 a study was carried out in Ireland involving Second-Level pupils and teachers to investigate the areas of difficulty in Leaving Certificate Organic Chemistry (O'Dwyer & Childs, 2011). An intervention programme called *Organic Chemistry in Action!* was developed using these findings and those from Chemistry Education Research (CER). This intervention programme is a research-based resource designed to facilitate the teaching and learning of Organic Chemistry. The intervention materials were designed with specific reference to the current Irish Leaving Certificate Chemistry syllabus (DES, 1999). However, the materials are adaptable for use with introductory Third-Level Organic Chemistry and the proposed new Leaving Certificate Chemistry syllabus (NCCA, 2011).

This programme was trialled in 6 Second-Level schools in Ireland with 87 pupils. Feedback from the participants (teachers and pupils) as well as comparison with a Control Group using the traditional approach in 9 schools (117 pupils) was used to evaluate the intervention. The findings show that the programme had positive effects on the pupils' attitudes, interest and understanding of Organic Chemistry. The success of the intervention programme showed that it is possible to integrate innovative teaching strategies in Irish Leaving Certificate classrooms. However, the feasibility of such alternative teaching methods is limited by the restriction of the current curriculum and the focus on examination results in current Senior Cycle classrooms

INTRODUCTION

The difficulties of Organic Chemistry have been investigated and researched in many other countries. Organic formulae (Johnstone, 2006), curved arrow diagrams (Bhattacharyya & Bodner, 2005, Ferguson and Bodner, 2008), mechanisms (Rushton *et al*, 2008) and laboratory classes (Greenbowe and Schroeder, 2008) have all been identified as difficult topics. Many innovative teaching programmes have been implemented effectively in other countries to alleviate the difficulties identified in Chemistry. Examples include context-based programmes (Bennett and Lubben, 2006; Parchman *et al,* 2006) and programmes to facilitate cognitive development (Adey, 1999) amongst other initiatives.

The *ITS Chemistry* (Increasing Thinking Skills in Chemistry) programme was designed to facilitate the teaching of Irish Leaving Certificate Chemistry. This programme focused on the concepts of the mole and the particulate nature of matter. It was effective in improving pupils' cognitive ability and understanding of Chemistry (Sheehan, 2010).

Organic Chemistry accounts for a substantial amount of the Leaving Certificate Chemistry syllabus (20%) and examination (25%). However, there has been no explicit research carried out investigating the difficulties experienced by Leaving Certificate pupils in their learning and understanding Organic Chemistry.

METHODOLOGY

The project was carried out in two cycles. Cycle One of the project involved an investigation at Second-Level involving Leaving Certificate Chemistry teachers and pupils. From this investigation a number of key topics were identified as difficult in Leaving Certificate Organic Chemistry: IUPAC Nomenclature, Functional Groups, Characteristics of Organic Compounds, Reaction Types, Reaction Mechanisms and Practical work (O'Dwyer & Childs, 2011). Cycle Two involved the development, implementation and evaluation of an intervention programme in Irish Second-Level schools programme to address the issues identified in Cycle One.

The *Organic Chemistry in Action! (OCIA!)* programme was developed using the findings from Cycle One of the project and also from the relevant findings in CER. The ten key design criteria used in the development of the programme are outlined in Figure 1 (O'Dwyer & Childs, 2012). The programme was designed to cover the content of the current Leaving Certificate Chemistry syllabus (DES, 1999). Teaching and learning strategies were integrated with the design criteria with a specific focus on the relevance to the areas of difficulty that were identified by teachers and pupils in Ireland.

The *OCIA!* programme was implemented in 6 Second-Level schools with 87 sixth year Leaving Certificate Chemistry pupils. A Teacher Guide, Pupil Workbooks and Teacher Resource Kit containing all the necessary resources to implement the programme were provided for each of the participating teachers.

Figure 1: Ten Design Criteria for the *Organic Chemistry in Action!* programme.

The *OCIA!* programme was evaluated using three lenses: the participating teachers, participating pupils and through comparison with a Control Group. The Control Group were 117 sixth year Leaving Certificate Chemistry pupils from 9 different schools, who had been taught Organic Chemistry in the traditional manner. A combination of qualitative and quantitative methods was used to gather data from the participating pupils and teachers. The same Organic Chemistry Test for Understanding was given to both cohorts of pupils at the end of their study of Organic Chemistry.

RESULTS

Due to the multi-faceted nature of the programme, it is difficult to determine which criterion contributed most to the improvement in pupils' attitudes, interest and understanding of Organic Chemistry. The main feedback from the participating teachers is shown in Figure 2 below. The most effective design criteria are identified. Most of the teachers' concerns about the programme, were issues relating to deviation from syllabus content and concern about examination preparation.

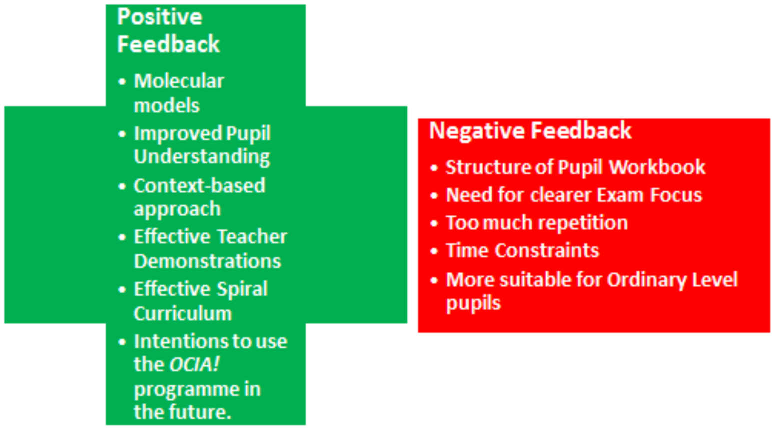

Figure 2: Summary of positive and negative feedback from participating teachers in the *Organic Chemistry in Action!* Programme.

The *OCIA!* programme had a significantly positive effect on females as well as on pupils who had studied Higher Level Junior Certificate Mathematics and those that were studying Higher Level Leaving Certificate Chemistry.

The Control Group of pupils had a stronger background in Science and Mathematics from their Junior Certificate. Despite this, the pupils in the Intervention Group performed better (median score=49.00%) than the pupils in the Control Group (median score=44.75%) in the Test for Understanding. A significantly higher percentage of the Intervention Group (70.0%) than Control Group (51.3%) enjoyed studying Organic Chemistry ($\chi^2(3)=8.853$, $p=0.012$). More of the Intervention Group than the Control Group found Organic Chemistry in the Leaving Certificate Chemistry course easier to learn (49.0% vs. 37.6%) and one of the most interesting areas of the course (66.0% vs. 51.3%). On a five-point Likert scale, pupils in the Intervention Group rated the following Organic Chemistry topics as significantly easier to learn than the pupils in the Control Group: Drawing, Isomerism, Classification, Addition reactions, Substitution reactions, Elimination reactions, Redox reactions and Carboxylic acids.

Pupils in the Intervention Group were more confident about attempting an Organic Chemistry question in their Leaving Certificate examination and these pupils also performed better (median score=7.0) than the Control Group (median score=6.0) on a past examination question included in the Test for Understanding. This provides evidence that the *OCIA!* programme was effective in preparing the pupils for the terminal examination as well as improving attitudes, interest and understanding.

CONCLUSION

The results indicate that this inquiry-based approach, based on ideas from CER which also aimed to develop cognitive skills and to relate Chemistry to real contexts, was successful in addressing, in part, some of the difficulties in teaching and learning Organic Chemistry at second level.

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SURVEYING PRIOR CONCEPTUAL UNDERSTANDING OF DIRECT CURRENT RESISTIVE ELECTRIC CIRCUITS OF FIRST YEAR STUDENTS IN ELECTRICAL ENGINEERING: AN UPDATE

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There is an increasing diversity of educational background of students entering Level 7 and Level 8 programmes in engineering in Irish third level education. Student reasoning about basic electricity concepts often differs from accepted explanations. The paper reports, analyses and reflects on the results of a multiple-choice diagnostic test to assess student understanding of such concepts (developed by Engelhardt and Beichner (2004) for U.S. high school and college students) taken by four cohorts of students, on the same DIT Level 7 engineering programme, from 2008-12 (*n*=106) and two cohorts of students, on the same DIT Level 8 engineering programme, from 2010-12 (*n*=64). This paper updates a previous contribution (O'Dwyer, 2009) that described the application of the test to two cohorts of Level 7 students in the 2008-9 academic year.

BACKGROUND

The author has had responsibility for instruction, at various times since 2004, of direct current resistive electrical circuits in modules in the first year of the three-year, Level 7, DT009 programme in electrical engineering, and the four-year, Level 8, DT021/DT081 programme in electrical/computer engineering, at Dublin Institute of Technology (DIT). Many aspects of direct current resistive electrical circuits are introduced to students in the early cycle of second level education. For example, the Junior Certificate Science Syllabus (NCCA, 2003), advises, amongst other skills, that students on completion of the subject should be able to "set up a simple electric circuit, use appropriate instruments to measure current, potential difference (voltage) and resistance, and establish the relationship between them"; "demonstrate simple series and parallel circuits containing a switch and two bulbs"; "define and give the units for work, energy and power, state the relationship between work and power, and perform simple calculations based on this relationship". These areas are covered well in popular second level books and workbooks (*e.g.* Henly and Quirke, 2003a; 2003b). These skills are further developed should students study Physics or (more rarely) Physics and Chemistry to Leaving Certificate level. Of the Level 7 students who replied to a survey conducted by the author from 2008-11 (*n*=80), 45% of students sat a subject in which direct current resistive electric circuits were treated in detail (typically Physics or Physics and Chemistry in the Leaving Certificate); 77% of Level 8 students who replied to a survey from 2009-11 (*n*=56) had done likewise.

However, many students struggle with the topic, with students' reasoning about basic electrical concepts often differing from accepted explanations. The author has noticed in intensive teaching that this appears to apply to students of all previous educational backgrounds in the topic. This is an international phenomenon, with Engelhardt and Beichner (2004), for example, reporting that U.S. high school and university students have similar conceptual difficulties, even after instruction in the subject. These authors supply a 29 question multiple-choice test, which they label the Determining and Interpreting Resistive Electric Circuits Concept Test (DIRECT), to tease out student misconceptions; a sample of questions from the test is provided in the appendix. They assess the test for validity and reliability, and provide detailed data regarding experiences of testing 1135 students, 681 at university level and 454 at high school level.

The author applied this test to four cohorts of students, on the same DIT Level 7 engineering programme, from 2008-12 (n=106), and two cohorts of students, on the same DIT Level 8 engineering programme, from 2010-12 (n=64). The test duration is 30 minutes. The test was taken by the students at the start of instruction in the topic, and was not flagged in advance. This meant that the author could identify the nature of student misconceptions prior to material being covered in the lecture and laboratory environment, allowing the misconceptions to be addressed.

ANALYSIS

The data from the test was analysed in a number of ways. Table 1 compares the mean value of correct answers for the DIT student cohorts to a student cohort detailed by Engelhardt and Beichner (2004). The US high school students had completed relevant learning prior to taking the test.

Table 1: Mean value of correct answers (in percentage) of student cohorts.

Student cohort	**%**	***n***
DIT, Level 7, Year 1, 2008-12	42	106
DIT, Level 8, Year 1, 2010-12	42	64
High school students (USA)	41	454

Clearly, the performance of all student cohorts is approximately the same. Interestingly, there is no difference between the mean performance of Level 7 and Level 8 student cohorts, even though, for example, of the students who took Physics or Physics and Chemistry in the Leaving Certificate, a much greater percentage of Level 8 students (89%; n=28) than Level 7 students (47%; n=57) completed the higher level course. Other work performed by the author has shown that there is no statistically significant relationship between an individual's results on the DIRECT test and associated Leaving Certificate Physics or Physics and Chemistry grades (when converted to CAO point scores). Clearly, there is an unexpectedly low benefit, on average, for student understanding of concepts in electricity after students complete the Physics or Physics and Chemistry Leaving Certificate curriculum.

On the other hand, there is a highly statistically significant, weakly positive correlation between the performance in the DIRECT test and, respectively:

- Semester 1 examination performance in the Electrical Principles subject, for the Level 7 cohort of students, from 2008-12 (n=92, p<0.001, r=0.36).
- Terminal examination performance in the Electrical Principles subject, for the Level 7 cohort of students, from 2008-11 (n=66, p<0.001, r=0.46).

However, there is no statistically significant relationship between performance in the DIRECT test and, respectively:

- Semester 1 examination performance in the Electrical Systems subject, for the Level 8 cohort of students, from 2010-12 (n=54, p>0.05, r = 0.00).
- Terminal examination performance in the Electrical Systems subject, for the Level 8 cohort of students, from 2010-11 (n=29, p>0.05, r = -0.08), though this sample size is small.

More work is required to determine the reason for the differences in the experiences of Level 7 and Level 8 students summarised above. Based on this data, the DIRECT test does not reliably predict students who may be in danger of failing their Year 1 examinations in the relevant subject; such a predictive capability would be useful, as it would allow targeting of learning resources to these students in particular.

More detailed analysis on the answers to individual questions is available from the author. Table 2 shows how well the Level 7 (*n*=27) and Level 8 (*n*=39) cohorts of students, in the 2010-11 academic year, performed on each of the instructional objectives that the test was designed to measure; data for Level 7 students are in brackets.

Many of the objectives listed in Table 2 are compatible with the desired learning outcomes of the Junior Certificate Science programme, in particular (NCCA, 2003). It is clear that the concept of current, in particular, causes difficulties for students.

Table 2: Mean value of correct answers (in percentage) of DIT student cohorts.

Objective	Question	%
Physical aspects of DC electric circuits (objectives 1-5)		**49 (40)**
1. Identify and explain a short circuit	10, 19, 27	45 (48)
2. Understand the functional two-endedness of circuit elements	9, 18	54 (44)
3. Identify a complete circuit	27	48 (44)
4. Apply the concept of resistance	5, 14, 23	41 (36)
5. Interpret pictures and diagrams of a variety of circuits	4, 13, 22	59 (45)
Energy (objectives 6-7)		**53 (50)**
6. Apply the concept of power to a variety of circuits	2, 12	52 (62)
7. Apply a conceptual understanding of conservation of energy	3, 21	54 (38)
Current (objectives 8-9)		**21 (23)**
8. Understand and apply conservation of current	8, 17	32 (44)
9. Explain the microscopic aspects of current flow	1, 11, 20	13 (9)
Potential difference (voltage) (objectives 10-11)		**42 (36)**
10. Current is influenced by potential difference and resistance	7, 16, 25	77 (60)
11. Apply the concept of potential difference to a variety of circuits	6, 15, 24, 26, 28, 29	25 (37)

THU 18.00 - 19.00

CONCLUSIONS

The author describes experiences of using the Determining and Interpreting Resistive Electric Circuits Concept Test to evaluate and analyse the level of conceptual knowledge of basic electricity ideas of a number of cohorts of first year Level 7 and Level 8 engineering students. The author agrees with the conclusion of Engelhardt and Beichner (2004), that the test has potential "in evaluating curriculum or instructional methods as well as providing insight into students conceptual understanding of d.c. circuit phenomena". Identifying the misconceptions and difficulties determined by the test allows explicit addressing of these problems in the learning environment. The work reported in this paper has been restricted to particular engineering student cohorts but could be applied more widely to Irish students studying basic electricity in science and engineering programmes in second level and third level education.

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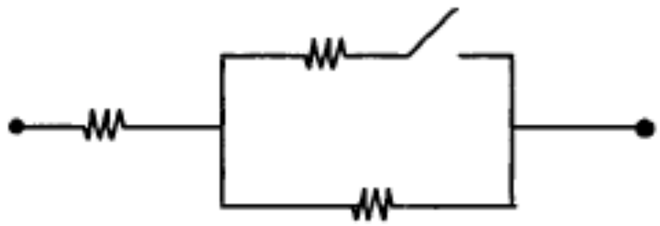
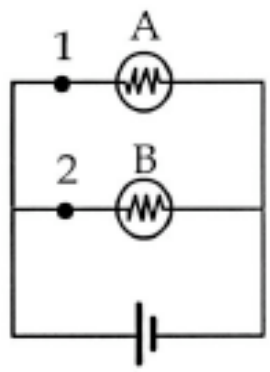
APPENDIX: SAMPLE OF QUESTIONS FROM THE DIRECT TEST

Q14. How does the resistance between the endpoints change when the switch is closed ?



(a) Increases (b) Decreases (c) Stays the same

Q19. What happens to the brightness of bulbs A and B if a wire is connected between points 1 and 2 ?



(a) Increases (b) Decreases (c) Stays the same

(d) A becomes brighter than B (e) Neither bulb will light

Q11. Why do the lights in your home come on almost instantaneously ?

(a) Charges are already in the wire. When the circuit is completed, there is a rapid re-arrangement of surface charges in the circuit.

(b) Charges store energy. When the circuit is completed, the energy is released.

(c) Charges in the wire travel very fast.

(d) The circuits in a home are wired in parallel. Thus, a current is already flowing.

COMPARISON OF EXAMINATION PERFORMANCE IN MATHEMATICS, PHYSICS AND ELECTRICITY OF FIRST YEAR, LEVEL 7 STUDENT COHORTS IN ELECTRICAL ENGINEERING

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This contribution reports on the highly statistically significant relationship ($p < 0.001$) established in student examination performance in the three central scientific subjects in a Level 7, Year 1 engineering programme at Dublin Institute of Technology. A range of data is taken over seven academic years (from 2005-12 inclusive). Recommendations for learning and teaching as a result of this analysis are proposed.

BACKGROUND

The three-year, Level 7, Bachelor of Engineering Technology degree in Electrical and Control Engineering of the Dublin Institute of Technology (DIT) educates students for careers in Ireland's electrical power, automation, robotics, pharmaceutical and manufacturing industries (DIT, 2012). The predecessor of this course was established in September 1967 as a result of discussions between the then Kevin St. College of Technology with the Electricity Supply Board (ESB), regarding their future requirements for technician engineers. The first students were recruited from both clerical and technical departments within the ESB. In 1967, the College's prospectus stated that the first year of the course covered the subjects Mathematics, Physics, Electricity, Drawing, Materials and Processes and General Studies; it was planned that later years would deal with electrical equipment, machines, materials and techniques together with appropriate instruction in the background sciences and industrial practice. The course description is similar to what it was forty-five years ago; the changes are in the details of the "electrical equipment" (O'Dwyer, 1997).

Such technician programmes are now referred to as Level 7 programmes; candidates apply for such programmes (in common with all higher education programmes) through the Central Applications 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; the minimum points level for the programme was 185 in 2009 (CAO, 2009b), with a median points level of 265 (DIT, 2010). 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, between 25 and 35 learners commence the degree programme, the majority of whom 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 in Ireland) and a further small group of international students.

Considering the first year of the current programme, the three central scientific subjects of Mathematics, Engineering Science and Electrical Principles map onto the corresponding subjects of Mathematics, Physics and Electricity proposed in 1967. Since 2005, the author has had responsibility for development, instruction and assessment in the present version of the Electrical Principles subject and, more widely, has been Year 1 tutor with a broad responsibility for student learning in all subjects.

DESCRIPTION

Considering the three central scientific subjects, they are each divided for learning into two thirteen-week semesters; in each semester, students attend five structured learning hours in each subject each week (three hours lectures and two hours tutorials in Mathematics; two hours lectures, two hours laboratories and one hour tutorial in the other two subjects). The subjects are assessed in the following manner:

- Module examination (12.5% of the subject mark for all subjects), held after the completion of the first semester.
- Terminal examination (75% of subject mark for Mathematics, 50% of the subject mark for the other two subjects), held after the completion of the second semester. This examination has a compulsory question and five other questions, three of which are to be attempted.
- Continuous assessment, based on laboratory and student project work, makes up the remainder of the Engineering Science and Electrical Principles subject credits.

EXAMINATION PERFORMANCE RELATIONSHIPS

For the three subjects, the relationships between individual student performances in the module examinations are studied for the four academic years from 2008-2012 inclusive; for the terminal examinations, relationships are studied for six academic years from 2005-2011, inclusive. A summary of this work is as follows:

- There is a highly statistically significant, positive correlation between performance in the Electrical Principles and Engineering Science subjects, in the module examination ($n=115$, $p<0.001$, $r=0.68$).
- There is a highly statistically significant, weakly positive correlation between performance in the Electrical Principles and Mathematics subjects, in the module examination ($n=115$, $p<0.001$, $r=0.40$).
- There is a highly statistically significant, positive correlation between performance in the Electrical Principles and Engineering Science subjects, in the terminal examination ($n=159$, $p<0.001$, $r=0.73$).
- There is a highly statistically significant, positive correlation between performance in the Electrical Principles and Mathematics subjects, in the terminal examination ($n=153$, $p<0.001$, $r=0.65$).

The weakly positive correlation determined between the Electrical Principles and Mathematics marks for the module examinations is largely due to poor student performance in Mathematics in the 2011-12 academic year; this requires further study.

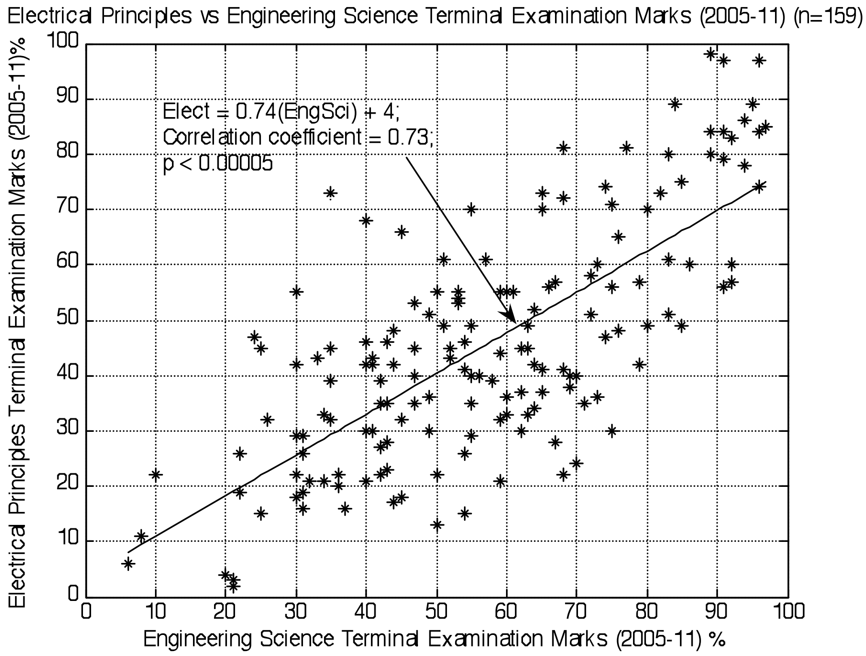

Figure 1: Relationship between the terminal examination marks for Electrical Principles and Engineering Science (Physics) 2005-11.

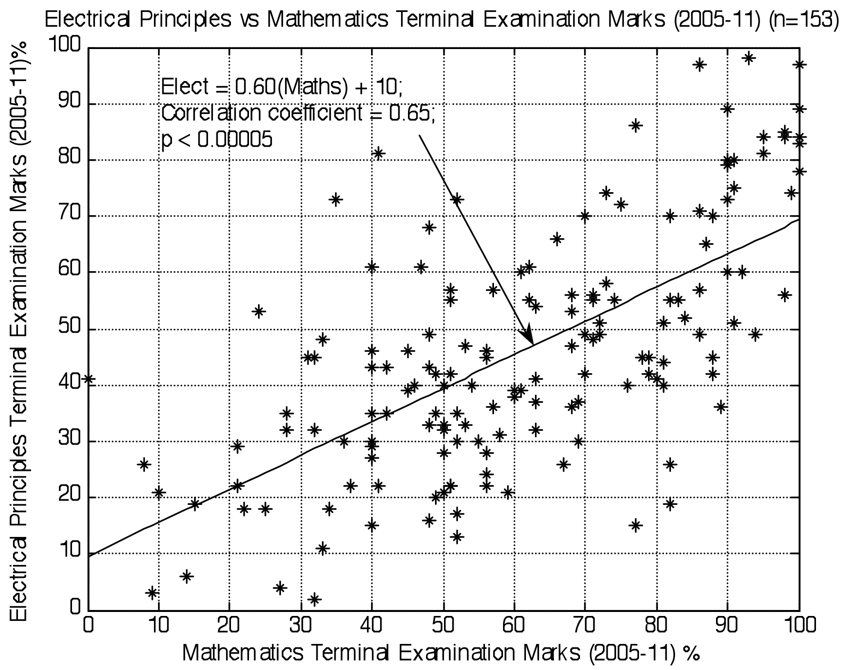

Figure 2: Relationship between the terminal examination marks for Electrical Principles and terminal examination marks for Mathematics 2005-11.

Figures 1 and 2 show the relationships between subject terminal examination performances summarised above.

CONCLUSIONS

The author has taken an evidence-based approach to examining student performance, in the module and terminal examinations, on the core subjects in the first year of a three-year, Level 7, degree programme in Electrical Engineering at Dublin Institute of

Technology over the 2005-12 period. The conclusions of this work are that there are highly statistically significant relationships between student module and terminal examination performances in these core subjects.

Mean student assessment performance in these core subjects remains disappointing. In the 2012-13 academic year, the author will take the following actions with the aim of engaging students more deeply in the subjects:

(1) In the first classroom session, the learning outcomes of the individual subjects will be explained in detail. In addition, the author will continue to communicate to students the statistically significant relationships between assessment performance and lecture attendance that has been reported in other work (O'Dwyer, 2011).

(2) Throughout the lecture programme, regular formative assessments, perhaps with the aid of clickers, will be encouraged; preliminary work on a pilot study carried out by the author has revealed that such formative assessments have improved student performance in achieving some learning outcomes in the Electrical Principles subject over the past three academic years.

(3) Further active learning techniques, including more structured mini-projects, will be proposed.

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THE ELEPHANT IN THE ROOM: IRISH SCIENCE TEACHERS' PERCEPTIONS OF THE PROBLEMS CAUSED BY THE LANGUAGE OF SCIENCE

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The language of science is a problem that students face in both second and third level education. Wellington and Osborne (2001) claimed that "language is a major barrier (if not the major barrier) to most pupils in learning science" (p. 2). Science has its own language and difficulties presented in acquiring and understanding the language act as barriers for many pupils. However, to-date in Ireland, little research has been conducted into the problems caused by language in the teaching and learning of science at second level.

The purpose of this paper is to examine the level of awareness of Irish science teachers of the problems that the language of science poses to their pupils. This preliminary work also identifies whether teachers have experienced any of these problems and assesses if and how they respond to the problem(s) created by the complex and multi-faceted nature of the language of science.

Improving the quality of second level science education is vital to producing Ireland's 'knowledge economy' and scientifically literate citizens. The old proverb says that given a fish, one can eat for a day; taught to fish, one can eat for a lifetime. We cannot improve second-level science education without addressing the underlying problem of scientific language, as language is a major barrier for many students in understanding and enjoying science in the junior cycle. Helping students to master the language of science enables them to become fishers themselves, with a lifetime thirst for knowledge and the skills to seek and learn on their own (Staver, 2007).

THU 18.00 - 19.00

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ADAPTING CASE LESSONS FOR THE IRISH CURRICULUM

Susan Ryan and Odilla Finlayson

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Getting teachers to change their teaching methodology is not an easy task. Teachers are individuals and therefore there is no standard format or recipe to follow that will prove successful for everyone. There are many factors that influence how often and by which approach a teacher teaches science. These include a teachers' attitude towards science, their background in science education and their confidence in their own science content knowledge. While this is evident for all teachers, there is a particular issue with primary level teachers in that while they may have a positive attitude towards science, generally their background and confidence in their own science content knowledge can be very limited.

In this study, the CASE methodology was selected as the emphasis is on the development of scientific thinking skills in the students rather than merely scientific content knowledge. While CASE was developed for the UK curriculum, the strands can be adapted for the Irish primary level curriculum, focusing particularly on meeting specific learning objectives. The teachers taking part in the study use the CASE lessons as the focus for changing their teaching methodology.

INQUIRY BASED BIOLOGY EDUCATION - PILOTING THE UNIT "BLOOD DONATION" IN SLOVAK SCHOOLS

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The implementation of teaching biology based on scientific inquiry according to the Seventh Framework Programme project ESTABLISH started in Slovakia in the academic year 2010/2011. Eight primary and secondary schools were involved to verify the unit *Disability* - the pilot material that was produced for this project. In the next academic year 2011/2012, we started verification of the second unit - *Blood Donation* in Slovakia. Teachers who have used these materials in the learning process in schools received a training course of 12 hours. The course was attended by 20 teachers of biology, who chose activities from the unit *Blood Donation* based on the level of their schools (lower secondary, upper secondary) and the age of their students, and applied these activities in classes. Teachers communicated and exchanged experiences with each other. They documented their experiences, observations and ideas in feedback sheets and they also made photographic material of the work of their students. The contribution informs about the piloting of the *Blood Donation* unit and experiences of teachers with activities related to researching blood as a precious fluid, which means life, its donation, collection, and storage conditions.

THU 18.00 - 19.00

INTRODUCTION

Blood is a unique organ in which cells are not bonded together but they are free in plasma and they are movable. If you lose a lot of blood in an accident, you are in danger of death. There are diseases, however, which cause that blood does not carry out one of its functions. Blood transfusion can save a human life in this case. Up to the present there has not been anything blood could be substituted by. Students experience lies in the fact, that each of them has been injured, has bled and undergone blood tests. They are also familiar with the fact that in hospital blood is not only taken from the body but there are situations when, in contrary, it has to be added to the body to prevent man from dying. Polymers and metals which are used in making aids for taking, collection, transport and storing blood as well as equipment use to ensure sterility of aids used when handling blood are represented technologies. Also of some interest is the information about efforts of scientists to develop a blood substitute that in an emergency could save life if there were no suitable donor. Inquiry based science education (IBSE) activities focused on this topic were verified in Slovak schools. In inquiry-based learning students are presented with a challenge - such as a question to be answered, an observation or data set to be interpreted, or a hypothesis to be tested and accomplish the desired learning in the process of responding to that challenge (Prince and Felder, 2007).

METHODOLOGY

Unit Blood Donation was developed for FP7 project ESTABLISH - European Science and Technology in Action Building Links with Industry, Schools and Home (2012). It consists of 12 inquiry-based activities. Pilot verification of unit *Blood Donation* has been implemented in the school year 2011/2012 in schools in the Slovak Republic. A total of 18 primary and secondary schools have been involved. The age of the pupils in primary schools was 11 to 15 years; in secondary (grammar) school the age of students was 11-15 and 15-18 years. The theme was to be included in different schools in different grades depending on the planned training program in schools. Teachers received a training course of 12 hours. They provide feedback to the most common form of survey responses of students. The following are specific examples of the piloting unit *Blood Donation* at one elementary school and two grammar schools, which operate the authors of this paper.

RESULTS

Pupils of the lower secondary schools, between the ages of 12 and 15, participated in the activities of the IBSE unit *Blood Donation*, which were appropriate to their age. Students, divided into groups, sought answers to questions such as: why do people need a blood transfusion, who may become a blood donor, how often can persons donate blood, is blood from one donor enough, can anyone be a donor, what blood groups exist, what does blood consist of, and how can it be stored. Students may use the Internet or books. They have many own questions such as: which is the most common blood type, can a monkey donate blood to a human, etc. Students divided into groups construct a model of matches - red, blue and colourless. The input information was that each gene is composed of two matches. One gene comes from the mother, the other from the father. In the case of blood groups both alleles manifest themselves together and the result is the blood group A, B, AB or O. Using the IBSE method students used their model to solve tasks, such as to write down the possible combinations of blood groups of parents, who can have a child with the blood group O. This activity is very interesting for pupils, because it relates to everyday life. Those students, who did not know his blood group, were interested in how a blood group can be determined. The activity is easy to prepare. Students remember it for a long time thanks to the illustration and motivation. Pupils, who had taken part in direct blood collection during the action of “Valentine’s blood drop” have had a discussion in the rooms of the Thomas Aquinas secondary school with older student-donors about the questions: why they decided to donate blood and what were their motivations. They continued in a direct discussion with experts from the transfusion centre. They received answers on the questions, like: what are the necessary conditions for the blood transfusion, what requirements have the donor to fulfil for the blood collection, how is the sterility during the manipulation with blood secured, which analyses of blood are made after the collection, what is the situation with artificial blood. The pupils were interested also in instruments and devices used during the blood collection, from what material are they manufactured and which normative should they comply, in which way and how long the blood can be stored, etc. The activity realized as an excursion is attractive for the pupils. They realized the importance of blood donation, the relevance of the examination and storage of blood, they tested their communication skills. The pupils have worked before the realization of the game “Scientific conference” in three-member groups with assigned roles (physician, worker of transfusion centre, geneticist, physiologist) using study literature about the blood (from the internet, technical literature, journals, CD, excursions, etc.). The main goals of each trio were: a) to work on the information gained in the form of a presentation, b) to have a presentation on a conference and c) to discuss the given topic with schoolmates. The groups of reporters and TV-workers process the information during the conference prepare an article and an interview with the representatives of each role. The pupils acquired skills in information processing. They realized the importance of individual roles, their interconnections, the meaning of the scientific knowledge, of its popularization in the public, and contribution to our life. The pupils learned skills in presentation, discussion and communication on different levels.

In terms of secondary (grammar) schools all 12 IBSE activities of the *Blood Donation* unit have been verified. Students obtained new knowledge about blood - its composition, importance, sedimentation, conditions for blood donation, the blood groups, of the inheritance of blood groups using an innovative method of its own active research. In activities students reflect their ideas, propose solutions, models, they formulated hypotheses and argued. They obtained information with disparate sources - papers, Internet, family members or transfusion stations staff. Students have learned also to defend their arguments before classmates, ask questions, hear opinions of others, play role of different experts.

At grammar school in Gelnica following activities had the greatest positive response of students: the visit of mobile transfusion unit at school, the visit of blood transfusion centre, determination of blood group, the selection the blood for transfusion to a specific patient, scientific conference and making of a model of blood sedimentation. Students were very active, curious and resourceful. They designed and implemented its own model of sedimentation the blood using a thick fruit syrup, flour and water. Thus students get a better and fuller picture of deposition of blood cells in the tube and they will be aware of the effect of density and particle size on the sedimentation rate. Visit to the transfusion centre allowed students an opportunity to inspect the room and equipment for blood donation and separation of its components. They saw the way of storage of blood components and they could catch blood-sampling bags in their hands. Several students during a visit the blood transfusion station said they want to become blood donors. The activity for blood group was conducted with a simulated set, because using living materials and blood is prohibited at Slovak schools. The task of the students was to determine the ABO blood group and Rh factor of unknown samples on the results of knocking down/non-coagulated the blood with simulated anti-A, anti-B and Rh reagent. The students worked in groups and waited impatiently for the results of the reactions and very wanted to know, how would be looked the result with their blood. Students found their blood relatives and blood relatives of their family members. If they had not known their blood groups, they researched options hypothetically based on blood groups of their parents or sibling and so on. Students investigated the percentage of blood groups in the class also, while the most represented group was group A and group AB was at least. We compared results with the global and European average. Students responded positively to interactive computer simulations, where their task was to predict the outcome and then verify the accuracy of predictions. They draw conclusions and they generalized them. They showed their skills, tactics, logic and combinatorial thinking.

The scientific conference provided a wealth of amusing situations. Students are literally caught on the roles of doctors, experts, journalists and presenters, although they had never been on the conference. The form of the scientific conference we took advantage in an activity Storage of the blood. As actual and for the practice usable theme we used Umbilical cord blood. Students had rehearsed information and they had to use them correct in the context. That they argued their own expressive style meant to acquire this information and that they understand them. Role playing we used in a game of doctor and patient - we used various model situations - increased number of white blood cells, frequent nosebleeds, administration of anti-fever at elevated temperatures near 37 degrees above. The doctor had to know the patient to explain the cause of his illness and the way to heal.

In the L. Stöckel grammar school in Bardejov we realized IBSE in three groups of students. Two groups, 15 members in each, of third year students in the general class, and

23 students of fourth final year in the elective Seminary of animal and human biology. The aim of this support groups has been to learn themes “Body fluids” and “The circulatory system of man” by method of IBSE and deepen of the practical application as well as to acquire deeper knowledge. This method attracts attention of not only students, who are interested in biology in a greater extent - plan to study biology and graduated in the future - but also students who are oriented technically or humanities. This group of students primarily interested in the practical aspects, such as finding the genotype of parents, siblings and their own blood group, but the immune response to Rh factor in respect of the mother (Rh-), foetus (Rh +). However, despite the relaxed atmosphere of 1-2 students in both groups remained well to this form of teaching apathetic. We checked suitability of this form of teaching by a simple questionnaire, in which 80 % of students identified IBSE as motivating way of learning.

In the fourth year of study dominated discussion – presentation, promotion work patterns. From the all topics being most students interested in a discussion group devoted to the genetic nature of blood and blood groups as genetic material. In addition to the assumptions of inheritance of blood groups, pay much attention to the possibilities of using stem cell, pluripotent haematopoietic stem cells taken from umbilical cord blood at birth in medical practice. Gynaecologists considered this material often as a waste and its collection and storage of individual and funded exclusively by patients. Students did not understand how it is possible that in today's modern society there is not the genetic material withdrawn automatically for each newborn, since cells with a private individual’s HLA typing and the minimum degree of external injurious effect. This group of 19 years old students already understand the principles of blood donation, its essence, and 40 % had donated blood at least once. The result of application of methods of IBSE in the fourth year of high school graduates is a positive influence on thinking and personal development. But due to the knowledge necessary for graduation and entrance exams, this method was not accepted in terms of these students, because they consider inquiry-based activities as relaxation but not extending their knowledge of biology. However, if such a method should replace the traditional form of education, should give students knowledge of proper impact.

CONCLUSION

All verified activities of unit Blood donation are very appropriate for primary and upper grammar schools in Slovakia. A benefit of IBSE is to attract interest of students, their commitment and proactive approach. Learning with pleasure is so interesting they did not notice that they learn. Acquired knowledge is easier to remember and especially is useful in next life. Personal experience or discovering by self as a form of learning or acquisition of practical knowledge in comparison to traditional teaching methods is more effective in the quality of student performance. Experience forms support a motivation as well as enhanced efficiency of remembering not only the scientific terms, but also the principles of several physiological processes in human body. Increase student interest in the topic such as blood donation, is undoubted, it promotes personal development and obtains a positive human relationship to donate. Visit to the transfusion centre was an opportunity to know the technology and the practical aspects of blood donation.

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INQUIRY-BASED ACTIVITIES FOR THE TOPICS PLASTIC AND PLASTIC WASTE

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The implementation of teaching chemistry based on scientific inquiry according to the project Establish started in Slovakia in the academic year 2010/2011.

The verification showed that Subunit Visible holes complies with the State Educational Programme for chemistry of basic schools in Slovakia – the proposed activities are appropriate for the 6th class for the topic Mixtures and chemical substances and for the 7th class for the topic Physical and chemical processes.

Verifying the lesson *Invisible holes* revealed that not all proposed experiments can be incorporated into chemistry teaching in Slovak schools as not all of them comply with the State Educational Programme; some chemicals are used that a teacher must not work with for safety reasons.

The lesson *Exploring holes* has been tested in basic and grammar schools on a sample of 250 pupils and 150 students, and a total of 12 teachers. The teachers and pupils answered a questionnaire after the teaching unit had been completed.

It has emerged that pupils found the activities useful, entertaining and interesting. The teachers appreciated the fact that pupils do not get ready-made information but by carrying out practical tasks and by mutual communication they acquire knowledge that will be long-lasting. Pupils learn to perform scientific activities, be responsible, work in teams, be tolerant, communicate, and express their opinions. It was seen as a disadvantage that it is rather demanding for a teacher because they have to prepare trials and it is also time-consuming in the class.

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DESCRIBING EXPERT CLASSROOM PRACTICE IN INQUIRY-BASED MATHEMATICS AND SCIENCE

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Whilst recognising good teaching is generally unproblematic, expert classroom practice continues to defy attempts to at description. Current policy in teacher education places considerable emphasis on specific features such as lesson planning, but generally fails to provide a vocabulary to discuss less well-defined aspects of what good teachers do which cannot be captured in such plans. I will report on a small-scale pilot study of the classroom practice of experienced teachers of mathematics based on a model that identifies the importance of attentional skills as providing highly contextual knowledge which shapes teachers' actions *in the moment* in the midst of the complexity of classroom activity. This study suggests that the ability to recognise where the attention of pupils is focussed plays a key role in teachers' responses to situations that cannot be pre-planned. Engaging children in an inquiry-based approach to mathematics and science education requires teachers to have the confidence to create open-ended situations in which the trajectories of pupils' attention cannot be pre-determined. I will provide examples from work with teachers exploring mathematical and scientific inquiry in the topic of flight, within the EU funded Fibonacci Project.

CREATING SPACE FOR FORMATIVE ASSESSMENT IN SCIENCE CLASSROOMS

Chris Harrison

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This session will focus on the types of changes teachers need to make in their classrooms to allow a more formative approach to assessment to develop. It will begin with a short video summarising the work of the King's-Medway-Formative-Assessment-Project (KMOFAP), which brought the ideas from the Black & Wiliam (1998) review on formative assessment into reality in 6 schools in England. It will look at the types of changes that some of the teachers made in their classrooms to foster this approach to teaching and learning and provide opportunity for participants to think about how similar developments might happen in their own classrooms or with the teachers they currently work with.

INQUIRY-BASED TEACHING AND LEARNING OF DIRECT CURRENT ELECTRICITY

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Electricity is one of the basic areas of physics that are very important at all levels of physics teaching. At the primary level young children gain experience with simple electric circuits. At the secondary level electricity is taught more systematically. However, the concepts of electricity belong to the most difficult concepts for students to grasp. It is around us but at the same time it is invisible. Current and voltage are difficult to understand because they cannot be observed directly. As a result, there are many misconceptions concerning electricity identified by physics education research. Taking into account the physics education research results on students misconceptions there is a set of activities on direct electric current designed within the international FP7 project ESTABLISH. Most activities are aimed at students' independent investigation with strong emphasis on the students' inquiry. They were selected and prepared with regard to the Inquiry-based science education (IBSE) approach. There are teachers' materials with suggestions how to use them in the class as well as the corresponding worksheet for students prepared with emphasize to the level of inquiry the activities are targeting. The workshop presents the overview of the designed activities and it offers participants to carry out several of them.

BACKGROUND

Within the FP7 project ESTABLISH (www.establish-fp7.eu), a consortium of partners from 11 European countries including Slovakia, the main objective is the dissemination, use and promotion of inquiry-based science education across Europe. One of the main goals is to prepare instructional materials following the agreed structure for teachers and students with strong emphasis on IBSE methods. One of the teaching units developed within the project is the unit of *Direct Current Electricity*. The topic has been chosen as a result of continued difficulties that students usually have in this field. Electricity is one of the basic areas of physics that are very important at all levels of physics teaching. At primary level young children gain experience with simple electric circuits. At the secondary level electricity is taught more systematically. However, the concepts of electricity belong to the most difficult concepts for students to grasp. It is around us but at the same time it is invisible. Current and voltage are difficult to understand because they cannot be observed directly. As a result, there are many misconceptions concerning electricity identified by physics education research (Sherwood and Chabay, 2012; UDallas, 2012; Haertl, 1982; Engelhardt and Beichner, 2004). Taking into account the physics education research results on students' misconceptions there are a series of activities designed respecting the principles of inquiry-based learning to confront these common misconceptions.

METHODS

A series of activities have been designed within the unit *Direct Current Electricity*. All the activities strongly emphasize students' active involvement mainly through experimentation at different levels of inquiry including interactive demonstration/ discussion, guided discovery, guided inquiry, bounded inquiry and open inquiry that corresponds to different levels of teachers'/students' involvement and active participation (ESTABLISH, 2012; Wenning, 2005). In the process of teaching it is up to the teacher and the level of his students to change the activity to more open investigation or vice versa. The activities are designed to confront common misconceptions and they are currently piloted by selected teachers in order to get feedback to make some improvements.

EXAMPLES OF IBSE ACTIVITIES

The unit *Direct Current Electricity* involves 16 activities altogether, some of them consist of several parts. They offer a wide range of IBSE activities on different inquiry level. The teacher can choose the activity that is appropriate for his own curriculum. The activities start with basic understanding of simple electric circuit towards the conceptual understanding of the concept of conductivity and resistance, behaviour of different elements in a dc circuit, resistance and temperature, understanding the concept of power dissipated in a circuit, battery properties and its basic characteristics and its reasonable use including alternative electrical sources, *e.g.* photovoltaic and fuel cells. Each activity is complemented with a teachers' material that is a guide for teachers how to work in the class as well as worksheets for students to hand them out to students to follow when carrying out the activity. Many of the designed activities are enhanced by ICT when a computer with interface and sensors is used to make real-time measurements of physical quantities and helps to find and analyze the relationship between the measured data in order to draw reasonable conclusions. There are also computer files ready for teachers to use created in COACH 6 system (COACH, 2012). Here are several examples of designed activities with different level of inquiry.

How is it connected inside the black box?

The activity is designed in order to deepen students' knowledge about the simple electric circuit when students are supplied with black boxes each with four connectors that are mutually interconnected in different ways using wires or resistors. Students are let to perform their own experiments in a guided discovery/inquiry way. In accordance with the principles of inquiry-based learning students first draw their possible ways of interconnection, then they propose a procedure for investigation and finally, they perform an experiment to reveal the internal structure of the boxes. They can use a power source, wires and a bulb to indicate the current (yes or not, strong or less strong) through a selected part.

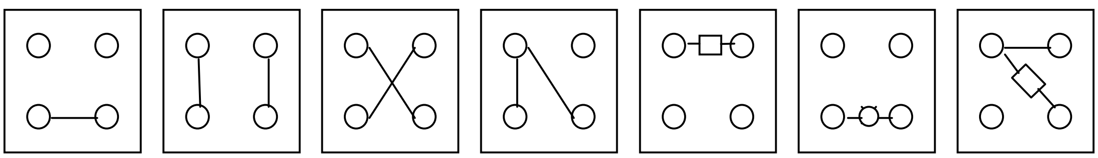

Figure 1: Possible interconnections in the black box.

Build your own thermometer

The main idea is to find out the main difference between the metals and semiconductors in terms of the temperature dependence of their resistance and understand that based on this dependence the element can be used as a device for measuring temperature. In both cases students carry out measurements and the following analysis in a guided inquiry mode.

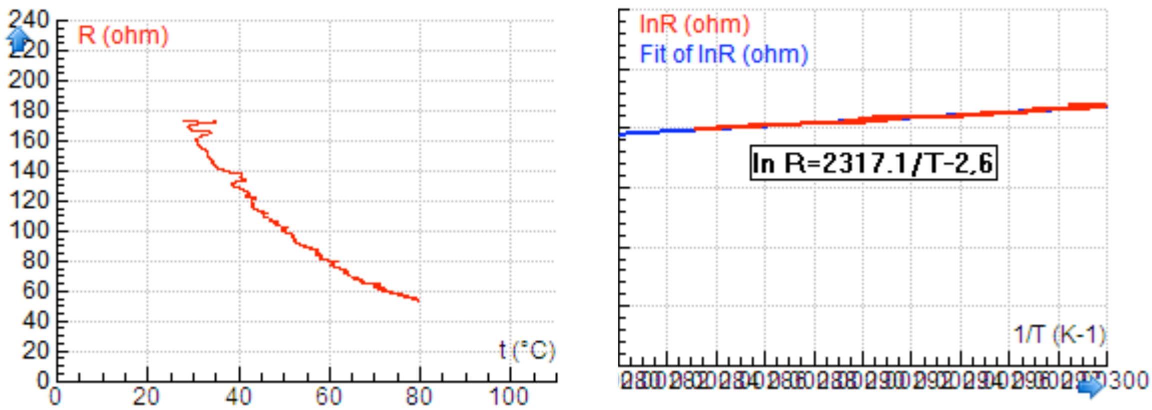

Figure 2: Example of thermistor calibration result.

The ready-made result can be used in case of lack of time but real measurement is preferable. In both cases the analysis should lead to the data fit that is linear for the metal but much more complicated for thermistor (fig.2). We introduce the idea of the temperature calibration. For students who are already familiar with the exponential function the thermistor calibration can be done. So, at the end, students get the thermistor calibrated for temperature measurement. They can compare their thermometer with data from the temperature sensor and they realize how the temperature sensor works.

Intriguing behaviour of bulbs

This activity is aimed at the conceptual understanding of the concept of power and energy dissipated in the resistor. From experimenting with bulbs new problems can emerge for students to solve.

- Problem 1: If we connect two identical bulbs to the circuit they shine equally brightly. The same thing happens with bulbs different from the first case but also identical. When connecting two different bulbs, one lights up but the other does not (or very faintly).
- Problem 2: At the moment we connect two different bulbs in series it can be seen that one of them will light up later then the other. There is a noticeable delay between them.

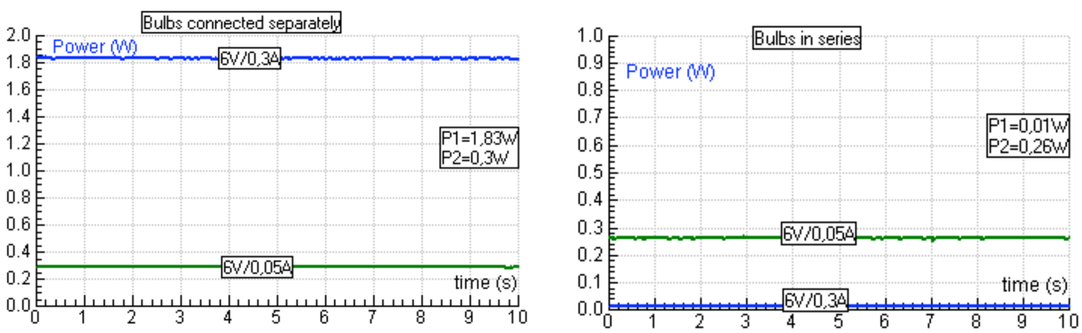

Figure 3: Example of measurement results for two different bulbs connected to 6V power source first separately (left) and then in series (right).

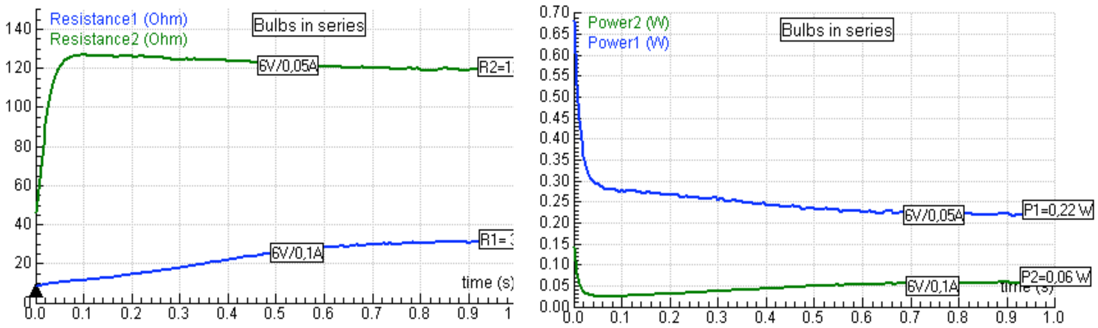

Figure 4: Example of measurement results for two different bulbs connected to 6V in a transition state.

In these cases we can let students do guided inquiry to carry out experiments according to the instructions in their worksheets or depending on the level of students they can proceed in a bounded inquiry mode in order to design their own experimental setup and decide about the quantities to be measured as well as the further analysis to carry out.

How electric eel kills its prey

In this activity students should apply the knowledge about batteries connected in series and parallel in a real life situation of the animal world. Students search information about the electric eel and on the basis of the searching results they can prepare a short presentation analyzing and explaining the fact that the electric eel can manage to produce a current in order to kill its prey without shocking itself. The interdisciplinary physics-biology approach can be enhanced by looking up information about the anatomy and physiology of electric eel (electric ray, electric catfish, etc.) and its organs producing electricity.

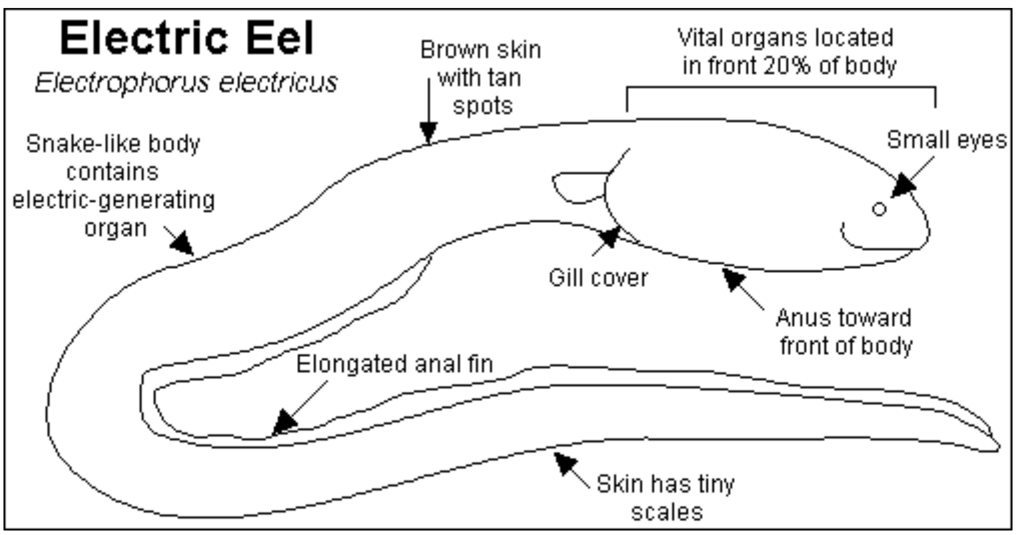

Figure 5: Schematic picture of electric eel[1].

The activity can be carried out in a bounded inquiry mode, e.g. as a take-home assignment. Students search information in groups or individually in order to present and discuss it in front of the class.

[1] The picture is taken from http://www.chm.bris.ac.uk/webprojects2001/riis/Electr2.gif

Batteries and their reasonable use

When understanding the principles and properties of batteries, students can work on the industrial applications and environmental and ecological aspects of batteries. This activity is aimed at small home assignments meant as project work to search for information on a selected problem and prepare a short presentation for the class. The activity can be carried out as an open inquiry assignment. Student working in groups can formulate their own problem to solve. They use internet resource and other available printed resources to search relevant information. Possible assignments to carry out an open inquiry on industrial and environmental aspects of batteries can include:

- Look for information about non-rechargeable batteries that are available in stores. Find out what materials they consist of, what are the voltages produced and energy supplied and what they are mainly used for.
- Look for information about chargeable batteries, e.g. a car battery. Describe its properties and name the possible problems the user can come across with.
- Look for information about chargeable batteries that are available in stores. Find out what materials they consist of, what are the voltages produced and energy supplied and what they are mainly used for.
- Compare batteries of the same size and emf from different producers.
- Battery electric vehicle and its future perspective.
- What rules should people follow in regard to batteries disposal and recycling (where is a battery recycling place close to your school?)
- What are the environmental hazards of batteries?

Based on searching and selecting relevant information about the problem students prepare a short presentation for the class that can lead to a wider discussion and argumentation.

CONCLUSIONS AND IMPLICATIONS

Within the Establish project there are a set of instructional materials currently being developed and tested. They involve student learning activities that are designed with strong emphasize on inquiry-based science teaching and learning. That means students carry out activities supported by appropriate materials (worksheets, ICT support, and other sources) that help them discover concepts and relationships rather than listening to what teacher says, demonstrates and explains. The materials developed on the topic of *Direct Current Electricity* are complemented with the number of activities enhanced by ICT, mostly data logging using COACH system. Some of these activities have been already tested in Slovak schools and they have been modified according to teachers' comments. Materials are still being piloted by teachers in order to get feedback about their possible use and appropriateness in different school environment. The results, however, are strongly influenced by the teacher who plays a key role since the success of the IBSE method depends on the level of teachers' awareness of how to teach and what methods to use. From this point of view much has to be done in order to make teachers feel comfortable and self-confident in this changed environment.

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GETTING YOUR HANDS ON ASPECTS OF THE NATURE OF SCIENCE

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This workshop will feature a brief introduction to some important elements of the nature of science (principally the issues of inference, induction and deduction) that should be part of any complete programme of science instruction. Participants will then make several examples of hands-on teaching tools and practice with them. Additional materials will also be provided that exemplify the targeted issues in the nature of science. Teachers of any instructional level are encouraged to attend.

Almost 20 years ago, Richard Duschl (1985) wrote an important essay reminding science teachers that the descriptions of "how science functions" typically provided in class and in textbooks had fallen out of step with the most accurate interpretations. Many cheered this article in hopes that, at last, one of the most important missing elements of science instruction would finally be addressed as accurately and completely as are the topics of plate tectonics in Earth science, mitosis in biology, pH in chemistry, and Newton's laws of motion in physics.

Unfortunately, the impact of Duschl's plea has been mixed. There has been a welcome proliferation of nature of science (NOS) elements and recommendations. Professional organizations including the National Science Teachers Association have issued position statements both advocating and defining relevant aspects of NOS (NSTA, 2000). Increasing numbers of NOS standards appear in both United States (AAAS, 1990; 1993) and foreign reform and standards documents (McComas and Olson, 1998). The National Science Education Standards specifically includes standards focusing on science as a human endeavour and the nature and history of science across all grade levels (NRC, 1996; 141, 170–171, 200–201).

These NOS recommendations are a step in the right direction. However, calls for the inclusion of NOS in science teaching have been made for almost a century (CASMT, 1907) with frequent reminders during much of this time (Herron, 1969; Kimball, 1967; Robinson, 1969; Duschl, 1985; Matthews, 1994; McComas, Clough, and Almazroa, 1998; and Lederman, 1992; 2002). The reality is that in spite of these continuous and well-reasoned recommendations, some students and teachers alike still fail to understand even the most basic elements of this important domain (Abd-El-Khalick and Lederman, 2000). Studies show that a few teachers do not even value the inclusion of NOS elements in instruction (Bell, Lederman, and Abd-El-Khalick 1997).

A consensus of key NOS ideas appropriate for inclusion in the K–12 science curriculum has begun to emerge from a review by science educators of the extensive literature in the history and philosophy of science. The authors in this issue of The Science Teacher suggest surprisingly parallel sets of NOS content goals for K–12 science teaching that do not oversimplify science itself or overburden the existing science curriculum. This article presents nine key ideas, which represent both a concise set of ideas about science and a list of objectives to shape instruction in any science discipline.

CORE NOS IDEAS

1) Science demands and relies on empirical evidence.
A hallmark of science is the requirement that data, open to review by others, be provided to justify all final conclusions. Of course, some ideas in science begin as exploratory notions; much of theoretical physics functions in just such a fashion. For example, Einstein's predictions about the impact of massive objects on the path of light were not dismissed outright due to lack of evidence, but neither were they accepted until evidence became available. In 1919, an expedition was mounted to test Einstein's prediction that the light of a distant star would be shifted slightly when it passed near the Sun. When the prediction was observed, a basic tenet of Einstein's new worldview was confirmed—with evidence. Although Einstein had faith in his assertion, the expedition data were needed for the rest of the scientific community to confirm the prediction.

The requirement for empirical evidence is accompanied by the caution that not all evidence is gained through experimental means, although that is frequently called the "gold standard" of science. In addition to experiments with their rigorous tests and controls, science also relies on basic observations (consider the work of Fossey, Goodall, and Galdikas as they studied the great apes) and the historical explorations that have added so much to our understanding of the fossil record and geology generally. Many scientists use some combination of historical, observational, and experimental methods; the key point relating all of their investigations is the production and analysis of evidence in the form of data, measurements, photographs, meter readings, and other related observations. Despite its importance in other aspects of human affairs, faith alone in the correctness of one's views plays no final role in science. Science by its very nature is, and must remain, an empirical data-driven pursuit.

2) Knowledge production in science includes many common features and shared habits of mind. However, in spite of such commonalities there is no single step-by-step scientific method by which all science is done.
Although common features in the practice of science, like logical reasoning and careful data collection, are part of all good science, there is no universal set of steps that begin with "defining the problem," extend to "forming a hypothesis," "testing the hypothesis," and finish with "making conclusions" and "reporting results." Such a stepwise method commonly provided in science textbooks may be effective as a research tool, but there should be no implication in classroom discussions that all scientists use any single method routinely. In fact, studies of scientists at work reveal many idiosyncratic ways of approaching research and even of coming up with research problems in the first place.

3) Scientific knowledge is tentative but durable. This means that science cannot prove anything because the problem of induction makes "proof" impossible, but scientific conclusions are still valuable and long lasting because of the way that knowledge eventually comes to be accepted in science.
Induction is the knowledge generation process by which individual data points related to the problem or phenomenon are gathered until a general trend, principle, or law emerges from this mass of data. Prediction and deduction are used to evaluate the validity of the initial conclusion. This cycle of induction and deduction, a hallmark of logic, is far from perfect. There is simply no way to know that one has amassed all of the relevant data nor is there any way to be sure that the generalization suggested will hold true for all space and time. However, the logical knowledge generation process described briefly here is the best we have yet developed to provide ideas that are both useful and valid despite an inability to offer absolute proof. We can have confidence that scientific conclusions formed in this fashion will be long lasting or durable because of the rigorous, self-

correcting nature of the scientific process and the requirement that conclusions are agreed to by consensus of the scientific community.

> What Is NoS?
>
> The definition and scope of NOS is quite basic; NOS is the sum total of the "rules of the game" leading to knowledge production and the evaluation of truth claims in the natural sciences. We have learned much about how science functions from reviewing its products, watching scientists at work, and viewing their interactions as a community. There is an entire domain of study called the social studies of science, which involves historians and philosophers of science along with sociologists who focus on scientists working in the laboratory, field, and in professional contexts. Even psychologists and physiologists interested in how human observations are made have helped shed light on aspects of the scientific enterprise. The work of these scholars has produced a description of how science functions from which we can derive a definition of NOS to inform the science curriculum.
>
> Defining science and its mechanisms has become an important enterprise even for the courts. Following a charge from creationists regarding what could be discussed in science class, Judge William Overton (1985) in the case of McClain vs. Arkansas Board of Education synthesized the testimony of a variety of experts including Michael Ruse and Stephen Jay Gould. He wrote that science is guided by natural law and explains by references to natural law. It is tested against evidence from the empirical world and has conclusions that are tentative and potentially falsifiable. This focus on the "natural" is a key element of science. Science cannot delve into metaphysical questions and must rely on evidence gained from nature—either directly or through inference.

4) Laws and theories are related but distinct kinds of scientific knowledge.
One of the most resilient misconceptions about science is that laws are mature theories and, as such, laws are more valuable or believable than are theories. Laws and theories are related but individually important kinds of scientific knowledge and both should be considered valuable products of the scientific endeavour. Laws are generalizations or patterns in nature (such as Charles's law), while theories are explanations for why such laws hold (such as the kinetic molecular theory of matter, which suggests that tiny particles behaving like billiard balls become more active as temperature rises). Many of the problems associated with evolution education arise when teachers fail to make the distinction between the reality that change through time has occurred (evolution with a law-like character) and the explanation for how evolution occurs provided by Darwin and Wallace (most accurately called the Theory of Evolution by Natural Selection). Those who understand the distinction between laws and theories would never call evolution "just a theory!"

5) Science is a highly creative endeavour.
Scientists, through their selection of problems and methods for investigation, would certainly agree that their work is creative. Even the spark of inspiration that leads from facts to conclusions is an immensely creative act. The knowledge generation process in science is as creative as anything in the arts, a point that would be made clearer to students who examine process as well as content.

Unfortunately, the average student is more likely to describe science as a dry set of facts and conclusions rather than a dynamic and exciting process that leads to new knowledge. In our quest to teach students what has already been discovered, we typically fail to provide sufficient insights into the true and creative NOS exploration. Some studies have shown that otherwise bright students reject science as a career choice simply because they have had no opportunity to see the creativity involved.

6) Science has a subjective element.
One of the little known aspects of science is that, because of its status as a human activity, it has a subjective component. Two scientists looking at the same data may "see" and respond to different things because of their prior experiences and expectations. This does not make science less rigorous or useful since ultimately the results will have to be discussed and defended before the larger scientific community. However, the initial discovery and analysis are ultimately personal and uniquely subjective events.

The prior insights that some scientists bring to the process of investigation explain why some individuals make monumental breakthroughs while others do not. Scientists recognize the role and challenges of subjectivity. Ideas and conclusions must be reviewed by other experts in meetings and through the publication peer review system. These processes ensure that the important subjective element in science is tempered by valid checks and balances.

7) There are historical, cultural, and social influences on science.
Science is a large and powerful enterprise that lies within the greater human social system. What research is performed and what research is discouraged or even prohibited is best understood by considering human forces such as history, religion, culture, and social priorities. Given the expense associated with scientific research, many would argue that scientists should consider only practical topics. In fact, there are societal pressures associated with certain domains of research. It should be no surprise that some kinds of research are favoured and some are discouraged.

The debate regarding stem cell research and therapeutic human cloning is a current example of the interplay of science and cultural forces. Research directions such as these could be potentially fruitful and interesting, but for a variety of reasons extending far beyond science itself, these areas of research are presently controversial. Depending on the situation, it may be said that these social forces could either impede or support science. It may well be that Darwin's explanation of evolution by natural selection and the related notion of survival of the fittest could have been subtly suggested by the kind of ruthless capitalism Darwin saw around him.

8) Science and technology impact each other, but they are not the same.
Many confuse the terms science and technology, often considering them synonyms. Roughly speaking there are two kinds of problems investigated by modern science. Some problems relate to a particular need such as how to produce a more effective or less expensive music storage device, how to increase the agricultural yield of a plot of land, or how to vanquish a particular disease—all worthy endeavours. These challenges are technological in nature and represent what is frequently called "applied" science. On the other hand, "pure" science aims at basic understanding of the fundamental nature of reality sometimes called "knowledge for knowledge sake." Some of the discoveries of pure science, like the laser, were originally just curiosities until their utility later became apparent. Some technological innovations, such as the microscope, have provided scientists the ability to look more deeply into the ultimate nature of reality.

According to Weaver (1953; 47), "what science ought to be is what the ablest scientists really want to do"; however, the reality is far more complicated. Science and technology, and the cultural forces that surround them, are inexorably linked. Most times it is simply not possible for scientists to explore only in those directions that they find most interesting. Funding, as well as institutional and social priorities, simply do not typically permit what Weaver has advocated in the most pristine sense.

9) Science and its methods cannot answer all questions.
One of the most important elements of NOS is for students to understand that limits exist to science and to appreciate that some questions simply cannot be investigated using scientific means. For instance, it may be possible to determine what percentage of the population likes a particular work of art, but it would be unreasonable to expect that science could fully explain why such an opinion exists. Such is also often the case with questions of morality, ethics, and faith—for many the domain of religion.

Knowing that science cannot and should not address all questions is vital if we are to avoid the common but false premise that science and religion are at war. To the contrary, science and religion play vital, but distinct, roles in human affairs. If only we could ensure that our students understand the distinction between reason and faith, science and religion, and the roles these two worldviews play in human affairs. In fact, an explicit focus on NOS as an integral part of the science curriculum would go a long way to accomplishing just such a goal.

The challenge before us is to ensure that these core NOS notions are featured prominently and explicitly in the science classroom, textbooks, in descriptions of how science functions, and in discussions of laboratory and other hands-on work. Even teacher-made final exams and new high-stakes tests should contain significant numbers of nature of science items, a state of affairs that would inform students and teachers alike of the importance of NOS as a focus of instruction. Finally, we must engage in the development of engaging curriculum models focusing on this important topic and insist that textbook authors weave NOS lessons through the content chapters instead of relegating it to the introduction, as is so often the case. NOS should be a central instructional purpose rather than an optional prelude.

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TEACHING OF ARGUMENTATION WITHIN THE SCIENCE CURRICULUM

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This paper reports the outcomes of a project where communities of science teachers in four secondary schools aimed to develop and embed the teaching of argumentation within the science curriculum for students aged 11 to 16 years. Through a process of collaborative professional development two lead teachers from each school sought to work with all the teachers in the community of their science department to promote the use of argumentation in science. An initial stimulus for development was provided by a series of university-based meetings where the lead teachers from all schools engaged in professional development workshops. Drawing on resources from a range of sources, lead teachers worked with colleagues in their schools to develop argumentation activities and teaching strategies. To investigate the process of development in each school, data were collected from interviews with lead teachers, notes from meetings held within departments for reflecting on and sharing practice, curriculum developments using argumentation including resources and lesson plans, and recorded observations of lessons of teachers in each department. Interpretive analysis of these data sources has demonstrated the importance of individual conceptions of science teaching, approaches to leadership of the project within each department, and the nature of collaboration exercised between teachers working within the community of the department.

TEACHING ABOUT THE NATURE OF SCIENCE: IMPACT OF A CONTINUING PROFESSIONAL DEVELOPMENT PROGRAMME ON PRIMARY TEACHERS PARTICIPATING IN THE FIBONACCI PROJECT

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The Fibonacci Project in Ireland has focused on developing experienced primary teachers' skills and knowledge in teaching about the Nature of Science (NoS) through inquiry. Previous research suggests that when teachers teach about NoS, this benefits teachers and pupils in terms of confidence, enthusiasm, engagement and involvement in inquiry-based learning (Akerson *et al*, 2009; Murphy *et al*, 2007,2011). Research on the effectiveness of Continuing Professional Development (CPD) in primary science suggests that experienced teachers only change classroom practices after approximately 80 hours' intensive, sustained professional development (Supovitz and Turner, 2000). This paper will reflect on some of the Irish Fibonacci teachers' experiences of and attitudes towards teaching about NoS through inquiry during this two year CPD programme. The impact these NoS lessons have had on pupils' learning in science will also be examined.

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MIND THE GAP

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The perception of a gap between education practitioners and researchers has been a source of commentary for over 100 years (e.g. Korthagen, 2007; Hedderly, 2005). More recently, this has been more tightly described in terms of impact on practice, especially in teacher education programmes. In this paper, I propose to clarify what the gap might be, identify attempts to deal with it, and suggest future work. I have reviewed some of the body of literature relating to the gap and conclude that part is real, part is a perception, and some is simply failing to recognise the source of research outcomes that have influenced practice. There are many influences over the relation between research and practice that acts as barriers. These include views of teachers that research is of no use, even before becoming teachers (Hobson et al, 2009), the lack of incentive for researchers and teachers to engage with ensuring that research has an impact, who could be important actors in the process, a shortage of appropriate journals for professional articles that teachers read, and a lack of funding for long term implementation. Vanderlinde & van Braak (2010) report the strong influence of mediators such as teacher educators. The literature survey also highlights attempts to raise the impact of research, such as journal clubs, practitioners reading for higher degrees, and systems in the workplace to promote knowledge of research. The article describes the work of a voluntary teacher researcher group attempting to bridge the gap between teachers and researchers for 15 years.

INTRODUCTION: THEORETICAL BACKGROUND, QUESTION OF RESEARCH

The perception of a gap between education practitioners and researchers has been a source of commentary for over 100 years (*e.g.* Korthagen, 2007; Hedderly, 2005). More recently, this has been more tightly described in terms of impact on practice, especially in teacher education programmes. In this paper, I propose to clarify what the gap might be, identify attempts to deal with it, and suggest future work. There are many influences over the relation between research and practice that acts as barriers. These include views of teachers that research is of no use, even before becoming teachers (Hobson *et al*, 2009), the lack of incentive for researchers and teachers to engage with ensuring that research has an impact, who could be important actors in the process, a shortage of appropriate journals for professional articles that teachers read, and a lack of funding for long term implementation. Vanderlinde & van Braak (2010) report the strong influence of mediators such as teacher educators. The literature survey also highlights attempts to raise the impact of research, such as journal clubs, practitioners reading for higher degrees, and systems in the workplace to promote knowledge of research.

The research questions are:

1. What is the perception of the gap between practising teachers and researchers?
2. How does a community of researchers and practitioners in a teacher researcher group engaging in and with science education research facilitate impact in the school classroom?

METHODOLOGY OF RESEARCH

The research methodology is Case Study, with a significant range of documented evidence from the group web site, emails and reports of activity, and a questionnaire to elicit participants' views on the impact, an article in School Science Review, and presentations at conferences. The web site contains notes of intended action, reports of activity, and reflective contributions. Members were contacted to provide information about their contributions, impact and suggestions for improvement, through a structured email. Care has been taken to assure participants of anonymity where information is not in the public domain. Documentary evidence was analysed in detail with reference to Research Question 2 with respect to both supporting and contradictory comments (there were no contradictory comments, as it turned out).

RESULTS OF RESEARCH

The literature review points to a long-established perception of a gap between practising schoolteachers and researchers (Korthagen, *op cit*). Researchers assert that teachers do not read their work and are not interested. Teachers assert that papers are written in an impenetrable language in hard-to-access theoretical journals, and that the topics are not relevant.

The evidence presented points to an existing interest among a group of teachers and researchers in engaging with research linking their work, leading to the establishment of a long lasting and self-sustaining group. A collaborative atmosphere developed where a group research project was identified, and tasks allocated by agreement. The group shared the process of reviewing the literature at group meetings. Methods of data collection to explore specific research questions were devised by the group, taking note of existing methods, and subject to intense discussion to ensure the highest validity and reliability. Sometimes, data was collected from across a group of schools by members of the group, and handed over to the individual leading that part of the research. Data was analysed jointly at group meetings, but each segment was owned by an individual or a small group. This ensured that there was validity in the analysis. Interpretations were presented at group meetings and subject to scrutiny. Group members also reported how their schemes of work at school had been influenced by their findings and examples will be given.

Publication of the research proved to be a sticking point. The group organised a conference to which were invited other teachers, policy makers from the Department for Education, and other researchers. Attendance at this was successful and most of the group presented their findings. However, the greatest impact was in the teacher researchers departments. In one case, that of word equations, there has been no change at policy level, despite the strong research evidence provided.

Feedback from members who have attended one or more meetings has been positive, with self-reported evidence of changes in their practice. Examples of evidence:

1. What is the extent of your involvement with PALAVA? *I attend meetings whenever I can*
2. What influenced your decision to attend PALAVA? *A desire to remain in contact with current research with teachers and John*
3. For you, was PALAVA valuable? *Yes, because I am able to listen to what is current in science education research and hear practising teachers experiences, concerns and the research they are engaged in and would like to pursue.*

6. What have you taken from PALAVA sessions? *Inspiration*
7. What could have improved/ increased what you gained? *(My) regular attendance at meetings*
9. Do you have any other comments? *The group is led/steered/motivated by John in a way that allows all attendees to contribute or not. It is a supportive, collaborative and non-threatening environment, good forum for exchange of ideas.*

DISCUSSION, CONCLUSIONS, PERSPECTIVES

Comments from researchers and teachers who have negative feelings about the gap suggest that neither side appreciates the different purposes of the publications. Research articles are for peers and often contain professional shorthand. Articles in professional journals have some impact, but participatory workshops as part of professional development have greater impact on change.

The teacher-researcher model shows significant benefits in this Case Study. It attracts members who respect practice and research, a strong staring position. Principles such as collaborative ownership of research questions and methodology contribute to successful outcomes. In this particular case, a weakness is in publishing the outcomes of such work, apart from at conferences. Perhaps, this could be facilitated through writing workshops for teachers and researchers. Changes in practice are both common and sustainable, even when there is only one teacher-researcher in a school.

Any development of this form of bridging must retain the voluntary nature of the group, since it is this that provides commitment. Inevitably, this will limit its impact but it is only suggested as one approach among many.

FURTHER RESEARCH AND IMPACT ON THE CLASSROOM

Some recommendations are:

1. Research into teachers' and practitioners' beliefs must continue.
2. Teachers and researchers must work together more as equally valued partners, principally to understand each other and generate more respect.
3. Those who provide professional development must have a foot in the researcher ethos, as well as a foot in the practitioner ethos.
4. Mediators, such as teacher educators, must be supported in their efforts to bridge the gap.

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FRI 10.00 - 11.20

MIXED MESSAGES CONCERNING SCIENCE TEACHING: THE CONTESTED FEASIBILITY OF ACTIVE LEARNING

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This paper draws upon empirical data from a two-year study of student teachers at University College Cork. Student teachers experienced mixed messages with regard to visions of good science teaching. Specifically, these messages revolved around the extent to which active learning methods were advisable and/or feasible in the classroom. The data collected from the student teachers suggests that mentor teachers are important in the formation of a science teacher but it is important that these mentors must be disposed to reform based teaching and the teaching of science through inquiry if student teachers are to become competent science teachers.

INTRODUCTION

Social constructivist teaching approaches have being emphasised in the reform of science education (Kang, 2008). Kang suggests that teacher education programs should nurture teachers who readily adopt social constructivist teaching practices as they are advocated in the current science education reform. However, nurturing in this manner is difficult for a number of reasons. Kang cites Marks and Gersten (1998), who reported that when teachers perceived differences between their own beliefs and those proposed by the teacher educator their changes in teaching practices were slow and gradual.

Jones and Carter (2007; p. 1067) remind us that 'one of the consistent research findings is the link between science teachers' epistemological beliefs and their instruction.' Crawford (2007) concluded from her study of prospective science teachers that:

> The most critical factor influencing a prospective teacher's intentions and abilities to teach science as inquiry is the prospective teacher's complex set of personal beliefs about teaching and views of science. A prospective teacher's personal view of teaching science as inquiry, comprised of his or her knowledge of scientific inquiry and of inquiry-based pedagogy and his or her beliefs of teaching and learning, is a strong predictor of a prospective teacher's actual practice of teaching science. (Crawford, 2007; p. 636)

Russell and Martin (2007; p. 1153) suggest that pre-service programmes should highlight the need for explicit attention to epistemological issues associated with teaching science and learning to teach. Significant attention must be given to the epistemological beliefs of prospective science teachers, both in terms of the science concepts they will teach and in terms of the educational concepts they bring to a pre-service program.

Experiential learning, through teaching practice has long been a staple part of teacher education programmes. According to Monk and Dillon (1995), it is a given that teachers in schools have an essential part to play in partnership with university staff in the training of pre-service teachers. The observation of teachers in action is an important part at the commencement of training and also as the student teacher progresses and develops skills and the formation of a teacher of science can be significantly aided by the support of an experienced schoolteacher working with the novice in the school setting (Allsop and Benson, 1997). However, Kang (2008) again reminds us that field experiences easily reproduce traditional teaching practices. She stress that in order to stop continuing the status quo and encourage more reform-oriented teaching practice, teacher education programs should help pre-service teachers become critical about the status quo and provide them with tools for dealing with the kinds of teaching conditions that impede teaching practices for reformed teaching goals based on sophisticated epistemologies.

Roth and Tobin (2001) propose co-teaching as a viable model for teacher preparation. They describe it as ‘working at the elbows’ of someone else, and this enables beginning teachers to experience appropriate action at the right time. In their article, they describe in vignette form, the experiences of one trainee teacher, Scott, who reports of his dismay at the “lack of fit between science teaching espoused in his university methods course and his experience in the classroom” (p. 743). They also propose that knowledge to teach is something that is learned not just by being in a classroom and with other teachers in a physical sense but also by sharing the same activity, its intentions and concerns. It is something enacted and can therefore be observed only by participating in action. Allsop and Benson (1997) also commented on the ‘lack of fit’ mentioned above, as any teacher education program involves trainees trying to learn in two very different sites, namely the school and the university. An idea which is seen as valuable in the university course, e.g. constructivist theories of learning may be judged as valueless in the school. Moreover, they make the very valid comment that student teachers are likely to be learning strategies for survival rather than the habits of good teaching. This ‘simply wishing to survive teaching practice’ mode of operation was also noted by Haggarty (1995) in her work with trainee mathematics teachers. Employing such a modus operandi often resulted in active learning methodologies such as practical work being rejected because of likely control problems rather than used because of its potential in improving conceptual understanding.

METHODOLOGY

This paper draws on the Learning to Teach Study (LETS), the first of its kind on the Postgraduate Diploma in Education (PGDE) in Ireland, funded by the Department of Education and Skills (DES), which developed and implemented a study of initial teacher education in the PGDE in post-primary education (Conway et al 2010). Adopting an interpretive approach, LETS involved the collaborative development of three interviews protocols and a survey by the research team. The LETS study was undertaken over three years (2007-10) and involved the participation of an experienced research team from the School of Education, UCC. The team brought a variety of experiences and insights to the research task, and within the overall socio-cultural understanding that framed this study, were able to contribute their specialised knowledge in areas such as inclusion, equality and diversity, second language teaching, the teaching of mathematics and of science etc. The research team itself can be seen in this context as a community of learners, participating together in the task of achieving an understanding of the process of learning to teach. The principles of the interpretive research genre (Mertens, 2010) informed the LETS research project.

The methods used included semi-structured interviews; analysis of documents and a survey questionnaire (see Table 1 for overview of interview foci). Using a multiple-case study research design, seventeen student teachers were interviewed on three occasions over the course of an academic year. A survey focused on the prior experiences and beliefs (e.g. about learning) that student teachers bring to the PGDE, including a measure of their teaching efficacy and knowledge about reading literacy and inclusion, was completed in March 2009 by 133 of the 212 students of the 2008/2009 PGDE cohort (a response rate of 63%) of whom fifty were learning to teach science. For the purposes of this paper, we draw on excerpts from interviews with student teachers of science.

Table 1: Overview of Semi-Structured Interviews with Student Teachers.

Part	Interview domains: January 2009	Interview domains: March 2009	Interview domains: May 2009
A	Background, previous experience, motivation to learn to teach	Update on progress learning to teach	Opportunity to learn to teach
B	Opportunity to learn to teach	Opportunity to learn to teach	Critical incidents in learning to teach and in school
C	Critical incidents in learning to teach and in school	Critical incidents in learning to teach and in school	Understanding of subject teaching, inclusion and reading
D	Understanding of subject teaching, inclusion and reading literacy	Understanding of subject teaching, inclusion and reading literacy	Future plans
E	Summary: SWOT 1	Summary: SWOT 2	Summary: SWOT 3

RESULTS

In this section, we highlight one finding from the LETS project as it pertains to trainee science teachers namely the mixed messages received by them concerning science teaching and the contested feasibility of active learning. Interview excerpts from four participants, Marissa, Sinead, Thomas and Aoife are used as evidence to highlight the importance of congruency between the personal science teaching beliefs of the student teacher and their teaching practice mentor and school if they are to develop into competent and confident teachers of science.

The School Way v The Student Teacher Way

Marissa's 'good' science teaching was to focus what is on the syllabus – "this is what students need to know". The school message on preparing students for exam or teaching to the test was difficult for Marissa, she explains:

> There is a focus on active learning during the course but from what I have heard from other teachers there is no time for that or there is not as much time. But then some teachers in the school do have time for it. I wonder is it just a choice people make. (Interview 2, p. 9)

Marissa elaborates further that this exam-focussed approach was an impediment to her vision of good science teaching and her subconscious adherence to adopting a more investigate, constructivist style in her teaching:

> You know I could have great exciting practical classes but I just don't have the time to do it if I need to cover the material I need to and I could make it a lot more interesting, I think I could if I had a lot more freedom and if I was focussing on the skills and the art of teaching the students how to learn themselves rather than delivering information. (Interview 1, p.8)

However, the most interesting account of mixed messages and competing viewpoints in relation to science teaching comes from another student teacher, Sinead. In her second interview (pp. 12-14), she describes an incident that occurred at an in-service event that was enlightening to her vis-à-vis how a school implements a syllabus requirement. Coursework is a mandatory part of the current Junior Certificate Science Syllabus.

Students are expected to carryout an extended investigation into a topic and write a report on their investigation.

Sinead thinks that the carrying out of such investigations is worthwhile and would afford the students an opportunity to engage in self-directed learning and to “think outside the box”. However when the Coursework was carried out in her school, she found that the students “are very used to being drilled” and so:

> …they [teachers] decided what experiments to do and they decided how they would do them. And then they told the students how they will do the experiments. And the students went through the experiments with the teacher and basically the teachers did all the thinking and the students did what they were told. (Interview 2, p. 10)

However, Sinead soon learned that this was a school-based way of fulfilling the coursework requirements. She attended an in-service event for teachers of science and discovered from conversations with other attendees that when describing the approaches used in their schools that the other teachers were “talking about the students doing the thinking” and resources the students themselves were using.

Sinead describes her shock to discover that

> Oh, my God, people really do that. But in my school the students aren’t given the responsibility because they haven’t been brought up in that way.

Sinead was thankful of the experience of going to in-service as she saw that:

> Teachers in other schools do as it is in theory and the students actually think up the stuff themselves and you have different students doing the experiment 5 different ways, and that is great, I am delighted and I am so glad that I went to the in-service and saw that. In college it is all about encouraging, like student centred type of thing and thanks to me just happening to go to these in-service days, I saw that science is taught in that way in schools. (Interview 2, p. 12)

So what are the lessons to be learned from Sinead’s account? Firstly, Sinead was fortunate to be able meet other teachers who presented her with a different approach to completing coursework. Monk and Dillon (1995) stress the essential role that teachers in schools have to play in the training of pre-service teachers. However, it could have been possible in this case for Sinead to accept the traditional, teacher-centred approach to science teaching, where the students did not engaged in inquiry themselves. However she acknowledges that the college and in-service presented an alternative view of science teaching, one which valued student inquiry. More importantly, this approach was congruent with Sinead’s own values and beliefs concerning good science teaching. She valued the idea of letting students work independently, using resources and developing their own experiments – in other words she displayed positive attributes of a teacher well disposed to teaching science as inquiry.

Aoife, a student teacher of science and mathematics also has an interesting take on student teachers seeking help from other experienced teachers in her teaching practice school. She describes them as not being very helpful:

> Interviewer: So if you were thinking about an issue there where do you go for help?
>
> Interviewee: Well you can brave it and go and ask one of the other teachers but often, rather than just answer the question you have asked they try and push their own way of doing it, it is very pushy, if you want to do it at all, you do it their way. So for example you are doing the science across the world project, you know, I asked them a question about even just getting into the computer room and what the situation there is and like, ‘why would you want to do a project like that?’ It wasn’t, ‘ok you are doing it so I will help you,’ it was, ‘why would you do it?’ So they were

> trying to turn me onto their own course. They are not very helpful, the science ones. (Aoife, Interview 1, p.5)

However, there are incidents where student teachers value the inputs from experienced teachers. There are some helpful teachers in the schools as Marissa recounts:

> The biggest experience was assisting another science teacher doing the investigation for the junior cert course with water baths and hot water…I wanted to look at her skills and how she approached things during class and that was quite helpful and interesting for me. Marissa (Interview, 2, p. 1)

This is an account of a worthwhile example of an experienced teacher helping a student teacher with lab work in a school setting, an important element of the training of pre-service teachers (Monk and Dillon, 1995)... Co-teaching and 'learning at the elbows' of someone else (Roth and Tobin, 2001) was provided to this student. She "jumped at the opportunity because it was seeing someone else teach as well as assisting." This was reported as a positive experience- she learnt about laboratory management and organisation. This mentoring was most welcome in the experience of this beginning science teacher; unfortunately in this case it was a once-off opportunity.

Thomas too, praises his mentor:

> I find from my mentor that the little hints and tips are a great help, it is not just general teaching practice theories, he actually gives us hints and tips about the actual concepts that I am teaching and I find them a great help. I can't really find them anywhere but it is just a built up knowledge he has over years of teaching the subjects. (Interview 1, p. 7).

Thomas is grateful for the opportunity of being able to learn from his mentor's vast experience. He puts it very succinctly when he states that he can't really source these "hints and tips" anywhere else. They have come from his mentor's lived teaching experience.

Student teachers are highly influenced by their mentors and other science teachers in their teaching practice school and so the relationship between them is crucial.

CONCLUSION

The teacher education community needs to cautious that mentors involved in initial teacher education programmes are open to reform based teaching and posses those sophisticated epistemologies, attitudes and beliefs concerning science that enables them to value an inquiry type approach to science teaching and so that those student teachers who are afforded an opportunity to learn "at their elbows" (Roth and Tobin, 2001) may also develop the habits of mind which facilitate a reform based approach to science teaching.

Mentor teachers are important in the formation of a science teacher but it is important that mentors or other science teachers with whom the prospective science teachers must work are disposed to reform based teaching, and the teaching of science through inquiry. Traditional notions of science teaching can be reinforced by teaching practice, but similarly submersion in a teaching environment and a chance 'to work at the elbows of' an experienced teacher who is knowledgeable about progressive teaching might change the attitudes and beliefs concerning science teaching that a prospective teacher brings with him or her to initial teacher education.

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FRI 10.00 - 11.20

GETTING YOUR HANDS ON ASPECTS OF THE NATURE OF SCIENCE (R)

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FRI 11.40 - 13.00

This workshop will feature a brief introduction to some important elements of the nature of science (principally the issues of inference, induction and deduction) that should be part of any complete programme of science instruction. Participants will then make several examples of hands-on teaching tools and practice with them. Additional materials will also be provided that exemplify the targeted issues in the nature of science. Teachers of any instructional level are encouraged to attend.

(For a paper by the author relevant to the workshop, see p.106)

IBSE: THEORETICAL AND PRACTICAL IMPLICATIONS

Nikos Valanides

University of Cyprus

Inquiry and scientific reasoning include theory generation, experiment design, hypothesis testing, control of variables and data interpretation. Klahr and Dunbar (1988; Klahr, 2000) proposed a model that conceives scientific reasoning as problem solving and is characterized by a dual search process that takes place in two related problem spaces-the hypothesis space and the experimental space. Searching the hypothesis space involves the process of generation of new hypotheses based on either some prior knowledge or as knowledge through experimentation. Searching the experimental space involves the performance of experiments that will yield interpretable results. A third process, known as evidence evaluation process, mediates search in the two spaces that assesses the fit between theory and evidence. Since the appearance of the Klahr and Dunbar's model of scientific reasoning (1988), there has been a move toward inquiry in which participants take part in all three phases of scientific activity (searching the hypothesis space, searching the experimental space, and evidence evaluation). These research projects are called self-directed experimentation research (Zimmerman, 2000) and correspond to a certain extent the nature of science that combines knowledge and the way it is constantly verified (validated) or even substantially revised. The proposed workshop will exemplify the self-experimentation process, using a specially designed device or corresponding software simulating the functioning of the device. Thus, participants will be provided opportunities to form and test hypothesis, and coordinate their hypotheses with evidence. The participants will be also instructed to finally model the functioning of the device by providing, for example, a causal relation among the relevant variables.

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THE INQUIRE PROJECT AND SOME IDEAS FOR ACTIVITIES RELATING TO BIODIVERSITY AND CLIMATE CHANGE

Alla Andreeva[1], Doris Elster[2], Suzanne Kapelari[3], Gail Bromley[4], Sue Hunt[4], Jan Möller[5] and Christine Newton[4]

[1]Moscow State University Botanic Garden

[2]Bremen University

[3]Innsbruck University

[4]Royal Botanic Gardens, Kew.

[5]Rododendron Park, Bremen

INQUIRE (www.inquirebotany.org) is a three-year project focusing on inquiry based science education and involving 17 partners in 11 European countries. Coordinated by the University of Innsbruck, Austria, the project is funded by the European Union under the 7th Framework Programme. Fourteen botanic gardens are involved in the project and are individually developing a one-year IBSE teacher training course, with support from Botanic Gardens Conservation International, King's College London, UK and the University of Bremen, Germany. The subject content of the courses focuses on biodiversity loss and climate change.

For this workshop we will introduce IBSE questioning and methods of assessment. We will also explore an activity entitled 'What we can learn by measuring plants', which is part of the INQUIRE course run at the Botanical Garden of Moscow State University "(Aptekarskiy Ogorod"). Teachers use this lesson with students in the garden.

The activities are based around comparative measurements of, for example, annual shoot growth, leaf asymmetry and leaf surface areas for various species of trees and bushes. The measurements performed by students teach them to identify plants, to compare data and to analyze the reasons for the observed differences. Students also construct hypotheses on differences in plant growth conditions and examine how global or local factors (including climate) may impact on growth and development. The measurements are compared against weather and other data to enable students to draw conclusions and develop hypotheses and forecasts of how these measurements may change in the future under various scenarios, which can then be modelled.

REFERENCES

http://www.inquirebotany.org

FRI 11.40 - 13.00

THE REVISED SENIOR CYCLE PHYSICS SYLLABUS – MAKING AN IMPACT

Jennifer Johnston[1], Anna Walshe[2], Joe Murphy[1] and Joanne Broggy[1]

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

[2]National Council for Curriculum and Assessment (NCCA)

Researchers, policy developers, and educators are placing greater emphasis on developing students' ability to think critically and creatively, are innovative and adaptive to change, who can work independently and in a team, are reflective learners and who are ready for the workplace in the 21st century (NCCA, 2011). In light of this the Irish Leaving Certificate science curricula and examinations are under reform. The change is focusing on embedding 'key skills' framework in the syllabuses.

The paper presents a collaborative project between the National Centre for Excellence in Mathematics and Science Teaching and Learning (NCE-MSTL), National Council for Curriculum and Assessment (NCCA), seven physics teachers, their students and their schools in the Munster region.

The aim of the project was to design, develop, implement and investigate teaching and learning tasks that incorporate the 'key skills' outlined in the learning outcomes of the revised senior cycle physics syllabus. The teaching and learning tasks were built upon the concept of impacts by asteroids with planetary bodies and the craters generated following such impacts. In preparation for the implementation of the revised LC Physics syllabus, the developed exemplar tasks and questions from this project will be included in the teacher guidelines that will accompany the syllabus. This project is timely as it is informing decisions on assessment and physics tasks that incorporate the 'key skills'.

A key outcome of this project was the development of specific tasks that operationalised the learning outcomes (Millar, 2012) and embedded the 'key skills' in the learning outcomes. The study was evaluated through teacher interviews and lesson observations, video recorded lessons, student written work, and student presentations. The key findings emerging from this study in relation to Asteroids, Impacts and Craters task development and how the learning outcomes were operationalised are outlined in the paper.

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PROJECT WE TEACH (LEARN) CREATIVE AND ACTIVE FOR LIFE

Zuzana Majerčáková and Katarína Jakubíková

Private grammar school aimed at sports in Košice, Slovakia.

The aim of the current school reform in Slovakia is to transform the traditional school into a modern educational institution. This can be attained only by transforming the traditional curriculum and procedures in education to match the current needs of modern society. On account of that, our grammar school was engaged into a project named *We teach (learn) creative and active for life* that ran under the national Operational Programme on Education. The main project goals were to develop and deepen the key teachers' competencies in order to change the traditional school into a modern one, as well as to innovate instructional means, curriculum, methods, and forms of education that would lead to creating a new school programme with emphasis on the use of activating and motivating different forms of education. Within the project we developed a set of activities in which we tried to connect the theory with pupils' own experiences. With regard to science education we prepared several activities, many of them enhanced by ICT, namely Science laboratory, English in Physics, Let's learn the nature around us involving all our senses and creative activities, Your help can also help and My first book and My first film studio for teaching informatics. All these activities were implemented at lower and upper secondary level. This contribution presents the activities developed in detail and discusses and analyses the results obtained by their implementation in the class as well as their future perspective.

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Project We teach (learn) active and creative, available on http://ssgkosice.stranka.info/index.php?vid=B

ASSESSMENT FIT FOR PURPOSE – SUPPORTING CHANGE IN IRISH SCIENCE CLASSROOMS

Anna Walshe

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Second component assessment in Ireland that includes a practical element has been the subject of much discussion and debate over the past number of years. The discussions have been wide-ranging and have featured a range of perspectives and understandings. What has become evident is that even the term 'practical assessment' gives rise to multiple and sometime conflicting interpretations. This paper will outline a collaborative project by the NCCA and a network of teachers from 26 schools to develop examples of practical assessment that would work within the Irish education system, and so feed into the discussion on practical assessment of science in Ireland.

One of the common criticisms of practical examinations is the tendency to concentrate on a written product without due emphasis on capturing the process and the thinking behind the doing. The challenge for the network was to design a set of assessment tasks that provided clear evidence of a candidate's science process skills, where the recorded data and observations were indicative of the candidate's performance and that the correct processing of data subsequently could be inferred to mean that the procedure (manipulation, observation, etc) has been carried out correctly. The tasks had to align with the learning outcomes of the revised Leaving Certificate science syllabuses, and be suitable for external assessment.

As well as the examples of assessment tasks, a key outcome of this work was the production of a number of video recordings of students carrying out the task under examination conditions. The existence of 'live' examples from Irish classrooms gave teachers, learners and the wider public a snapshot of what second component assessment might look like, and informed the debate on the inclusion of a practical element in assessment in Leaving Certificate science. This paper will outline the work of the network, and describe the process of generating the assessment tasks.

EFFECTIVE EVALUATION OF PHYSICS INSTRUCTION

Leanne Doughty, Eilish McLoughlin and Paul van Kampen

Centre for the Advancement of Science and Mathematics Teaching and Learning & School of Physical Sciences, Dublin City University, Glasnevin, Dublin 9, Ireland.

The technique of pre and post testing is often used to examine the level of students' understanding, and to identify students' preconceptions and misconceptions. Using pre-tests in advance of instruction to identify pre/misconceptions means that instruction can be designed that can directly tackle incorrect or incomplete understanding. Post-tests conducted after instruction, either directly following instruction or after a period of time, are then used to investigate if these pre/misconceptions were addressed successfully. Post-tests can also identify misconceptions students may have obtained as a result of the instruction or may highlight other unexpected student difficulties. Through comparison of pre and post-test data it is possible to determine the effectiveness of the instruction or intervention implemented. Through conducting student interviews a more specific and in-depth view of what students know can be gained.

This presentation will show the analysis of pre and post-test data from more than 450 students over the last 3 years, which has been used to investigate the effectiveness of curricula designed for an Introductory Waves and Optics course and an intermediate Electromagnetism course at third level. It will be outlined how through a combination of these results and the use of student interviews, instructional materials have been designed and improved.

DEVELOPING STANDARDISED TESTS OF POST-PRIMARY STUDENTS' MATHEMATICAL KNOWLEDGE IN THE CONTEXT OF THE IMPLEMENTATION OF PROJECT MATHS

Seán Close, Gerry Shiel, Joanne Kiniry and David Millar

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This paper describes and discusses some of the results of three pilot studies of standardised mathematics tests currently being developed for 2nd Year post-primary schools in the context of the ongoing implementation of Project Maths and the National Strategy for Literacy and Numeracy 2011-2020. The studies were carried out in samples of about 20 schools in March 2011, October 2011, and March 2012. The results reported here focus on the statistical indices of individual items or groups of items in the three pilot studies and are discussed in terms of the test framework dimensions such as mathematical content and cognitive process skills involved. The results are also discussed in terms of the Higher and Ordinary level courses in the Junior Cycle mathematics curriculum. The findings lead to a number of conclusions relating to the teaching, learning and assessment of mathematics at Junior Cycle level.

INTRODUCTION

This paper briefly describes and analyses the results of a series of three pilot studies carried out in the Spring and Autumn of 2011 and the Spring of 2012, as part of a project to develop a standardised mathematics test for use in the Second year of post-primary school and which would be compatible with the incoming Project Maths curriculum for Junior Cycle.

Project Maths

Project Maths is a revised mathematics curriculum that is currently being introduced into post-primary schools. The Project Maths curriculum is being phased in for both Junior Cycle and Senior Cycle over an eight-year period. It commenced with 24 pilot schools in September 2008 and it is planned that it will be fully implemented in all post-primary schools, across all classes, by June 2015. Project Maths places much greater emphasis on student understanding of mathematical concepts, with increased use of contexts and applications that will enable students to relate mathematics to everyday experience and develop their problem-solving skill (cf. Project Maths website at http://www.projectmaths.ie/overview/).

Rationale for standardised tests at Junior Cycle

The decision to develop new standardised tests of mathematics for the Second year of post-primary schooling was influenced by two reports:

(i) A study commissioned by the NCCA, that established a need for standardised tests of mathematics at lower secondary level, and pointed to the potential diagnostic value of such tests for parents, teachers and students (Shiel, Kellaghan & Moran, 2010).

(ii) The proposal in the Department of Education and Skills' *Literacy and Numeracy for learning and Life: The National Strategy to Improve Literacy and Numeracy in Schools* (DES, 2011) that post-primary schools should administer standardised tests in mathematics (and reading) to students at the end of second year and use outcomes for school self-evaluation and improvement, commencing in 2014.

In developing tests that would be suitable for second-year students from 2014 onwards, it was recognised from the outset that the phased nature of the implementation of Project Maths in schools would need to be taken into account. The findings of the pilot studies described in this paper highlight the difficulties of doing so.

Aims of the Pilot Studies.

The aims of the three pilot studies were to:

- Examine the suitability of the tests for Second year post-primary students with particular reference to issues relating to the implementation of Project Maths
- Identify problematic items using item analysis techniques
- Evaluate and refine test design and administrative procedures.

THE MATHEMATICS TEST FRAMEWORK

The implementation of the PM syllabus began in September 2010 for all schools and will not be fully implemented until June 2015. The assessment framework and specifications for the proposed JC standardised mathematics test is based on both the existing JC maths syllabus and the incoming Project Maths syllabus, for which there is a common syllabus for First year, though not for Second or Third years. The initial focus of test development is on producing tests for administration towards the end of Second year, beginning in 2014. The test framework has three principal dimensions – (i) *mathematics content;* (ii) *cognitive process skills;* and (iii) *task contexts*. A description of the three dimensions is as follows:

Content Strands: The content strands covered by the test include: (i) *Statistics & Probability*; (ii) *Geometry & Trigonometry;* (iii) *Number & Measure*; and, (iv) *Algebra & Functions* (these last two are separate strands in the current JC syllabus). They are also the principal strands of the incoming PM syllabus. Approximately equal emphasis is given to each of the four strands across all the test items.

Process Skills: The process skills assessed include (i) *Recall of relevant facts, terms & concepts*; (ii) *Implementation of standard procedures* (referred to as *instrumental understanding* in the Junior Cycle syllabus); (iii) *Reasoning & connecting* (referred to as *relational understanding* in the Junior Cycle syllabus); and, (iv) *Applying, analysing, & solving problems.* These cognitive process skills are in accord with those specified in the existing JC maths syllabus and the incoming PM syllabus.

Task Contexts: The contexts in which the mathematics is embedded include (i) *Practical contexts* (personal, social/occupational, scientific), and, (ii) *Pure mathematical contexts* (tasks which assess individual concepts or skills in isolation and not embedded in any practical context).

Calculators are permitted for the tests. The items were written by a team of experienced mathematics teachers who are seconded as Regional Coordination Officers in the implementation of Project Maths.

THE FIRST PILOT STUDY

Method

The first pilot study was carried out in March 2011 and involved a test containing a total of 95 items, with c.70% of them assessing the processes of reasoning and problem-solving (c.70% of items) and the rest assessing conceptual and procedural and procedural processes, across the four strands of the revised curriculum. Three quarters of the items were open response with other 20% being multiple choice. About 70% involved a practical context with the other 30% involving a purely mathematical context (cf. Table 1 below; also see Close, Shiel, Kinniry & Millar (2011) for a report of the first pilot study).

Table 1: Item Frequency by Content Strands for 1st Pilot Study Tests.

Content Strand:	**No. of Items**
Statistics & Probability	27
Geometry & Trigonometry	15
Number & Measure	30
Algebra & Functions	23
Total	**95**
Skill Category:	
Recall facts & terms; Implement procedures	28
Reason & connect; Apply, analyse & solve problems	67
Total	**95**
Context Category:	
Practical Contexts	67
Mathematical Contexts	28
Total	**95**
Item Format:	
Multiple Choice	19
Open Response	76
Total	**95**

The 95 items were divided evenly among three booklets (Bk.1 - 32 items; Bk.2 – 32 items, and Bk. 3 – 31 items). Students were allowed 45 minutes to complete the test.

Results

1026 students in ten schools in the greater Dublin area participated in the pilot study. Since these students were in Second year in 2010-11, they had no direct experience of the PM syllabus. The mean weighted item percentage scores on the three test booklets were: Booklet 1 - 37.02% (N = 352); Booklet 2 - 43.76% (N = 340); and Booklet 3 - 40.86% (N = 334). These figures were considered low for a potential standardised test.

The item characteristics of individual items were also examined in terms of their ability to discriminate among higher and lower achieving students. Table 2 shows the numbers of items in each booklet with difficulty levels less than 0.25 and discrimination levels (Point Biserial) less than 0.30. Whereas just 7 items did not meet the discrimination criterion of 0.30, 26 items had difficulty levels of less than 25%.

Table 2: Numbers of Items with Serious Problems by Booklet*:

		Number of Items with Potential Problems		
	Total Number of Items	Difficulty < 0.25 Only	Point Biserial <0.30 Only	Below criterion for both
Booklet 1	33**	8	1	3
Booklet 2	32	8	1	0
Booklet 3	31	7	2	0
All Booklets	96	23	4	3

*Criteria: Difficulty Level < .25; Point Biserial Coefficient < .30. ** One item could not be included in scoring due to misprint.

Discussion

Inspection of the 26 very difficult items showed that they all involved higher order cognitive skills of reasoning, applying, analysing and solving multi-step problems. Eight of the items related to the Probability & Statistics strand, 5 of which were on probability, a topic the students in the pilot study sample would not have been taught as it is on the PM syllabus but not on the current JC syllabus. A further 8 items involved applied algebra including interpreting, substituting or transposing verbal or symbolic formulae relating to practical situations or geometric patterns. Here again these latter skills are a major focus of PM but are given limited attention in the outgoing syllabus. The other 7 items required the solution of more complex multi-step arithmetic problems. Nineteen of the 23 very difficult items were set in a practical context and just three of them were multiple-choice.

THE 2ND PILOT STUDY

Method

The second Pilot study test, carried out in November 2011, consisted of a pool of 160 new items divided among four booklets (Bk. 4: 42 items; Bk. 5: 36 items; Bk. 6: 41 items; and Bk. 7: 41 items) each allocated 35 minutes for completion. About 60% of the items assessed the process skills of recalling conceptual knowledge and implementing procedures in mainly practical contexts (c.60%) across the four content strands, with the other 40% assessing reasoning and problem-solving, also in mainly practical contexts. All items in this study were in multiple-choice format. The classification of items by framework dimensions and item format is given in Table 3.

Table 3: Item Frequency by Content Strands.

Content Strand:	**No. of Items**
Statistics & Probability	41
Geometry & Trigonometry	35
Number & Measure	41
Algebra & Functions	43
Total	160
Skill Category:	
Recall facts & terms; Implement procedures	93
Reason & connect; Apply, analyse & solve problems	67
Total	160
Context Category:	
Practical Contexts	96
Mathematical Contexts	64
Total	160
Item Format:	
Multiple Choice	160
Open Response	-
Total	160

The four mathematics booklets were administered to 1242 students in their schools during the first two weeks of November. The booklets were distributed to the students on a rota basis so that no student was sitting beside another student with the same booklet and each booklet was taken by approx. one quarter of the students. They were allowed 35 minutes to complete their test booklets. Students had access to calculators. The booklets were then scored by a team of trained markers and the scores entered in a database for analysis.

Results

1242 students in 20 schools participated in the 2nd pilot study. These second-year students had been taught under the PM syllabus since the beginning of first year. The mean weighted item percentage scores on the four test booklets were: Booklet 4 - 51.7% (*N* = 307); Booklet 5 - 45.0% (*N* = 312); Booklet 6 – 44.5% (*N* = 315); and Booklet 7 - 48.4% (*N* = 318). These are an improvement on the Spring 2011 pilot study means but are still somewhat low for a potential standardised test.

As in the first Pilot Study, the item characteristics of individual items were examined in terms of their difficulty and ability to discriminate among higher and lower achieving students. Table 4 shows the numbers of items in each booklet with difficulty levels less than 0.20 and discrimination levels (Point Biserial) less than 0.25.

Table 4: Numbers of Items which fell below difficulty and discrimination criteria by Booklet*

		Number of Items with Potential Problems		
	Total Number of Flagged Items	Difficulty < 0.20 Only	Point Biserial <0.25 Only	Below criterion for both
Booklet 4	13	1	10	2
Booklet 5	7	0	4	3
Booklet 6	12	2	8	2
Booklet 7	11	1	4	6
All Booklets	43	4	26	13

*Criteria: Difficulty Level < .20; Point Biserial Coefficient < .25

Discussion

Inspection of the flagged items in conjunction with their item statistics suggested that about half of them may have been problematic due to difficulties students had in interpreting the text in the stem and/or due to distracters not performing as intended. Presenting items in some sort of practical context usually requires the use of a significant amount of text in the stem, and in some cases in the responses also. Traditionally students have been used to performing mathematics tasks which are embedded mainly in pure mathematical contexts, with little or no verbal text. Although PM is moving towards more contextualised tasks, textbooks and published materials and, hence teaching, have been slow to follow this trend. As with the first pilot study, this difficulty complicates the development of standardised mathematics tests particularly when the new PM syllabus is being implemented on a phased basis.

Most of the other half of the flagged items manifested a somewhat different problem. These items were attempting to assess students' knowledge in the Algebra and Geometry strands of the PM curriculum, more specifically the topics of: quadratics; mathematical modelling; coordinate geometry of the line; and application of geometric theorems. These topics do not appear to have been taught to many of the students doing the tests given their poor performance on what are, apart from the two modelling items, items requiring straightforward implementation of procedures and formulae. This may be due to the fact that there is no prescribed programme for Second year students in post-primary schools though there is one for First year students, or, it may be due to the pilot study being carried out early in the school year rather than later when these topics were more likely to have been taught.

3RD PILOT STUDY

Method

In the light of the results of the performances of students on the tests used in the 1st and 2nd pilot studies students it was decided to prepare separate test booklets for Ordinary

Level and Higher Level students in their second year of post-primary school, with each of the test booklets containing a unique set of 24 items combined with a common set of 16 linking items, making a total of 40 items per test booklet. There would be three forms (A, B, and C) for each test, that is, six tests in all. The distribution of items across the six tests, classified by content, process and context are given in Table 5. All the items were multiple choice and, aprt from six replacement items, were the same items as were used in the 2nd Pilot Study.

Table 5: Classification of items for 3rd Pilot Study by Strand, Process and Context.

		AH	BH	CH	AO	BO	CO	Link items	Total
Content Strand	**Stat. & Prob.**	6	5	4	9	5	8	4	43
	Geom. & Trig.	8	6	4	2	6	1	4	31
	No. & Meas.	3	6	5	8	8	8	3	41
	Alg. & Funct.	7	7	11	5	5	7	5	47
	Total	24	24	24	24	24	24	16	160
Skill Category	**Recall & Impl.**	13	11	11	13	17	17	7	89
	Reas. & P.S.	11	13	13	11	7	7	9	71
	Total	24	24	24	24	24	24	16	160
Context Category	**Practical**	9	14	16	15	17	16	10	97
	math.	15	10	8	9	7	8	6	63
	Total	24	24	24	24	24	24	16	160

Results

1603 students in 20 schools participated in the 3rd pilot study. Like the students in the second pilot study, these Second-year students had been taught under the PM syllabus since the beginning of First year. The mean weighted item percentage scores on the six test booklets were: Booklet A-Higher - 53% (N = 341); Booklet B-Higher, 57% (N = 342); Booklet C-Higher, 57% (N = 351); Booklet A-Ordinary 51% (N = 190); Booklet B-Ordinary 50% (N = 192); and Booklet C-Ordinary 45% (N = 187). These are an improvement on the Spring 2011 pilot study means but are still somewhat low for a potential standardised test, especially for those students likely to take the Junior Certificate Ordinary level.

These figures were further broken by test division i.e. into the 24 items *unique* to each test and the 16 items *common* to each test. This analysis revealed that the Higher level students achieved a mean percentage score of around 70% on the *common* items and the Ordinary level students achieved a mean percentage score of 42% on the same set of items. Also, Higher level students achieved a mean percentage score of around 50% on the *unique* sets of items (Booklets BH and CH) and the Ordinary level students achieved a mean percentage score of around 56% on their *unique* item sets (Booklets AO and BO). (see Table 6 below). The exceptions to these figures were the students who sat Booklet

A-Higher and Booklet C-Ordinary where performance was somewhat lower than on the other common and unique item sets. Analysis of item statistics revealed that these two anomalies appears to be principally related to the issue of variable content coverage in certain topics referred to in the earlier discussion of the results of the 2nd Pilot Study, i.e. the topics of quadratics; mathematical modelling; coordinate geometry of the line; and application of geometric theorems. These anomalies had negative effects on both item difficulty and discrimination.

Table 6: Mean percentage correct by booklet and by test division.

	AH	BH	CH	AO	BO	CO
Unique	42	49	49	57	56	47
Common	68	70	69	42	42	42
Total	53	57	57	51	50	45

FRI 14.00 - 16.30

Discussion

The results of the 3rd Pilot Study support the decision to develop separate standardised mathematics for Higher and Ordinary level students in the second year of their post-primary schooling. The inclusion of a common set of items on both tests will allow the placement of Higher and ordinary level students on the same performance scale to facilitate interpretation and reporting of results This will be achieved using item response theory methodologies.

CONCLUSIONS

The pilot studies described above highlighted a number of issues that needed to be considered in the development of standardised mathematic tests for post-primary schools including:

- The difficulty of developing standardised mathematics tests when a new PM syllabus is being implemented on a phased basis emerged. An added complication in this regard is that there is no prescribed programme for Second year students in post-primary schools though there is one for First year students (DES/NCCA, 2010). A consequence of this is that some topics may be covered in Second year in some classes, and in Third year in others.
- The difficulty in developing a single standardised mathematics test for both Ordinary Level track and Higher Level track students (with the former being mainly concentrated in DEIS schools). A decision was taken to develop two separate standardised tests for use in schools – a Higher level test and an Ordinary level test with a subset of common linking items in both tests.
- The need to increase the number of items that each student is asked to attempt, in order to improve reliability. However, computer-based adaptive testing, if used, could help to deal with this issue, by targeting items more precisely to student ability levels.

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MODELLING SCIENCE AND MATHEMATICS INTEGRATION AT SECOND-LEVEL: PROTOTYPING AND PROOF OF CONCEPT OF AN INTERVENTION

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FRI 14.00 - 16.30

Integration of science and mathematics may assist students to improve their interest and performance in these subjects. The emphasis on contextualised mathematics in the new Project Maths curriculum makes it now more feasible to foster the connections between these school subjects. This study is investigating the design and development of a suitable model of science and mathematics integration at second-level, through developing an appropriate Teaching and Learning Sequence for overlapping science and mathematics topics, and a series of Critical Integrated Skills Activities for science teachers. The methodology for this study is Educational Design Research, which is characterised by iterative design and formative evaluation of interventions in complex real-world settings. Working with teachers to inform, design, pilot and refine the intervention is an essential part of this methodology. The formative evaluation of prototypes of the integrated skills activities will culminate in the summative evaluation of their implementation in a quasi-experimental school-based intervention. Building on previous research work carried out in the National Centre for Excellence in Mathematics and Science Teaching and Learning, a 'proof of concept' approach is being used to evaluate the integrated Science and Mathematics Teaching and Learning Sequence. This offers a partial solution to an educational problem, where a full-scale field trial is not feasible. The paper will describe this innovative research design.

INTEGRATING SCIENCE AND MATHEMATICS AT SECOND-LEVEL IN IRELAND

Science and mathematics are naturally correlated in the physical world, yet as school subjects they can be quite separate, even where they share overlapping content (Czerniak *et al*, 1999; NCCA, 2005). Science and mathematics integration has been recommended as a way to increase student conceptual understanding of, interest in, and motivation to learn both subjects. The literature on science and mathematics integration indicates that, although it is often recommended, science and mathematics integration research has floundered to some extent possibly because of a lack of a clear definition (Hurley, 2001). Models of integration vary considerably (Pang & Good, 2000). In the Irish context, changes in the mathematics and science syllabuses mean that investigating a model for inquiry-based science and mathematics integration is now more feasible than ever before. However, much of the research on integration has been carried out in countries where teachers have considerable scope to develop their own curricula, and so is not directly applicable to the Irish context. A design research methodology is being employed in this project in order to design, develop and evaluate an appropriate model for integration. A literature review and an exploratory survey carried out in Cycle 1 of this project contributed to a contextual analysis that has lead to the formation of design guidelines for the development of a suitable model for science and mathematics integration. This model consists of three elements, which are currently being prototyped in Cycle 2 of the research: a syllabus map of the overlapping content on the science and mathematics curricula, a Teaching and Learning Sequence for overlapping science and mathematical content and skills, and a series of Critical Integrated Skills Activities for science classrooms. While formative evaluation of successive prototypes of the Critical Integrated Skills Activities can be followed by their summative assessment in a classroom implementation; this is not feasible for the final prototype of the integrated Teaching and Learning Sequence. Therefore the notion of 'proof of concept' has been adapted from product design in order to evaluate the final prototype of the Sequence.

INTRODUCTION TO DESIGN RESEARCH

Design research has been defined as the

> systematic study of designing, developing and evaluating educational interventions, (such as programs, teaching-learning strategies and materials, products and systems) as solutions for complex problems in educational practice, which also aims at advancing our knowledge about the characteristics of these interventions and the processes of designing and developing them. (Plomp, 2009: p.13)

Educational design research has its origins in the 'design experiments' movement that took off in the 1990s (Collins *et al*, 2004) in North America, the Dutch 'developmental research' in realistic mathematics education and van den Akker's more general design-theory oriented form of design theory research (Gravemeijer & Cobb, 2006). Design research refers therefore to a family of related research approaches that vary in aims and characteristics, and which can be found under the labels design studies, design experiments, development/developmental research, formative research, formative evaluation, and engineering research (van den Akker, 2006). A major motivation for doing design research is that it is pragmatic, aimed at developing interventions in real educational practice (van den Akker, 2006).

Engineering and Educational Design Research

The model, or at least metaphor, for educational design research is often taken from design research in engineering, akin to design science methodologies in software engineering development (Collins *et al*, 2004; Edelson, 2005; Middleton *et al*, 2008). As with engineering design processes, educational design studies can be said to end in 'products', or designed artefacts, which may be a piece of educational software, a set of educational materials, an educational programme, a model of practice, as well as design principles or theory (Kelly, 2004). According to Hjalmarson and Lesh (2008), engineering design involves the design and development of products that operate in systems, so it also includes the process of design as well as the tangible products of design. It is this interaction of process and product that is also important in educational design research. The process in educational design research, as in engineering design research, is therefore highly iterative, characterised by the prototyping of a solution, in collaboration with the end-users or practitioners (Plomp, 2009). Formative evaluation of prototypes therefore is central to design research processes, followed by summative or semi-summative field testing of the final design (Nieveen, 2009).

The Stages of Design Research

Plomp (2009) summarises the stages of design research, drawing on the work of a number of researchers. These are:

- *Preliminary research:* needs and context analysis, review of literature, development of a conceptual or theoretical framework for the study
- *Prototyping phase*: iterative design phase consisting of iterations, each being a microcycle of research with formative evaluation as the most important research activity aimed at improving and refining the intervention

- *Assessment phase*: (semi)-summative evaluation to conclude whether the solution or intervention meets the pre-determined specifications. As also this phase often results in recommendations for improvement of the intervention, we call this phase semi-summative (Plomp, 2009: p. 15)

Figure 1 depicts the relationship of Plomp's (2009) three stages for educational design research with the two cycles of research being carried out in this study.

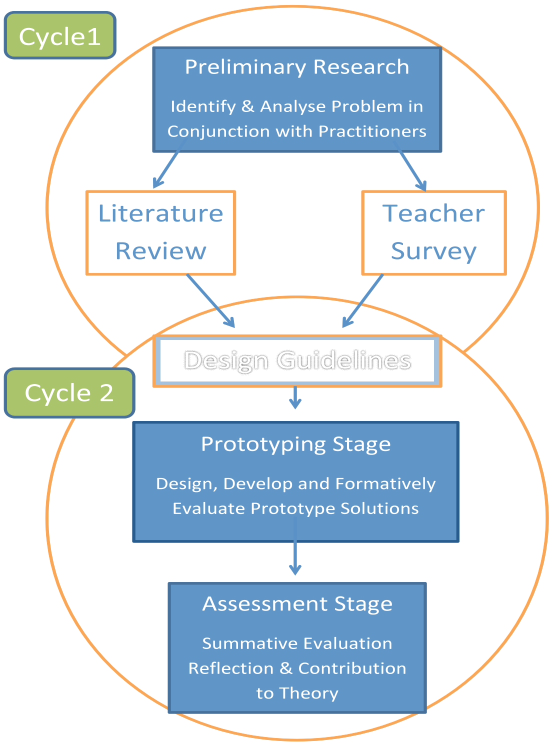

Figure 1: Overview of the research design for this study, showing how the two cycles of research relate to Plomp's (2009) three stages of Educational Design Research.

By analogy with engineering design, some researchers suggest that the preliminary phase constitutes, or should constitute, a feasibility study of the value, potential effectiveness, acceptability to end-users and other stakeholders, and other consequences of the intervention (Middleton *et al*, 2008). This follows from the reason one would choose a design research methodology: because the problem to be solved exists in a complex real-world situation with many variables – so called 'wicked' or open problems that are ill-defined (Kelly, 2009). The context analysis or feasibility study leads to system specification, or in the case of education, 'design guidelines', that permit an initial model or prototype to be built (Fitzgerald, 1990; Plomp, 2009). The aim of design research is to develop a final product, artefact or materials for use by users in a particular context, but also to develop design principles for developing similar products for use in other contexts (Hjalmarson and Lesh, 2008). More generally, the outcome of educational design research is not just the educational 'product', but also, as Figure 1 shows, the contribution to educational theory (Kelly, 2004).

Proof of Concept and Prototyping

A proof of concept may be said to provide a 'partial solution' to an educational problem (O'Meara, 2010). Proof of concept can be defined as 'a model of some part of a design that is used specifically to test whether a particular concept will actually work as proposed' (Dym *et al*, 2009). It is an essential part of the design process in the fields of engineering, architecture, Information Systems, and clinical medical trials, among others. According to Dym *et al*,

> In design the type of testing that is often most important is *proof of concept* testing in which a new concept, or a particular device or configuration, can be shown to work in the manner in which it was designed…Laboratory demonstrations of wing structures…can…be considered as proof-of-concept tests when they are used to validate a new wing structure configuration…In fact, even market surveys of new products…can be conceived of as proof-of-concept tests that test the receptivity of a target market to a new product. (2009, p. 166)

Engineering models are used to 'illustrate certain behaviours or phenomena as we try to verify the validity of an underlying (predictive) theory' (Dym *et al*, 2009: p. 165). This may be the final product of the research where a full field trial is not feasible due to practical constraints, as is the case, for example, for architects and engineers who design large structures. In these cases small-scale or software models are the closest that designers can come to the final product (Horenstein, 2010). However, this small-scale prototyping/modelling of the intervention can be said to establish important conceptual principles (Gregg *et al*, 2001), and this 'proof of concept' can form the basis for a further project with a full field trial. Similarly in education it is not always possible to do a final field trial with the target group, so the final 'proof of concept' may be provided by expert appraisal or a micro-evaluation of the final prototype (Plomp, 2009; Reimann, 2010). O'Meara, for example, employed a proof of concept approach for the evaluation of her model of professional knowledge development for mathematics teachers (O'Meara, 2010). This research builds on O'Meara's approach.

RESEARCH DESIGN

In this research project Plomp's stages of design research as outlined above are being used (see Figure 1). In the Preliminary Research stage (Cycle 1): a context analysis of the situation of science and mathematics education in Ireland was undertaken, and the international literature on science and mathematics integration was reviewed. An exploratory survey was carried out with teachers from five second-level schools. This investigated science and mathematics teachers' views and previous experiences of integration in order to inform the direction of the research project. The context analysis and literature review together have led to the formation of design guidelines that led to the decision that the most appropriate model for integrating science and mathematics at second-level is to design, iteratively develop, and evaluate the following three items:

1. Map the new Project Maths syllabuses onto the Junior and Senior Science syllabuses.
2. Develop a Teaching and Learning Sequence appropriate for overlapping topics and skills in science and mathematics.
3. Develop a series of Critical Integrated Skills Activities for science teachers to use at key intervals over junior and senior cycle, relating to the overlapping core integrated skills of data handling, representation and analysis in inquiry investigations.

Prototyping Science and Mathematics Integration

The current stage of the research, Cycle 2, encompasses the Prototyping stage, followed by the Assessment Stage. Prototypes of each of the three items, the syllabus map, the Teaching and Learning Sequence and the Critical Integrated Skills Activities are being developed and evaluated. The syllabus map and sequence together are feeding into the initial design of the Critical Integrated Skills Activities. The flowchart in Figure 2 illustrates the prototyping stages envisaged for each of these items and how they relate to each other. It also indicates the method of formative evaluation of each prototype.

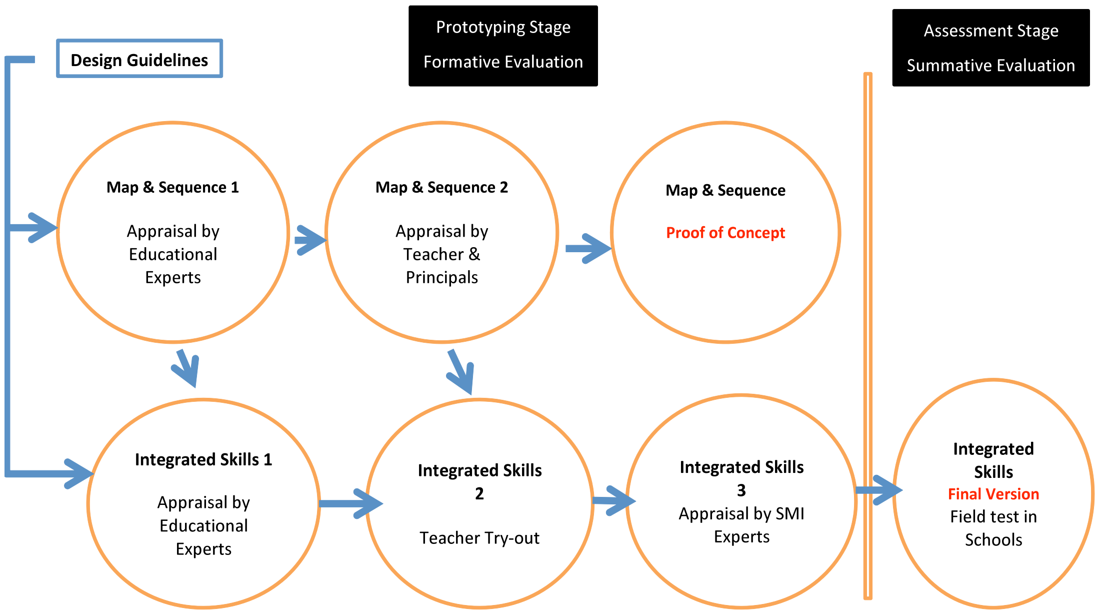

Figure 2: Diagram detailing the Prototyping and Assessment Stages of Cycle 2 of the research (Adapted from Mafumiko, 2006; Plomp, 2009)

Formative Evaluation, Proof of Concept and Summative Evaluation of Integration Prototypes

The method of evaluation chosen at each prototyping stage is related to three generic criteria proposed for high quality interventions: validity, practicality and effectiveness (Nieveen, 2009; Plomp, 2009; Mafumiko, 2006)**.** As indicated in Figure 2, the initial prototypes of the syllabus map and of the teaching sequence will be evaluated through the written commentary of, and interviews with, Irish educational and curriculum experts. They will be asked to consider whether these are valid designs, and how practical the integrated sequence would be if implemented. The initial prototypes for the Critical Integrated Skills Activities will be primarily evaluated for validity by expert appraisal and for practicality by teacher try-out and commentary. As it is not feasible to field test a full-scale prototype of the Teaching and Learning Sequence, proof of concept will be sought through its appraisal by experts and by practitioners and stakeholders. It will be possible therefore to make conclusions regarding its ‘expected effectiveness’ (Plomp, 2009). It is feasible, however, to field test the final prototype of the Critical Integrated Skills Activities within classrooms. This will be summative evaluation using a quasi-experimental non-equivalent control group design (Mafumiko, 2006; Tilya, 2003). It will therefore be possible to make conclusions regarding the actual effectiveness of the Critical Integrated Skills materials. Instruments for data collection will include pre- and post- tests of student conceptual learning, classroom observations, teacher interview and questionnaire, and student focus groups.

CONCLUSION

Design research methodologies are very suitable for the design, development and evaluation of school-based interventions. They involve practitioners at each stage, and permit the iterative refinement of prototype solutions, with the final educational 'product' being implemented in real classrooms. However, where it is not feasible to implement and evaluate the final prototype in a real-world setting, due to practical, ethical or financial constraints, proof of concept permits for the evaluation of the conceptual suitability of a set of educational materials, software, or, as in this case, a Teaching and Learning Sequence. Establishing the expected effectiveness of an exploratory prototype in this way means that educational 'designers', like designers in engineering, drug design, architecture and software, can explore the feasibility and conceptual viability of educational interventions that would be difficult or impossible to field test on a larger scale. This design research approach has been developed as part of the initial stage of this ongoing science and mathematics integration project.

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THE CHALLENGE OF CHANGE – EXPERIENCES OF PROJECT MATHS IN THE INITIAL GROUP OF SCHOOLS

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The revision of post-primary mathematics syllabi and the associated teacher professional development under Project Maths place greater emphasis on student understanding of mathematical concepts, on the development of mathematical skills, and on the application of knowledge and skills to solving problems in both familiar and unfamiliar contexts. This increased emphasis calls for a changed approach in the teaching and learning of mathematics, which presents many challenges for everyone involved.

This paper summarises the feedback from teachers of mathematics in the initial group of 24 schools in respect of their experience of change arising from the introduction of revised mathematics syllabuses and their assessment in the first four years of the project. The feedback was gathered through visits by the authors to each of the 24 schools in December 2011, where they met with mathematics teacher to reflect on their experiences of Project Maths, and a subsequent general meeting with representatives of these schools in April 2012.

The paper also considers the implications of the experience of Project Maths for other developments that involve changes in teaching and learning at second level. The experience of the initial group of schools involved in the project suggests that teachers need both extensive and intensive support to meet the challenges they face in changing their classroom practice.

TAKING THE TEACHING OF MATHEMATICS SERIOUSLY: MAKING MATHEMATICS TEACHING PUBLIC

Dolores Corcoran

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FRI 14.00 - 16.30

Researchers into mathematics teacher education in South Africa have identified three models of teacher education; classified as, look at me (a transmission model), look at you (a reflective model) and look at practice (an interactive, evolving model).The third is deemed to be most conducive to reform of mathematics teaching (Davis, Adler & Parker, 2007). Studying practice implies a nuanced and iterative approach to teacher development. It is premised on the 'situatedness' of particular contexts, focuses on the interface between learners and the mathematics, recognises student agency and is collaborative by nature (Corcoran, 2009). This presentation outlines two 'boundary objects' which have proven useful in the developing of mathematics teaching (Corcoran, 2011). The first is lesson study, a simple but profound protocol for studying teaching (Hart, Alston and Murata, 2011). The second is the Knowledge Quartet (KQ), a framework of eighteen to twenty contributory codes that identifies how the teacher's knowledge of mathematics impacts on a lesson. The KQ is categorised along four dimensions, Foundation, Transformation, Connection and Contingency (Rowland, Huckstep and Thwaites, 2005) and is a powerful aid in planning for or reflecting on mathematics teaching. Used in tandem, these tools can help teachers and student teachers to come to grips with the challenges and possibilities they face in attempting to develop mathematical thinking in their lessons.

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LEARNING TO BECOME A 'GOOD' MATHEMATICS AND SCIENCE TEACHER AT POST-PRIMARY LEVEL: INSIGHTS FROM THE LEARNING TO TEACH STUDY (LETS)

Paul F. Conway

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The last decade has seen an unprecedented policy interest globally in initial teacher education and how it interfaces with the rest of the continuum of teacher education (Darling-Hammond & Bransford, 2005). Within this context, there has also been a heightened interest in how 'good' teaching can be promoted in science, technology, engineering and mathematics (STEM). Drawing on insights from the Department of Education and Skills-funded Learning to Teach Study (LETS), the first ever programme level study of the Post-graduate Diploma in Education (PDE) in Ireland, this presentation will focus on a number of key challenges in promoting 'good' teaching in mathematics and science (Conway *et al*, 2010; Conway *et al*, 2011; Delargey *et al*, 2012). While some of these challenges are shared with teacher education more broadly, others are not. Among the issues the paper will discuss are: the image of the subject, the impact of the apprenticeship of observation on prospective teachers, the nature of reform-oriented teaching, understandings of the so called 'real' world and its meaning in curriculum enactment as well as the scope and design of problem solving.

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A SNAPSHOT OF SOME OF THE ISSUES SURROUNDING SCIENCE EDUCATION IN PRIMARY INITIAL TEACHER EDUCATION IN IRELAND

Clíona Murphy

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This paper will provide an overview of some of the key issues in relation to science education in initial primary teacher education in Ireland. Findings that emerged from two Irish studies will provide the context for this presentation.

The first study that will be considered is an all-Ireland longitudinal study that explored a number of avenues in initial teacher education in the areas of history, geography and science education (Waldron *et al*, 2009). The participants in this large-scale study consisted of 1, 400 student primary teachers in the five initial teacher education (ITE) colleges in the Republic of Ireland (RoI) and the two ITE colleges in Northern Ireland (NI). Key findings in relation to these primary student teachers' experiences and attitudes towards science and on their experiences of teaching science during school placements will be presented. Findings regarding how their concepts of good teachers of science had developed over the course of their bachelor of education (B.Ed.) degree programmes will also be considered.

The second study reported here followed on from the Waldron *et al* (2009) study and examined the impact a yearlong initial teacher education course had on 330 student primary teachers' conceptual and pedagogical knowledge on science, on their attitudes towards and concerns they held about teaching science in the primary classroom (Murphy and Smith, 2012). While this study revealed that the curriculum science methods course had a positive impact on developing students' scientific content knowledge, there were still high percentages of students who revealed inaccurate conceptions of many science concepts at the end of the course, which was a cause of concern for many of them.

Encouragingly, findings from both studies reveal that Irish student primary teachers hold positive attitudes towards science, feel confident about teaching science, maintain science is an important subject for children to learn and reveal strong commitments to active inquiry-based learning environments. However, a number of issues emerged that are a cause for concern, including students' scientific content knowledge and their perceived lack of confidence and competence in teaching science effectively. These concerns highlight a need for action on the part of teacher educators.

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ASSESSMENT IN TEACHING AND LEARNING

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SAT 9.00 - 10.00

THE PURPOSE IS LEARNING

We would all readily agree that our purpose is to promote effective learning in science and mathematics. But what counts as good learning in science and mathematics? Here is one approach to answering this question:

> To ask of other human beings that they accept and memorise what the science teacher says, without any concern for the meaning and justification of what is said, is to treat those human beings with disrespect and is to show insufficient care for their welfare.
>
> It treats them with a disrespect, because students exist on a moral par with their teachers, and therefore have a right to expect from their teachers' reasons for what the teachers wish them to believe. It shows insufficient care for the welfare of students, because possessing beliefs that one is unable to justify is poor currency when one needs beliefs that can reliably guide action.
>
> S. Norris (Alberta), 1997 in Science Education

The point here is that to reduce learning to the memorisation of facts is not merely ineffective, it is immoral. This not to argue that factual knowledge is unnecessary: thinking has to work with knowledge, and knowledge which has been learnt with understanding becomes a powerful resource in memory for any further learning work (see e.g. Willingham, 2009, Ch.2).

At a more general level, the lessons from studies of learning can be summed up very briefly in four principles as follows:

- Start from a learner's existing understanding.
- Involve the learner actively in the learning process.
- Develop the learner's understanding of the aims and criteria for effective learning.
- Promote social learning, i.e. learning through discussion.

These are not peculiar to science and mathematics, but in what follows I shall develop these four and then illustrate with examples their particular application in these fields.

ASSESSMENT FOR LEARNING

So what has assessment to do with a principled approach to learning? I shall address this question by discussing assessment for learning in this section. In subsequent sections I shall develop a broader perspective to include assessment of learning.

The distinctive features of assessment for learning may be described as follows:

> An assessment activity can help learning if it provides information to be used as feedback, by teachers, and by their pupils, in assessing themselves and each other, to modify the teaching and learning activities in which they are engaged. Such assessment becomes 'formative assessment' when the evidence is actually used to adapt the teaching to meet learning needs.
>
> (Black *et al* 2002 - inside front cover)

There is ample research evidence to show that teaching which uses assessment feedback in this way improves pupils' learning achievement (Black & Wiliam, 1998). However, the use of a formative approach involves changes in the teachers' role. Some such changes are summarised by the following reflection by a mathematics teacher who had been developing a formative practice:

> *Questioning*
>
> My whole teaching style has become more interactive. Instead of showing how to find solutions, a question is asked and students given time to explore answers together. My Year 8 target class is now well-used to this way of working. I find myself using this method more and more with other groups.
>
> *No hands*
>
> Unless specifically asked students know not to put their hands up if they know the answer to a question. All students are expected to be able to answer at any time even if it is an 'I don't know'.
>
> *Supportive climate*
>
> Students are comfortable with giving a wrong answer. They know that these can be as useful as correct ones. They are happy for other students to help explore their wrong answers further. (Black et al. 2003, p.40)

Research results on 'wait time' (Rowe, 1974) impressed teachers with the need to give pupils time to think; many encouraged pupils to talk with one another before answers were called for, so that as many as possible would feel confident about expressing their ideas. The corollary of this approach was that each question had to be sufficiently open, from the learners' perspective, that it called for thought, and had to be sufficiently central to the learning aims that it justified the time spent on discussing the ideas that ensued. It followed that closed questions, checking only on knowledge, would be seen to make little contribution to students' learning. If pupils had to think, their wrong or partly right answers would give information, about the pupils' understanding, which would help the the teacher to select the optimum way for the work to proceed. Examples of questions that might serve this purpose are:

> Do you think friction would be the same on the moon as on the earth?
>
> Which is the odd one out:
> bird, cat, fish, elephant? Why?
> piece of white paper, mirror, picture, television? Why?
>
> Is 0.33 the same as one-third, bigger than one-third, less than one-third, or can you not tell without more information?
>
> The following simultaneous equations have no solution: can you explain this, and use a graph to illustrate your explanation:
>
> $5 = 6y + 2x$
>
> $2 = x + 3y$

SAT 9.00 - 10.00

In some useful questions, there is no single right answer: the argument about reasons why different answers may be acceptable helps to explore and develop understanding. Further examples may be found in Black and Harrison (2004) and Hodgen and Wiliam (2006). The key issue is that the formative purpose of a question is achieved only if it elicits from pupils some significant indicators of their understanding and then enables the teacher, or other pupils, to respond by trying to correct or develop that understanding, and perhaps through several responses lead the whole class to share a discussion of the issue. Given that pupils participation is often unpredictable, the task of steering such dialogue is a delicate one. For example, a pupil's answer to a question can reveal how the pupil understands the issue, and the teacher can then respond to help develop that understanding. This is more difficult than it may seem. Consider this example, quoted by Fisher (2005) : a primary class had been drawing pictures of daffodils –

> Teacher: "What is this flower called?"
>
> Child: " I think it's called Betty"

The teacher might respond by asking other children the same question until someone produces the word daffodil. All could then be told that this was the 'right answer'. However, an alternative response could be to ask the class whether 'Betty' and 'daffodil' are the same sort of answer, which could start a discussion of the difference between individual names and generic names. The first response would have missed the learning opportunity which would be exploited by the second. What the pupil understood by the terms 'is … called' in the question was not the meaning that the teacher had in mind: it is commonplace that what is 'heard' in any discussion is not what the speaker intended – whether that speaker be a teacher addressing a pupil or a pupil addressing a teacher.

In composing a useful response, it helps if the teacher first asks the pupil to explain how he or she arrived at that answer, then accepts any explanation without comment and asks others what they think. This gives value to the first answer, and draws the class into a shared exploration of the issue. In doing this the teacher changes role, from being an interviewer of pupils on a one-to-one basis to being a conductor of dialogue in which all may be involved. This role is a difficult one, for on the one hand tight control over the discussion can inhibit involvement of the learners, but on the other hand loose control can lead to digression so that the purpose of the learning is lost. This is challenging, in that the diverse inputs from several pupils will create a more complex task of interpretation; a more detailed examination of this problem is given in Black and Wiliam (2009). However, as pupil-pupil interactions are encouraged, the teacher will have time to reflect on how best to intervene. At the same time pupils can be helping one another to either resolve, or to express more clearly, their difficulties.

The fundamental reason for encouraging the mutual involvement of as many pupils as possible in class dialogue is explained by Alexander as follows:

> Children, we now know, need to talk, and to experience a rich diet of spoken language, in order to think and to learn. Reading, writing and number may be acknowledged curriculum 'basics', but talk is arguably the true foundation of learning. (Alexander, 2006; p.9).

Research in many classrooms, quoted by Alexander, shows that such dialogue is rarely achieved. The norm is the use of closed rather then open questions, very brief pupil responses, and a 'dialogue' which is a sequence of teacher-pupil-teacher-pupil-teacher interactions, with few examples of pupil-pupil interactions, so that the teacher dominates the 'discussion'. However, teachers find it difficult to change from this pattern, for some fear that it will be difficult to deal with the unexpected in pupils' responses and that they may lose control of any free-ranging discussion.

In work with teachers, I and colleagues have argued that in written work as in discussion, the purpose has to be to provide feedback that helps learning. The difficult change here was for teachers to stop giving marks or grades on written work. They were encouraged by research findings that improved learning does follow if written comments are given without marks or grades (Butler, 1988: Dweck, 2000), and came to justify the new practice as follows:

- pupils rarely read comments preferring to compare marks with peers as their first reaction on getting work back;
- teachers rarely give pupils time in class to read comments that are written on work and probably few, if any, pupils reflect on them outside the class ;
- often the comments are brief and/or not specific, for example "Details?";
- the same written comments frequently recur in a pupil's book, implying that they do not take note of, or act on, the comments.

(Black *et al*, 2003; p.43)

In consequence, teachers realized the need to spend more time on careful formulation of comments that would help pupils to understand their faults and to improve their work. Such comments as "Be more sensitive" and "You are mixing up the words 'solution' and 'mixture'" give the learner no useful guidance, but if the latter were expanded to read "Allan, this is generally fine but you are mixing up the words 'solution' and 'mixture'. Look up what we all wrote down about the difference and then check through this piece again" this could help Allan to improve his understanding by revising his work. The key point is that the written work is not to be treated as a terminal test, for which the marks produced are the end of the matter, but as an opportunity, through formative feedback, for improving learning in a dialogue in writing.

One feature that distinguishes written from oral feedback is that there is time to frame comments that encourage further learning, with more opportunity for differentiation through separate interaction with individuals. The effects on motivation of the type of feedback is also important: as one teacher, involved in the work described by Black et al. (2003), discovered that the results were especially noticeable in lower attainers - grades could have a de-motivating effect with such students, undermining their self-esteem.

By encouraging pupils to read and act upon their written feedback, teachers can help them to reflect on their own approaches to learning. Such self-assessment by pupils is essential to their development as independent and responsible learners. In helping them to develop self-assessment, teachers obviously need to specify aims so that pupils can both steer their work towards attaining them and understand the criteria by which that work can be judged. However, the criteria in a new topic might be too abstract for the novice learner, and their meaning will only be grasped slowly by illustration through concrete examples. To meet this need, practice should involve the learners in assessing one another's work so that they might thereby develop the skills both of peer-assessment and, by seeing their work through the eyes of their peers, of self-assessment. For some tasks the assessment criteria might be well defined (e.g. assessment of a practical investigation to determine which one of sample pieces of two types of paper towel soaks up water more effectively), but in a more complex multi-variable problem (which of the two types as sold in the shops gives better value for money), the criteria themselves might be ill-defined or arguable.

Whilst peer-assessment through work in small groups can a powerful tool, helping pupils collaborate effectively in groups is essential to such work. However, whilst there is strong evidence that collaborative groups can improve attainment (Johnson *et al*, 2000), a survey of group work in a large sample of U.K. classrooms (Blatchford *et al*, 2006) shows that the type of collaboration that can engage pupils in reasoned arguments about their own and one another's contributions is not often found. Intervention programmes by Blatchford *et al* and by Mercer *et al* (2004) have demonstrated that students trained in such collaboration produce improved attainments, both in the quality of their arguments and in subsequent tests. The publications by Dawes *et al* (2004) and Baines *et al* (2009) give detailed and practical guidance to help teachers develop effective group work.

There is a more fundamental point involved here, which bears on all of my discussion up to this point. It is neatly expressed in Wood's (1998) reference to Vygotsky, as follows:

> Vygotsky, as we have already seen, argues that such external and social activities are gradually internalized by the child as he comes to regulate his own internal activity. Such encounters are the source of experiences which eventually create the 'inner dialogues' that form the process of mental self-regulation. Viewed in this way, learning is taking place on at least two levels: the child is learning about the task, developing 'local expertise'; and he is also learning how to structure his own learning and reasoning. (p.98)

This link between dialogue and structuring of one's own learning and reasoning draws attention to the fact that self-assessment is not only secured by special self-assessment exercises, but is also stimulated insofar as each pupils is actively involved in the learning dialogue. This is promoted both in whole class teaching, in feedback on each individual's written work, and when pupils work together in peer-assessment activities. Overall the aim should be to move pupils away from dependence on the teacher towards independence in each student's power to guide his or her own learning.

ASSESSMENT OF LEARNING

Formative assessment and summative assessment by teachers

Summative assessment by teachers can be considered from two perspectives, the first being the more or less frequent use of tests to check on pupils' progress, whilst the second involves the use of summative tests for high-takes testing, *e.g.* for awarding school-leaving certificates and/or for checking of the achievements of teachers and their schools.

For the first perspective, it is helpful to consider the formative use of summative tests. Students learn by marking one another's test responses, particularly if they have to develop the marking schemes in the light of their understanding of the criteria. As for the new way of looking at written work generally, the point is that a test, whilst serving the summative function, might also be used, through formative feedback, as an opportunity for improving learning.

This possibility of a helpful link between formative and summative roles of assessment in pedagogy can be further explored by the following simple view of pedagogy using a model of the five steps or phases involved in designing a learning exercise.

1. **Clear aims**: Here, priority may be given either to understanding the concepts and methods of a particular subject, or to developing pupils' reasoning skills: in the latter case the topic may only be used as a suitable context for such development.
2. **Planning activities**: Important criteria here are the potential of any activity to elicit responses which help clarify the pupil's understanding, the level of cognitive demand that a task makes, and its potential to generate interest and engagement.
3. **Implementation**: The way in which a plan is implemented in the classroom is crucial. This aspect has been discussed above in relation to dialogue in oral and written work.
4. **Review of the learning**: At the end of any learning episode, there should be review, to check before moving on. It is here that tests, with formative use of their outcomes, can play a useful part. Further work by pupils to deal with problems revealed by a summative test can be a contribution to their learning. Thus work in this phase may lead back to work in the previous phase. This helps both to consolidate the learning and for pupils to develop an overview of what they have learned. Thus it ought to be seen as an essential component of effective learning, not a disagreeable necessity
5. **Summing Up**: This is a more formal version of the Review: here the results may be used to make decisions about a pupil's future work or career – whether within or beyond the school, to report progress to other teachers, school managements and parents, and to report the overall achievements more widely to satisfy the need for accountability. This may be done by assessments by teachers, by external testing, or by a combination of the two. For this final phase, tensions arise between formative and summative requirements.

Consideration of this fifth stage can be about tests within each school for internal decisions, or about tests which serve external needs. To start with, I discuss the schools' own work.

In work that set out to develop teachers' summative assessment practices (Black *et al*, 2010; 2011), it was found that summative work in the three schools involved had not received the attention required to ensure its validity. To secure improvement, teachers had to work together on refining the aims of their assessments, on designing good assessment tasks to reflect these aims, and to assembling a set of tasks and tests from which a portfolio of attainments could be assembled for each pupil. In this work, detailed attention had to be paid to developing with teachers the skills, insights, and practical experiences that are needed, in such. They also had to collaborate in moderation exercises, in which, both within and between schools, they could share and align their assessments of sample portfolios. Such work was shown to produce several rewards. One was that the benefit of developing shared understanding of standards and criteria between teachers, within their own school, and then between schools who collaborate in local groups, helped to meet these needs through close professional collaboration. As one teacher explained:

> And we've had moderation meetings, we were together with the other schools, teachers in other schools looked at how rigorous our assessment would be and they criticised what, you know, our marking criteria is. And we changed it, which is all been very positive. (Mathematics teacher)

A second was that parents and pupils could be assured that the judgments made about pupils' progress by schools were rigorous and are based on standards and criteria that are comparable across all schools. Several teachers commented on this advantage - for example:

> But I think if all the teachers had more, possibly more ownership of what we are actually doing in terms of summative assessment then you would have more confidence in saying to parents, which I think is one of the biggest things I find with lower school. (Mathematics teacher)

A third potential reward would be secured if teachers could be given more responsibility in high-stakes assessments, and develop the confidence in their ability to do this effectively, so that they would be better able to work out ways of making creative alignments between the formative and the summative aspects of their work. The following quotation illustrates how the involvement of pupils in summative assessment tasks became a positive contribution to learning:

> I think one of the reasons is that it's a good task is that it's a real task. It's all based on A4, A5 and A6 you know, which is in real life, kids know that… they can physically hold up an A5 sheet against an A4,… a lot of kids are engaged straight away… it's a piece of work that every kid could achieve from. (Mathematics teacher)

The task involved here could not have been carried out in this way in formal test conditions. For tasks which are realistic, involving research, practical science tasks, and group collaboration, the teacher who is in charge of them has to play a large part in their assessment.

However, these findings were only achieved as a result of about 30 months of work in which teachers were given extra support, from the King's College research team with ideas and materials, and by support from their schools and district authorities, so that they could spend time on meetings both within schools and between the schools involved.

External summative assessments

Where teachers experience the accountability pressures of externally imposed tests, achieving helpful links between formative and summative practices may well seem impossible: one assessment diagnosis for England is that it has a disease that has developed from a flawed concept of accountability:

> Where summative becomes the hand-maiden of accountability matters can get even worse, for accountability is always in danger of ignoring its effects on learning and thereby of undermining the very aim of improving schooling that it claims to serve. Accountability can only avoid shooting itself in the foot if, in the priorities of assessment design, it comes after learning. (Black and Wiliam, 2007; p.10)

This phenomenon can be demonstrated in two ways. It was recognised in the national curriculum in England that to meet the requirements for validity in the assessment of science learning, extended practical investigations should play some part in the assessment programme: such work has to be assessed by teachers in the classroom. However, moderation, limited to external inspection of samples and by examiner visits, operated in the shadow of accountability pressure. This led teachers to ‘play safe’ by using only predictable tasks, which leading to the following statement by teacher which was characteristic of the views of groups of science teachers consulted in the study of Black *et al* (2004):

> My department and myself have very strong views about the coursework component of GCSE. Unfortunately, because these investigations are mainly not assessing what they are suppose to, we were unable to find anything positive to say about them apart from ‘in theory’. (p.16)

A second example is Fairbrother’s (2008) analysis of the questions and marking schemes of the national assessment test papers for age 14 pupils used in England in the years 2003-6, which showed that these paid very little attention either to the skills of scientific enquiry or to the use in science of the mathematics tested at those ages, and almost no attention to the higher order objectives of analysis, synthesis and evaluation. A telling feature was that in the marking schemes, 80% of the marks were allotted to components for each of which the marking alternatives were just one or zero. One source of this syndrome is that if test agencies have to work to curriculum aims described in only very general terms, they have to interpret these in the concrete terms of explicit questions, and if they have to frame these within constraints, of cost, and of testing to ‘cover’ several years of work within a few hours, concern for validity and for effects on learning are set aside. The process produces tests with the qualities described in Fairbrother’s analysis.

The outstanding problem here arises from the high-stakes consequences of external summative testing and the pressure they create to teach the superficial tactics which improve performance on formal tests, so limiting teachers’ freedom of manoeuvre in classroom work. By contrast, for their own in-school work teachers are more free make tests serve both the purpose of learning through dialogue and of the helpful review of the learning.

CHALLENGES FOR THE FUTURE.

For formative assessment

There are several formidable challenges. A first challenge is to escape from the superficial interpretations which have misled those attempting to develop formative practices (Black, 2007). For example, teachers may ask open questions, but then 'correct' the answers rather than use them to re-direct their work, or they may ask pupils to self-assess their work but then fail to use this information to formulate formative feedback. Many have interpreted the terms 'formative assessment' or 'assessment for learning' as incorporating all uses of assessment, and in this perspective focused on enhancing established practices of frequent testing, which may damage rather than enhance pupils' learning.

A second challenge is that implementing new formative practices is a very demanding task. For many teachers, these practices call for a deep change in their beliefs about their role in the classroom, with practical implications which many find 'pretty scary'. As pointed out one of the earliest reviews:

> To incorporate formative assessment into their teaching would involve teachers in far more than acquisition of the necessary skills… The changes in their classroom practice might also involve profound changes of role, even for teachers regarded by themselves and others as already successful… devotion to formative assessment is risky, taking a great deal of time and energy. (Black, 1993; p.79)

This initial disorientation was felt not only by teachers but also by students

> The first time I asked a Year 10 top set to work in groups to examine the errors they had made in a test and to help each other to understand fully what was being asked of them, it was unsuccessful…That lesson I heard several times 'Why don't you just tell us?' … they have realised that they have more to do in my classroom than absorb the syllabus—they have to take responsibility for their learning. (Black *et al*, 2003; p.87)

The changes needed cannot be produced by a short training session – they need the sustained support of collegial collaboration (Black & Wiliam, 2003). Studies of individual teachers show that each changes in a different way and with different personal perceptions of the task (Black *et al*, 2003 – chapter 6; Harrison, 2005; Lee & Wiliam, 2005). However, our evidence from such work confirmed the evidence of previous studies, that the development of formative assessment does improve student learning (Wiliam *et al*, 2004).

For summative assessment

The fourth and final challenge is to achieve a positive interaction between the formative, assessment <u>for</u> learning, and the summative, assessment of learning. However, to achieve this teachers have to play a leading role in the high-stakes summative assessments of their own students, and this means that the public must trust their judgments. To secure this trust, teachers may have to improve their own practices in summative assessment, which will require many to develop a basic understanding of and skills in assessment, based on a broad understanding of the main principles and practices involved, including a thorough understanding of the criteria of validity and reliability. Gardner (2007) has argued that the lack of such expertise is a notable weakness because it means that the profession cannot take control of an essential component of its work, it is a 'partial profession'. Thus, developing understanding and skills in formative practices is only one component in building the assessment strengths of the profession – one that can only achieve limited success on its own.

Such synergy requires national systems in which teachers' judgments are trusted, backed up by programmes of training and support to ensure that these judgments are of dependable, *i.e.* so that they deserve this trust. Examples of such systems are described in the study by Stanley *et al* (2009).

If teachers have very little control over high-stakes summative assessment of their students, they have to struggle with the tensions between work that engages students in learning and in their assessment, and a short-term emphasis on test preparation exercises. The effect on teachers of the pressures of external tests is to lower their status, depriving them of full ownership of their work, and making a negative contribution to the development of their own skills in assessment. If teachers had more control over the accountability measures, they would be in a better position to reconcile, within their own practices, the formative and summative purposes. Thus, one way to redeem the situation is for teachers to have more control over Step E.

There is second argument why teachers should play a more active role in the high-stakes summative assessments of step E. This stems from the fact that formal external tests are bound to be of limited validity. This point is explained in the following statement by Stanley *et al* (2009, p.31):

> … the teacher is increasingly being seen as the primary assessor in the most important aspects of assessment. The broadening of assessment is based on a view that there are aspects of learning that are important but cannot be adequately assessed by formal external tests. These aspects require human judgment to integrate the many elements of performance behaviours that are required in dealing with authentic assessment tasks.

A similar argument has been expressed in working papers of the inter-country meetings of the EU ministers of education (EU, 2010). The validity of high-stakes tests, whether external, or internal, or both, is going to be more rigorously challenged in future. At least some components of any set of 'authentic assessment tasks' will have to be implemented and assessed by teachers themselves. If this were to be achieved, then several new problems will arise. Three outstanding questions are: 'Do teachers have the understanding and skills do produce valid and reliable assessments?', 'How far do the instruments and procedures have to be uniform within and between different teachers and schools?', and 'Will the procedures needed to ensure comparability, within and between schools, of assessment results inevitably lead to the 'teaching to the test' practices which a reform was designed to escape?'

A harmonious inter-linking between the aims, classroom learning, and summative testing of students can only be achieved through investment in teacher development and not in the design, implementation and scoring of tests by agencies external to the schools which have to work to their demands. It this harmony cannot be achieved, teachers will face conflict between serving the full development of the capacities of their students to develop as autonomous learners, and training them merely to perform well in the narrow confines of the examination hall. Insofar as they have to yield in such conflict, they undermine themselves and their students: thus, my argument returns to my opening quotation in which Norris emphasises the moral responsibility of the teacher. Thomas Groome (1998) puts this in a different way, adding the extra dimension of the teacher's own moral status:

> Educators can take over functions that learners should be doing –learning how to learn, making up their own minds, reaching personal decisions. Such imbalance ill serves learners and can be destructive to educators. There is a fine line between empowering learners as their own people and overpowering them– making them too

dependent or indebted to teacher or parent. Walking this tightrope is an aspect of the educator's spiritual discipline of a balanced life. (p.348)

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FOSTERING FEEDBACK IN SCIENCE CLASSROOMS

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This session will look first at the research on effective feedback and then reflect on how such practices might work in science classrooms. Participants will discuss and highlight what they see as good practice in terms of feedback in science classrooms, what obstacles hinder these practices from being as effective as they might be and how teachers might be supported in providing opportunities for guidance and regulation of learning. This will be an active session where you will be asked to consider a wide variety of ways of feeding back, where you will mark a piece of work and where you will be challenged as to why teachers are sometimes conservative in making changes in the ways they work with learners… so come along and be challenged.

AN EXAMPLE OF ESTABLISH UNITS: DISABILITY

Margaretha Ekborg[1] and Christina Ottander[2]

[1] Learning and Society, Malmö University, Sweden.

[2] Department of Mathematics, Technology and Science Education, University of Umeå, Sweden.

In this workshop we will give examples of activities that will help students in secondary schools develop inquiry skills in an engaging way, and explain how they are based on research. We will start a discussion of the development of IBSE teaching and learning materials for teacher education at second level. The development of teaching material in the unit is research based to increase interest in science, to develop inquiry skills and to learn more about the industrial content knowledge (*i.e.*, knowledge important for people working in science and technology enterprises).

This workshop is based on the ESTABLISH unit *Disability* to demonstrate the ideas of ESTABLISH and to teach content in mainly Biology and Technology. This unit is about the human body, when it works and when it does not work perfectly, and what aids there are. The aim is for the students to gain knowledge about the human body and have the chance to learn about, reflect upon and discuss disability. Subject areas covered include biology, physics and technology.

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ESTABLISH project <www.establish-fp7.eu>

STARTING WITH INQUIRY

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For many Irish students, the transition from primary science to secondary science can be a rude awakening. Much of primary science is about doing investigations in a child-centred curriculum and is focused on science as it pertains to nature and the environment around the students. In many cases the first encounter with science at second level is a teacher-centred lesson on units and measurement at an abstract level, with a much more mathematical approach.

In this workshop, participants will get the opportunity to work through and discuss a self-contained inquiry-based unit that can be used from the first day of secondary school science. Most of the materials, which cover units and measurement, area and volume, and density, have been tried and tested in the classroom. The materials serve as a taster for the minds-on classroom: making predictions, verification through experimentation, answering what-if questions, use of computer simulations, small-group work, whole-group discussions, and activities ranging from quite structured to quite open inquiry.

DISCOVER SENSORS KILDARE VEC PROJECT: AN INQUIRY BASED SCIENCE TEACHING AND LEARNING INITIATIVE

Alison Cullinane, Jennifer Johnston, Stephanie O'Neill

NCE-MSTL, University of Limerick, Ireland.

The Discover Sensors Kildare VEC project is a major initiative promoting Inquiry Based Science Teaching and Learning (IBSTL) in Junior Cycle science in Ireland. Under the leadership of Discover Science Engineering (DSE) this project is in collaboration with nine Kildare VEC schools and forty science teachers. During the last three years, the Discover Sensors Kildare VEC Project has been developing teachers' IBSTL strategies through professional development workshops, centred around an IBSTL framework for Junior Cycle science. The workshops cover a range of teaching strategies such as the use of technologies in the classroom, and designing and developing alternative assessment questions and techniques, among others. The Discover Sensors Kildare VEC project is designed and developed by DSE's Discover Sensors team, in collaboration with the National Centre for Excellence in Mathematics and Science Teaching and Learning (NCE-MSTL), NUI Maynooth, and the NCCA.

WIKIS AS A TOOL TO PROMOTE SCIENTIFIC INQUIRY IN PUPILS FROM MIDDLE SCHOOL

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Ana Maria Freire and Cecília Galvão

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1649-013 Lisboa, PORTUGAL

The project *intTT: An INTegral Teacher Training for developing digital and communicative competences and subject content learning at schools* was funded by the Lifelong Learning Programme. The project aims at facilitating teachers' use of inquiry activities in classes, in order to develop students' scientific, communicative and digital competencies. International recommendations highlight the importance of developing these competencies for improving students' scientific literacy and research literature has pointed out some important features that inquiry activities should present in order to facilitate competencies' development. So, in order to achieve the defined goals, several activities were created and implemented which met, among other, the following criteria: (i) pupils should be actively involved during the overall activities' implementation process, (ii) teachers have to use wikis during the implementation of the activities, (iii) activities have to promote inquiry based learning. The present communication aims at describing the eight activities elaborated by the Portuguese team within the project. These activities were conceptualized for the 8th and 9th grade pupils, for exploring Electricity and Chemical Reactions subjects. The activities can be performed in the classroom, in school clubs or at home, presently or by means of virtual sessions. Furthermore, pupils have the opportunity to work individually or collaboratively in their knowledge construction concerning the topics discussed. Finally, the activities involve different kinds of tasks, such as researching different issues, elaboration on documents, recording and organizing information, practical activities, and participating in pedagogical games.

DESIGNING AND ENACTING AN INQUIRY BASED COLLABORATIVE LEARNING SCRIPT USING THE CADMOS TOOL

Mary Katsamani, Michail Boloudakis, Petros Georgiakakis and Symeon Retalis

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Educators often use learning design tools that can help them on creating learning scripts in a graphical way before enacting them in a learning delivery platform. The scope of this paper is to present the CADMOS learning design tool which allows educators to create learning scripts in a user friendly graphical environment and export them as Moodle lesson packages thus bridging the gap between design and enactment.

SAT 10.00 - 11.20

INTRODUCTION

In high school chemistry courses, laboratory experiences are considered very essential for students to increase their analytical skills and understanding of chemical concepts (Woodfield *et al*, 2004; Botch *et al*, 2007). Lab based learning problems linked to real-world scenarios can contribute to (Evans & Leinhardt, 2008):

- improving students' ability to work and collaborate with others, and to develop an awareness and control over their own thinking processes;
- giving students the opportunity to develop their problem solving skills;
- giving students the opportunity to be creative and use divergent or lateral thinking;
- showing students that science is more than 'getting the right answer'

Also, research studies in chemistry education have shown that laboratory based collaborative problem solving activities in chemistry can improve conceptual learning and increase student performance and motivation (Tsovaltzi *et al*, 2008). For several schools, maintaining a hands-on chemistry lab is not viable due to various reasons. One alternative to traditional labs is virtual labs, which can provide an interactive learning environment and connections to real world scenarios. A Virtual Laboratory allows students to design and perform diverse experiments in chemistry in a manner that resembles that of a real lab (Woodfield *et al*, 2004).

Activities that can be performed with the use of a highly interactive virtual lab help students not only have the opportunity to increase their analytical skills but also to acquire learning experiences with connections to real world scenarios via active engagement, inquiry-based learning and collaboration. Nevertheless, designing engaging learning activities in not an easy task for educators (Retalis *et al*, 2006). Educators often use a learning design tool, such as CompendiumLD and WebCollage (Neumann & Oberhuemer, 2009), that can help them on creating their learning scripts (*i.e.* sets of orchestrated learning activities) in a graphical way before their enactment in a learning platform such as Moodle.

There are also learning design tools like LAMS (http://www.lamssfoundation.org) that comprise capabilities for designing as well as enacting learning scripts at the same time, *i.e.* they offer a learning design authoring tool and a run-time learning delivery environment. However, these tools, though very powerful, do not allow an educator to enact a learning script in a preferred learning platform. The scope of this paper is to present the CADMOS learning design tool which allows educators to create learning scripts in a user friendly graphical environment and export them as a Moodle lesson package thus bridging the gap between design and enactment.

In this paper we are presenting how the innovative CADMOS learning design tool can be used for designing an inquiry based collaborative learning script in chemistry for high school children. More specifically, we will use as an example an inquiry based learning script that (i) concerns the properties of a pure compound and addresses the boiling point as a reference, and (ii) promotes the use of a Virtual Chemistry Lab which is an innovative software for the SMART interactive boards.

AN INQUIRY BASED LEARNING SCRIPT ON CHEMISTRY

In a class of the second grade of Greek gymnasium (children 14 years old), during the Chemistry lesson, we needed to discuss about the different states of materials. The example that the schoolbook is using is the one of water and the three states that can be found, depending of the temperature and pressure. In the curriculum of this specific chapter, teacher should present for the first time the meaning of what is a "property" of a compound by giving examples of the boiling and melting point of pure water. Even if the example is concrete, many students have problems in understanding these terms, and cannot match properties of a compound (such as the melting and boiling point) in specific conditions, with a specific compound.

For that reason we proposed an inquiry based learning scenario, using the Cyclic Inquiry Model (http://www.cii.illinois.edu/InquiryPage/). The purpose of this model is the creation of new ideas and concepts, and their spreading in the classroom by engaging students to ask and answer questions on the basis of collected information. The activity often finishes by the creation of a document that tries to answer the initial questions. In the cycle of inquiry there are 5 global steps: Ask, Investigate, Create, Discuss and Reflect (see Figure 1).

We have also used the Virtual Chemistry Lab, software that has been created by our lab, for use in SMART interactive boards and demonstrates a Chemistry Lab with several modules regarding solutions and their concentration measurement. We divide students in teams of 4, have them seated together and allocate numbers to them from 1 to 4 and we announced the problem to be solved. We asked them what they think will happen if in the same vessel we put some amount of pure water and some of pure alcohol and we start heating it. The teacher in order to stimulate student's curiosity presents them an introductory video from the Science & the City episodes of Discovery Channel.

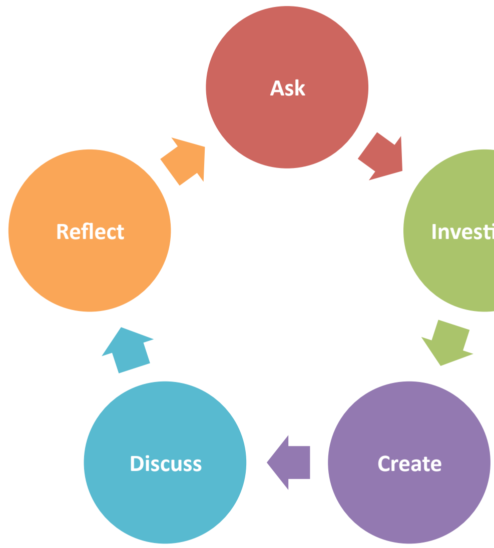

Figure 1. The 5 steps of the Cyclic Inquiry Model.

Then we ask students in each group to collect and exploit resources about the properties of pure water and alcohol, while they should also seek information about solutions and their properties. Each team that comes up with an idea could then uses the interactive board and conduct the experiment in the VCL software. In order to design their experiment several questions needed to be answered such as: What materials will you need? What will you measure in the experiment? How will you measure it? How long will you conduct the experiment? What do you predict will happen?

When each team's experiment ends the collected information is time to merge. Students can start now making links. In order the teacher to help them synthesize the meaning of this procedure, addresses several questions regarding the experiment findings that need to be answered at this time in a simple report which will be shown at a wiki: How did you conduct your experiment? What did you find out? Was your hypothesis correct? How do you know that the all the variables were predicted (like atmospheric pressure)? What would you do different if you knew what affects the boiling time of a liquid?

At this point, students share their ideas with each other, and ask others about their own experiences and investigations. Students in each group can compare their notes, discuss conclusions and share their experiences. Randomly teacher calls few of the paired students to share and present their findings in the class.

At the end of the inquiry cycle teacher will trigger a reflection process with the students. Teacher asks them to think again about the initial question, the path taken, and the actual conclusions. While students are looking back, questions like: Has a solution been found? Did new questions appear? What could be the new questions may arouse? If class feels that the topic has been covered then the activity is ending. The teacher finishes it by broadening: The initial questions with students' responses, the reformulated ones, and new ones that appeared during the activity. On the other hand if students feel that the questions need to be reformulated a new inquiry cycle begins.

DESIGNING WITH THE CADMOS LEARNING DESIGN TOOL

CADMOS is a user friendly graphical design tool that has been created in order to be used by novice learning designers, i.e. practitioners/teachers with basic computer skills and knowledge of learning standards, for specifying and orchestrating the activities of a learning script following a layered process (Katsamani & Retalis, 2011). Using CADMOS (see Figure 2), a designer starts with the conceptual model of a lesson by specifying the learning activities that a student or a group of students should perform as well as the support activities that a teacher/tutor should do during the learning process. Each of these tasks is associated to a learning resource (digital asset) like text files, music files, video etc., or a learning service such as forum, chat, voting system, etc. The conceptual model of a unit of learning looks like a concept map. Then, the tool automatically creates the order of the execution, *i.e.* the flow model, by putting the specified activities the one after the other using the metaphor of a "swim lane" of the corresponding actor. The designer can intervene in order to add conditions like the time duration of an activity, as well as specific rules, *e.g.* if the students' grade at a self-assessment activity is lower than a threshold, they cannot proceed to the next activity but have to repeat some learning activities. Additionally the teacher may divide the activities into phases.

The most innovative feature of CADMOS is that it enables a learning designer to export the learning script in a form that could be uploaded to a Moodle platform for being enacted as an online course.

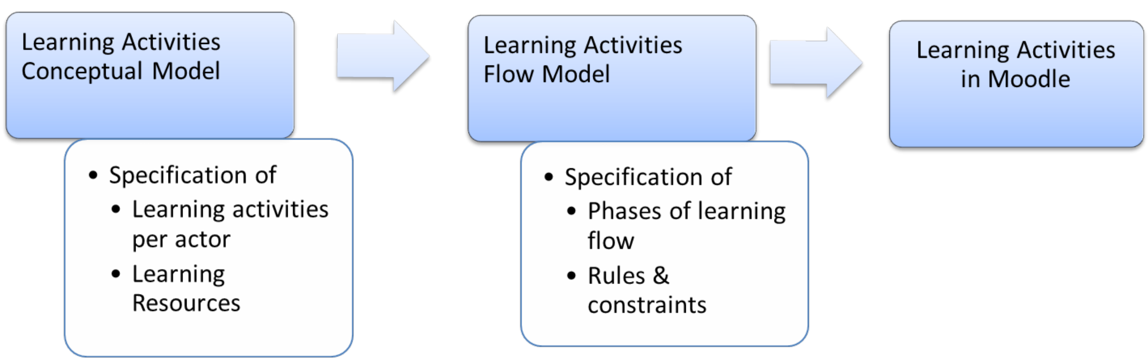

Figure 2. The learning design process supported by CADMOS.

Figure 3, 4, and 5 show snapshots of the way the above mentioned inquiry based learning script on chemistry had been modelled using the CADMOS tool (*i.e.* conceptual model, flow model, learning activity enactment).

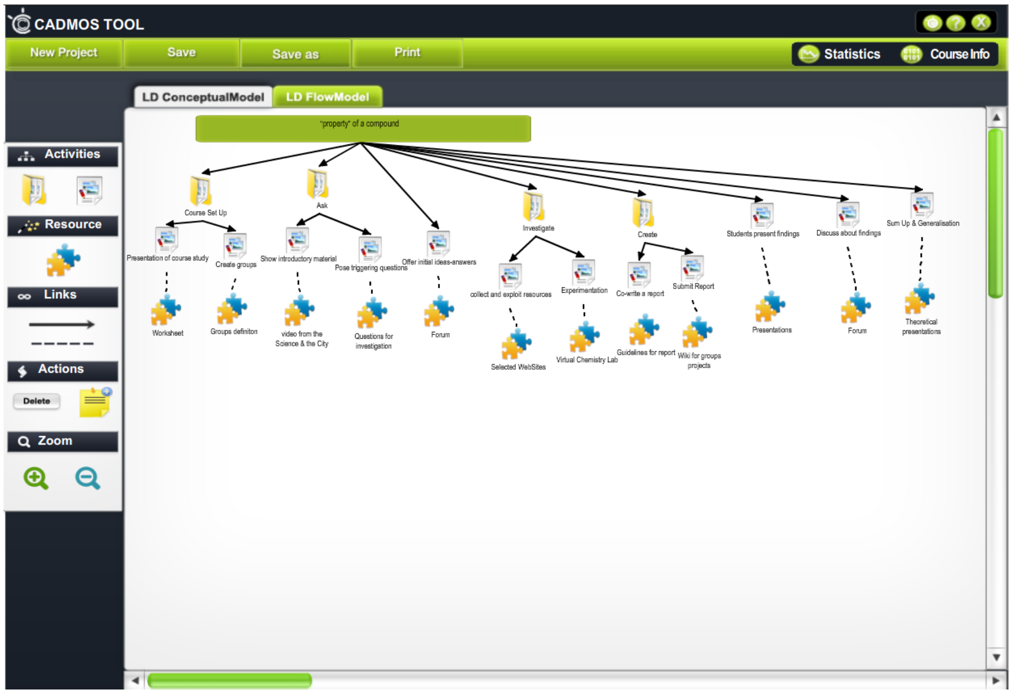

Figure 3. Screenshot of the learning activity conceptual model in CADMOS.

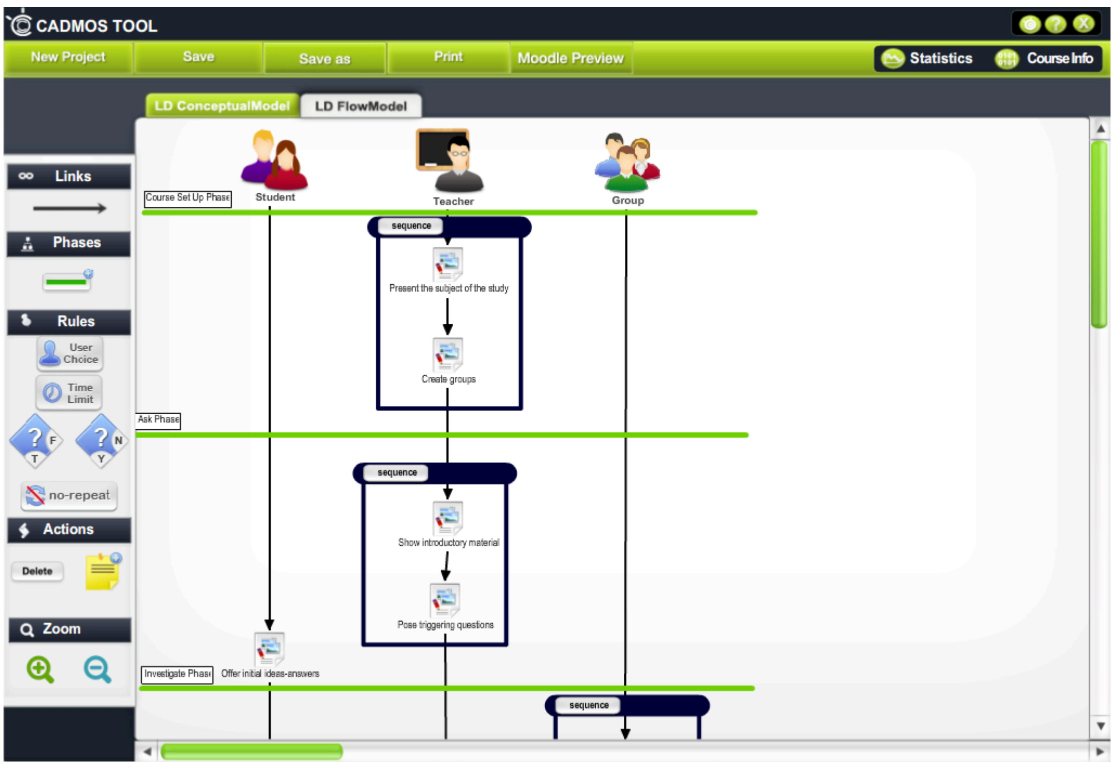

Figure 4. Screenshot of the learning activity flow model in CADMOS.

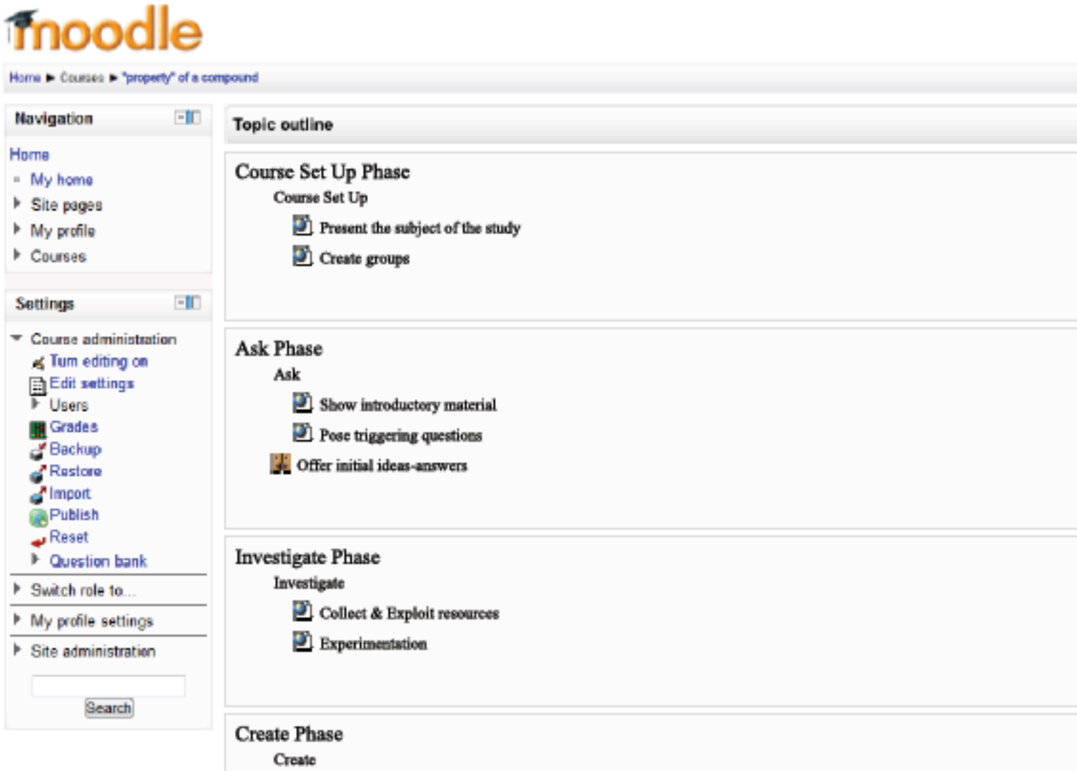

Figure 5. Screenshot of the way the learning script is enacted in Moodle.

CONCLUDING REMARKS

Learning designers, with the aid of visual design tools, create sketches and models that can be used to communicate ideas and understand the design situation (Nelson & Stolterman, 2003). They can also satisfy the need to collaboratively propose, discuss and evaluate designs. CADMOS is an IMS LD level A & B compliant graphical learning design editor that has been created in order to allow novice learning designers, i.e. practitioners/teachers with basic computer skills and knowledge of learning standards, to easily and quickly specify and orchestrate the activities of a learning script as well as enact it as an online course in Moodle. Bridging the gap between design and enactment is very essential for a designer who can better figure out how a learning script can be offered to As shown in this paper, CADMOS can be used for designing inquiry based learning scenarios in science subjects. CADMOS has been used and evaluated by teachers with very encouraging results (see Katsamani & Retalis, 2011).

ACKNOWLEDGEMENTS

This work has been partially supported by the SAILS project that has received funding from the EU Seventh Framework Programme (http://www.sails-project.eu/) as well as by the VCL project funded by SMART technologies.

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START IT UP – INTRODUCING INDEPENDENT THINKING AND PROJECT SKILLS FOR FIRST YEAR ENGINEERING STUDENTS

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The initiative described in this paper is one undertaken with first-year Mechanical Engineering students taking a NQAI Level 7 programme at the Dublin Institute of Technology (DIT). The exercise given to the students required them to analyse an open-ended design problem, re-interpret it in their own words, and then outline and implement a workable solution.

The aim of the exercise is to encourage independence and organisation, skills that will be required both in their Final Year Project, and throughout their working lives. 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. The students were informed, in general terms, that an excel spreadsheet would be the best method of solving the problem, but that its design was entirely up to them.

At the end of the first session, students completed a brief survey, and also had to submit an outline of their solution, with an explanation of their choices and final recommendations before the second session. At the end of the second and final session, the students completed another brief survey, and submitted their final design solution.

The exercise was open ended and students were given the freedom to go into as much detail as they wished within the time provided. The exercise proved challenging for many students, more used to well-defined laboratory work during the rest of the year. The good students rose well to the challenge, producing a wide variety of interesting and satisfactory designs that met the brief. The feedback was compared to the solutions provided, and also to other relevant parameters, viz. the students' attendance (a measure of their commitment to the programme) and their exam results (a measure of their academic abilities).

SAT 10.00 - 11.20

STARTING WITH INQUIRY (R)

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For many Irish students, the transition from primary science to secondary science can be a rude awakening. Much of primary science is about doing investigations in a child-centred curriculum and is focused on science as it pertains to nature and the environment around the students. In many cases the first encounter with science at second level is a teacher-centred lesson on units and measurement at an abstract level, with a much more mathematical approach.

In this workshop, participants will get the opportunity to work through and discuss a self-contained inquiry-based unit that can be used from the first day of secondary school science. Most of the materials, which cover units and measurement, area and volume, and density, have been tried and tested in the classroom. The materials serve as a taster for the minds-on classroom: making predictions, verification through experimentation, answering what-if questions, use of computer simulations, small-group work, whole-group discussions, and activities ranging from quite structured to quite open inquiry.

SAT 11.40 - 13.00

SCIENTIX: FROM ONLINE COURSES TO HANDS-ON EXPERIMENTS

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INTRODUCTION TO SCIENTIX

The Scientix project of DG Research and Innovation aims to encourage networking between the different stakeholders in Science education: teachers, projects and researchers. To do so it launched a portal in May 2010, organized a European conference in May 2011 and is continuously organizing workshops and online courses.

Besides information on public funded projects and having the usual sections: forums, chats, news and newsletters; the Scientix portal has a repository of materials including lesson guides, animations, simulations, reports, videos, etc which teachers can use in their classes form different projects.

The key difference of the Scientix repository compared with other similar repositories is the possibility for teachers to request the translation of the materials to any of the 23 official languages of the Commission. This translation is carried out by official translators and is completely financed by the European Commission. This is what we call the translation on demand of resources of Scientix.

WORKSHOP: FROM ONLINE COURSES TO HANDS-ON EXPERIMENTS

The Scientix portal has a Moodle platform where teachers can find a selection of courses to follow at their own pace. These courses range from learning ICT tools, *e.g.* HTML (to create basic webpages) or Google forms, to science topics and tools like Nanotechnology or Geogebra. During the workshop participants will get an overview of the possibilities of using Scientix for their lessons and will carry out examples of hands-on-experiments from the Science Moodle courses.

MANAGING THE INQUIRY CLASSROOM: ISSUES AND TENTATIVE SOLUTIONS

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UOP_PERG (University of Palermo Physics Education Research Group),
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This workshop is based on the ESTABLISH unit *Designing a Low Energy Home: Heating and Cooling*, and in particular on the classroom issues found during its experimentation in different classroom contexts. A brief introductory talk will describe the main characteristics of the unit and will present some problems pointed out during the classroom activities and in the managing of the classrooms. Such problems will be classified as: teacher difficulties, student difficulties, difficulties with tools, and difficulties with the student worksheets. An analysis of appropriate scaffoldings to overcome such problems will be also presented.

Successively, workshop participants will explore the details of the described difficulties/problems and extend our list by introducing other difficulties/problems they found in the implementation of an Inquiry-Based unit in different kinds of classrooms. Moreover, they will be requested to identify appropriate scaffoldings to overcome such problems/difficulties and to compare and contrast how such scaffoldings are appropriate in different national contexts.

FOR BETTER OR WORSE? TEACHERS' PERCEPTIONS ON THE CHANGING ROLE OF STANDARDISED ASSESSMENT IN PRIMARY SCHOOL EDUCATION IN IRELAND

Michael Mc Namara

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Given the recent implementation of the newly constructed government strategy *Literacy and Numeracy for Learning and Life* (Department of Education and Skills, 2011), never before has standardised assessment been attributed such prominence within our primary education system. For primary school teachers, *i.e.* the test administrators, revised procedures outlined in this new strategy embody a significant shift in the ideology, and indeed the practice, governing pupil assessment in this area. This paper outlines current doctoral research on this topic, which focuses on the changing role of standardised assessment within our education system. In doing so, it initially explores significant developments relating to this form of assessment within the Irish context, and subsequently discusses key decisions made to date relating to the research design.

INTRODUCTION

The standardised assessment of Mathematics and English reading has undoubtedly become the object of growing international debate in recent years, primarily owing to its capacity to essentially embody a tool of teacher accountability. In support of this stance, Kohn, a leading theorist in the United States, strongly believes that "standardised testing has swelled and mutated, like a creature in one of those old horror movies, to the point that it now threatens to swallow our schools whole" (2000, p.1). Kohn's strong position on this topic can be directly attributed to the 'high-stakes' testing culture present in the Unites States, whereby serious, and often financial, consequences can be associated with standardised test results. Consequently, this can serve to undermine the value of this form of assessment in relation to teaching and learning in the classroom, as questionable practices such as 'teaching to the test' can often infiltrate classroom practice in a bid to boost results obtained from the tests.

Though a relatively recent addition to the Irish education system, the origins of which need only be traced back as far as the late 1970s (ERC, 1976), this form of assessment has already been deemed a 'medium-stakes' practice within our context (NCCA, 2005). However, when one considers developments in this area since 2005, as outlined in the following section of this paper, one must ask if perhaps recent requirements relating to standardised assessment may indicate a shift in the 'stakes' involved in our national testing culture, and if so are we ultimately heading in a direction which will serve to enhance or undermine the value of this form of assessment within our primary school education system?

Standardised Assessment Developments within the Irish Context

Pre-2006 standardised assessment became increasingly widespread within the Irish primary school education system. This popularity can be attributed to international trends in assessment at the time, as well as the ability of this form of assessment to aid schools in complying with assessment procedures as outlined in the Education Act (Government of Ireland, 1998). During this period schools administered standardised assessments primarily based on localised decree, as opposed to official statute. However, in July 2004, with an estimated ninety-five per cent of primary schools already implementing standardised assessment the then-Minister for Education and Science stated in his press release that "standardised test results play an essential role in the evaluation of the work of schools" (Minister Noel Dempsey, 2004) and therefore announced his intention to make standardised testing a formal requirement within primary schools nationwide. Consequently, decisions made in this regard were disseminated nationally to primary schools in circular 0138/2006. This policy document stated that

> all students should take standardised tests in English reading and Mathematics at the end of first class OR the beginning of second class, AND at the end of fourth class OR the beginning of fifth class" (Department of Education and Skills, 2006, p.1).

Additionally, the results of these tests were to be shared with parents, teachers, the school principal and the Department of Education Inspector, in effect instilling a 'medium-stakes' testing culture within the Irish context (NCCA, 2005).

This testing culture remained unchallenged until the most recent wave of reform was initiated in 2011 with the introduction of the new government strategy – *Literacy and Numeracy for Learning and Life* (Department of Education and Skills, 2011). This national plan requires "all primary schools to administer standardised tests of English reading and Mathematics to all eligible students at the end of second, fourth and sixth class" (p.81), thus indicating an increase in the frequency with which pupils must undergo formal assessment throughout the duration of their primary schooling career. Furthermore, requirements documented in this strategy clearly outline that the results of these tests are now to be shared amongst an increased number of educational stakeholders, namely school boards of management and the Department of Education, albeit in aggregated form. Thus, given this new shift in ideology which evidently heralds a more intense approach to standardised assessment, one cannot but question if we are moving in a direction that will ultimately contribute to or detract from teaching and learning in the primary school classroom. This belief is further supported by the NCCA who state that

> in a world where measurement, evaluation and accountability are becoming an ever-increasing part of public life, the 'measurement' of education comes in for increasing scrutiny and the object of growing debate. (NCCA, 2005; p.12).

Rationale for Undertaking Doctoral Research in this Area

It is this topical debate, coupled with my own experiences as a practitioner utilising this form of assessment that has led to the formation of my current doctoral research, which aims to explore standardised assessment primarily from the teacher's perspective. As a practitioner in the field I have become consciously aware of the myriad of views and experiences teachers have relating to the usage and influences of standardised assessment. Given that it is these teachers who are most experienced in, and solely responsible for the implementation of this form of assessment, it stands to reason that their individual and collective voices in this regard should be included in evaluative research on this topic, a central feature my doctoral study aims to incorporate. Furthermore, given that the limited body of non-government based literature in this area is mainly comprised of advisory documents as opposed to directed research (INTO, 1997, 2010; NCCA, 2005, 2007), I feel that a study of this nature would certainly enhance the valuable information provided by existing studies in this area (O'Leary, 2006; Mac Ruairc, 2009), in adding a fresh and current perspective.

The Research Questions

In order to effectively achieve the objectives outlined above research questions have been carefully constructed, employing a multi-perspective approach, in order to comprehensively explore current issues relating to standardised assessment previously unaddressed. Collectively, these research questions aim to obtain differing, yet interconnected viewpoints relating to the usage of standardised assessment in primary schools, ultimately allowing the researcher to gain a more holistic appreciation of the experiences and issues teachers face when implementing this form of assessment in their classrooms. Given the nature of the research questions (as outlined in table 1 below) the views of those most experienced in the usage of this form of assessment, namely primary school teachers, will constitute the main focus of inquiry in this study. Additionally, in order to effectively contextualise the data obtained from the primary school teachers, the expert opinions of a Department of Education and Skills (DES) Inspector, a National Council for Curriculum and Assessment (NCCA) Executive and a standardised test creator will also be collected and analysed.

Table 1: Research Questions.

Question No	Question Content
1	What are teachers' views on the use of standardised test results as a tool of teacher accountability?
2	How are teachers responding to the role allotted to the use of standardised assessment in the new literacy and numeracy strategy?
3	How does standardised testing impact upon teachers' classroom practice?
4	How do teachers believe standardised assessment impacts student learning?

METHODOLOGY

Research Design

Predominantly located within the Interpretivist/Constructivist paradigm, this doctoral research essentially aims to understand socially constructed views deriving from "the world of human experience" (Cohen & Manion, 1994: p.36), specifically in the area of standardised assessment. In order to truly gain an appreciation of such experiences rich verbal data will be required detailing teachers' experiences and opinions in this regard, naturally denoting that the research will be mainly qualitative in design. This stance is further supported by Sherman and Webb, who state that "qualitative research has the aim of understanding experience as nearly as possible as its participants feel it or live it" (1988, p.7). As I will be aiming to 'understand' teachers' experiences relating the usage of standardised assessment within this doctoral study, as embodied in their verbal responses, it was decided that a qualitative approach in this regard would be justly validated.

Research Strategy

Within this research design, it was further decided that a social survey strategy would be most appropriately employed when collecting data as this approach would allow an extension of the sample size beyond that afforded by other research strategies, such as ethnography or case studies, thus strengthening validity and generalisability, and would also allow for several data collection methods to be adopted simultaneously.

Naturally, as there is a strong focus on obtaining rich verbal data interviewing became the preferred method of data collection. A semi-structured approach in this regard will be utilised with those partaking in this study. Defined by Cannel and Khan (1968) as a "two-person conversation initiated by the researcher for the specific purpose of obtaining research-relevant information, and focused by him on content specified by the research objectives" as quoted in Cohen and Manion, 1994; p.271), this particular interview method was deemed most appropriate for use in this study as it will allow me the freedom to deviate from the interview schedule if necessary in order to probe questions further and expand upon material of interest.

The use of 'expert interviews' (Meuser and Nagle, 1991; Flick, 1998) will additionally be employed when interviewing the DES Inspector, the NCCA executive and the standardised test creator. Here, Flick highlights that "the interviewee is of less interest as a person than in his or her own capacity of being an expert for a certain field or activity. He or she is integrated into the study not as a single case but as representing a group (of specific experts)" (1998, p.92). In this manner, the specialised data gained from any one of the participants noted above is seen as being representative of that group of 'experts', and in addition, each of those interviewed using this method will essentially enhance the research by providing data relating to the research questions from a unique perspective.

Importantly, collecting data in the manner outlined above will facilitate triangulation to occur in the research, whereby data collected by one method (interviews with the primary school teachers) will be cross-checked with that obtained from other viable sources (the expert interviews and an in-depth literature review). The presence of this methodological feature will further impact positively upon the validity of the research findings (Denscombe, 1998; Flick, 1998; O'Leary, 2004) as it allows the researcher to gain "a more holistic view of the setting" (Denzin and Lincon, 1994; p.224).

The Sampling Process

As issues relating to standardised assessment within a primary school context are being examined by the research questions, teachers who administer such assessments in these settings will naturally constitute the main focus of this study. In this manner, the sampling technique can be considered 'purposive', a technique Mason defines as "selecting groups or categories to study on the basis of their relevance to your research questions" (2002, p.124). Other techniques, such as random sampling, were deemed unsuitable for use as participants obtained in this manner may not be practicing teachers in a primary school, and thus would not be familiar with standardised assessment. When considering sample size it was decided that a sample large enough to ensure representativeness should be formulated. Thus it was decided that two counties with large urban and rural populations would be included to achieve this aim; namely Dublin and Galway. Furthermore, by including two such densely populated areas it ensured that if schools initially selected for inclusion opted not to partake, other equally viable options could be easily sought.

Given that primary schools in both Galway and Dublin are to be invited to participate in the research, it stands to reason that the DES Primary School Database 2012-13 for each region will collectively form the sampling frame. In order to ensure representativeness and facilitate in the comparison of data collected amongst participants within the study, the participant selection framework documented in table 2 below was formulated. This method of participant selection is again quite purposive in nature as school 'types' are being specifically targeted in relation to their likelihood in providing differing perspectives, which will inform the research.

Table 2: Participant Selection Process.

Variables: Small School = S Large School = L Rural School = R Urban School = U DEIS School = D General School = G	
Schools to be Included in the Research	
SDR	SGR
SDU	SGU
LDR	LGR
LDU	LGU

As outlined in the table above, school compositions are included in the sample, which aim to expose differences in the opinions and experiences of teachers in relation to the usage of standardised assessment. Small schools of less than 100 pupils, for example, are more likely to be administering standardised assessments within multi-class settings than are large schools with pupil populations of 300 or more. Unsurprisingly, data obtained from both sources in this area may highlight a difference in teachers' experiences, particularly in relation to accountability. Likewise, it is expected that such comparisons may again come to the fore when exploring the data obtained from 'general' schools (a category comprising of Catholic Schools, Educate Together Schools and Gaelscoileanna) with that collected in DEIS schools, where expectations of pupil performance by educational stakeholders may be of a lower nature.

Importantly, in each site outlined in table 2 above it is proposed to target specific staff members in order to obtain, and later analyse, differing perspectives within each school relating to standardised assessment and its changing role within our education system. Therefore, in each participating school it is proposed to conduct semi-structured interviews with the principal, with a teacher who must legally send their results to the DES, and also with a teacher who is not required to do so. In doing so, insightful data can be collected and later analysed in order to highlight differences in the views held by those who are most likely to experience accountability (the principal and the teacher who sends their results to the DES) with those who are not (the teachers who do not send their results the DES).

Currently work is on-going in this area, whereby the piloting process is now underway in order to finalise procedures prior to the formal collection of data.

CONCLUDING COMMENT

Though in its initial stages as of yet, one can clearly observe from the account provided in this paper that a doctoral study of this nature is essential in effectively monitoring the quality of educational assessment within the Irish context. Furthermore, despite numerous recent developments in the field of standardised assessment in Ireland, it is interesting to note that research investigating systemic effectiveness has not been conducted in this area to date, prompting the obvious question- If we do not critically evaluate procedures defining standardised assessment in our past and present, how can we possibly implement this form of assessment to best effect in our educational future?

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THE WESTERN SEABOARD SCIENCE PROJECT: AN INNOVATIVE MODEL OF PROFESSIONAL DEVELOPMENT TO ENHANCE THE TEACHING AND LEARNING OF PRIMARY SCIENCE

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It can be seen from the international research literature (Jarvis and Pell 2004) that primary teachers' confidence, competence and attitudes towards teaching science is a world-wide concern. The literature on how to improve teaching of science focuses largely on two areas (a) support, in the form of professional development (b) improving teacher confidence and competence.

The Western Seaboard Science Project (WSSP) is a two year experimental professional development project for teachers of primary science. The main aims of the project include:

- investigate the extent to which a professional development programme designed in the light of recent research findings can bring about improvements in confidence, competence and attitudes among primary teachers where the teaching of science is concerned;
- investigate the extent to which pupils' attitudes towards school science are improved;
- break down the insulation and isolation teachers experience in their day-to-day professional lives;
- develop sustainable "learning communities" between participating teachers.

The WSSP model gives teachers opportunities to: collaborate with their peers, reflect on their pedagogic practice and focus on pupil learning (Hogan *et al.,* 2007). This paper will chart the progress and discuss the key findings of the initiative.

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SAT 11.40 - 13.00

"THE QUALITY OF AN EDUCATIONAL SYSTEM CANNOT EXCEED THE QUALITY OF ITS TEACHERS"

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The title chosen for this paper is a quote from the McKinsey report of 2007 in which 25 of the world's school systems were examined to determine why some systems are more successful than others. Three factors were found to be the most important; two of which related to the quality of teachers, hence, "the quality of an educational system cannot exceed the quality of its teachers". This paper reports the findings of a pilot study on the understanding of fundamental chemistry concepts by pre-service science teachers in a university in Ireland. Understanding was assessed using a chemistry concepts diagnostic instrument to determine the number and type of chemistry misconceptions among this group. A selection of these findings is presented here. A wider-scale study, including pre-service teachers from institutions across Ireland, is currently underway, the results of which will be presented at the conference.

INTRODUCTION

The Irish Education system is producing students with average reading and scientific literacy and below average mathematical skills (Perkins *et al*, 2011). The quality of teachers is one of the main factors affecting the quality of educational systems (Barber and Mourshed, 2007). McKinsey consultants have identified raising the calibre of pre-service teachers as a successful strategy for improving educational systems like Ireland (Mourshed *et al*, 2010). There are two modes of entry into the science teaching profession in Ireland: concurrent and consecutive. In the concurrent model prospective candidates study science, pedagogy and education in a four year undergraduate course. In the consecutive model, science graduates complete a postgraduate diploma in which they study pedagogy and education for one year. Teachers with a good understanding of fundamental chemistry concepts are required to ensure the education system is serving the needs of its learners. Misconceptions in science have been well researched internationally among students at all levels of education (Kind, 2004; Sheehan, 2010). Recent studies in Ireland have found that misconceptions remain prevalent in primary and post-primary pupils. Teachers must be sufficiently prepared, both in their subject matter knowledge (SMK) and pedagogical content knowledge (PCK), to identify and directly target misconceptions among their pupils (Shulman, 1986).

METHODOLOGY

A pencil-and-paper instrument, the Chemistry Misconceptions Identification Instrument (CMII), was designed and used in this study. The fundamental conceptual areas of the Irish Leaving Certificate chemistry syllabus and misconceptions associated with these areas were identified in the literature. Conceptual questions were developed by the authors or selected from the literature where available. A number of different styles of questions were used: traditional multiple choice, pictorial and two-tier multiple choice. The instrument was composed of 23 questions in the following areas: Particulate Nature of Matter (10), Stoichiometry/the Mole (4), Chemical Bonding (5), Equilibrium (2) and

Other (3). The fundamental conceptual areas included in the instrument were the Particulate Nature of Matter (PNM), Mole, and Chemical Bonding. Equilibrium was also included given the difficulty associated with this area among qualified and pre-service teachers in other countries (Cheung, 2009; Ozmen, 2008). The resulting instrument was reviewed by experts and administered to 212 (response rate of 77%) pre-service science teachers qualified to teacher Junior Certificate chemistry across each year of study in a concurrent teacher education programme. The results were analysed using Predictive Analytics Software v18.0.3.

RESULTS

Figure 1 shows the performance in the instrument of pre-service science teachers in their first, second, third and fourth years of study of a concurrent teacher education programme. The majority (>80%) answered less than 40% of the questions correctly.

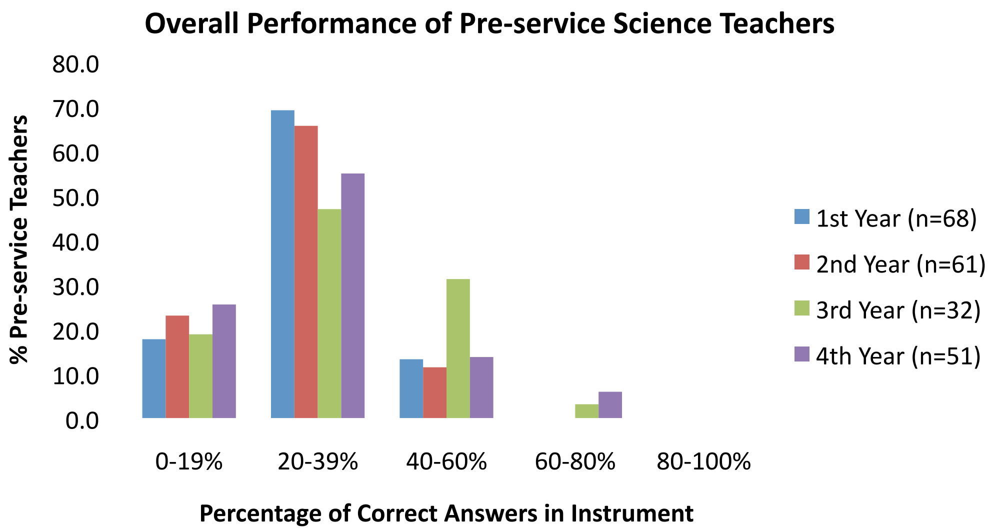

Figure 1: Performance of Pre-service Science Teachers in the Instrument.

The mean score for the group was 30.8%. Pre-service teachers demonstrated poor understanding in all the conceptual areas (M < 45% in all areas) with PNM being the most poorly understood area (M =28.2%) as shown in Table 1.

Table 1: Breakdown of Mean Scores for Each Conceptual Area in the Instrument.

Concept Area	Questions	Average Score (*N*=212)	% not attempting section
Particulate Nature of Matter	Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q11	28.2%	0
Stoichiometry	Q8, Q9, Q10, Q12	43.0%	0.5
Chemical Bonding	Q13, Q14, Q15, Q16, Q20	32.7%	1.4
Equilibrium	Q17, Q18	31.1%	0.9
All Areas		30.8%	0

Table 2: List of Misconceptions Identified in > 10% of Pre-service Science Teachers.

Concept Area	Subtopic (where relevant)	Misconceptions Identified	% of sample (N=212)
Particulate Nature of Matter	Atomic Structure	Use of Octet Rule analogy to explain differences in ionisation energies	42.0%
		Use of relation-based reasoning to explain differences in ionisation energies	34.4%
	Chemical Formulae & Equations	Confusing the meaning of coefficients and subscripts	56.5%
		A failure to conserve atoms or understand the role of a limiting reagent	74.9%
	Phase Change	A belief that a phase change from liquid to gas involves the breaking of covalent bonds	30.1%
	Conservation	Matter not conserved as gas weighs less or is less dense than solid	27.8%
	Composition of Matter	Attributing macroscopic properties such as density, melting point and structure to a single atom	52.4%
		Identifying all pure substances composed of elements as homogeneous mixtures	20.7%
		Identifying pure substances composed of compounds as heterogeneous mixtures	25.5%
		Identifying substances containing more than one element as compounds	30.2%
Stoichiometry	The Mole	The mass of a particle affects the number of particles in one mole of substance	31.1%
		The type of particles affects the number of particles in one mole of substance	10.4%
		12g of Carbon contains a mole of electrons	58.0%
		Unable to apply mole ratio to generic chemical equation	30.2%
	Volumetric Analysis	Belief that a solution of 1M contains molecular mass of substance in 1 L of water	19.8%
Chemical Bonding		Belief that an ionic bond involves the sharing of electrons	15.6%
		The electron pair is centrally located in a covalent bond	30.2%
		Breaking bonds releases energy	61.1%
		Ionic bonding is always stronger than covalent bonding	19.3%
		The presence of metallic bonds raises the boiling point of a substance	12.7%
		N_2H_4 is a resonance structure	15.6%
		Lone pairs can never exist on adjacent atoms	16.5%
		Nitrogen forms triple bonds when possible	26.9%
Equilibrium		Reactant concentration increases as equilibrium is established	28.8%
		Concentration fluctuates as equilibrium is established	20.3%
		Failure to understanding meaning of equilibrium constant	49.0%

Common misconceptions in this area were: a failure to conserve atoms (74.9%), confusing the meaning of coefficients and subscripts in chemical equations (56.5%) and attributing macroscopic properties such as density, melting point and structure to a single atom (52.4%). A list of the specific misconceptions demonstrated by the cohort can be found in Table 2. A number of factors emerged as having a significant effect on performance in the instrument with pre-service teachers that were older, male, studying the physical sciences and had studied higher level chemistry and mathematics for the Leaving Certificate achieving higher scores ($p<0.05$ for all factors). There was also no significant difference ($p>0.05$) between student teachers specialising in biology and physics (M=25.8%) and those specialising in biology and chemistry (M=29.4%). Interestingly, there was no change in the number of misconceptions associated with the year of study or with the number of chemistry or science pedagogy modules studied ($p>0.05$).

DISCUSSION

The main finding of this pilot study is that basic chemistry concepts are poorly understood by pre-service science teachers and four years of a concurrent teacher training course do not appear to promote better understanding. Over 80% of the group achieved less than 40% in the instrument, with an average score of 30.8%. On the surface this result seems surprising, even shocking, yet it is really no surprise that learners in the Irish Educational system do not develop conceptual understanding. The assessments pupils take at the end of the Junior Certificate and Leaving Certificate programmes encourage pupils to rote-learn material and to use algorithms. These types of examinations have been found to encourage the development of misconceptions and learning difficulties in chemistry (Nahum *et al*, 2004). Sheehan (2010) found that the majority of Junior Certificate (67.2%) and Leaving Certificate (63.8%) students achieved less than 40% in a chemistry concepts test, which contained a number of the same conceptual questions used in this study. Based on these results it is to be expected that those entering third-level education should also have a high number of chemistry misconceptions. One might expect students' understanding to improve during the course of their third-level education, however, traditional teaching methods, commonly employed in Irish universities, have been shown to have no effect on the misconceptions of students (Mulford and Robinson, 2002; Zoller, 1993). While this is of concern for all learners in third-level education, it has particular significance for pre-service science teachers. Teachers who have inaccurate subject matter knowledge are more likely to create lesson plans which include misconceptions, present inaccurate representations, reinforce misconceptions and be unable to detect misconceptions among their students (Hashweh, 1987).

The correlation between age, gender and study of mathematics and performance in the CMII may be associated with higher cognitive levels. Male students at university level are more likely to operate at the formal operational level according to Sheehan (2010) and Shayer and Adey (1981) found a direct correlation between cognitive development and age. As previously mentioned, those studying the physical sciences achieved higher scores than those studying biological sciences with either a chemistry or physics elective. Fieldsend *et al* (2012) found that those specialising in biology demonstrated deficient subject matter knowledge in the physical sciences while those studying the physical sciences did not demonstrate deficiency in biology to the same extent. Possible reasons for this are currently being explored by the authors and it is hoped that future work may offer insight to these results.

The limitations of this study include its semi-longitudinal nature; four different groups were involved over the four years of study rather than tracking the understanding of a single group over four years. Furthermore, there are limitations associated with the instrument used. The advantage of a pencil-and-paper instrument is that data can be collected from larger numbers. However, some responses may have been random guesses and there is no way to identify these responses from those reflecting legitimate misconceptions. Since this study was carried out, interviews with pre-service science teachers have indicated that the style of some questions may have been difficult for the group to interpret, e.g. a high linguistic demand. However, despite these limitations the results would suggest that the traditional teaching methods used in chemistry lectures and the content or strategies used in science pedagogy lectures are not successful in reducing misconceptions and promoting conceptual understanding among this sample of pre-service science teachers.

CONCLUSION

The results of this pilot study suggest that not only is the Irish Educational System failing to produce conceptual understanding in learners entering third-level education but that this teacher education programme is not addressing this issue and is producing teachers which are not equipped to deal with their pupils ideas and may in fact reinforce misunderstanding among their pupils. This may result in a perpetual, vicious cycle in which pre-service science teachers' conceptual understanding of chemistry remains undeveloped throughout the course of a teacher education programme and they may reinforce the misconceptions of their future pupils some of whom will then enter teacher training programmes. These findings reinforce the old adage; 'Teachers teach as they were taught and not how they were taught to teach'.

FUTURE WORK

Since this pilot study was undertaken, the Chemistry Misconceptions Identification Instrument has been modified based on interviews with pre-service teachers and expert review. The modified instrument has been administered to pre-service science teachers in both concurrent and consecutive teacher training programmes across Ireland. The data from these groups is currently being analysed and will be presented at the conference. Following the results of this study, strategies and materials will be designed to promote conceptual understanding of fundamental chemistry concepts and an intervention programme will be offered to a group of pre-service science teachers.

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INQUIRY APPROACH TO LEARNING SELECTED COMPUTER SCIENCE CONCEPTS

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Many computer science concepts and their relations seem difficult, so some teachers prefer more transmissive ways of their instruction in which pupils receive knowledge in ready form. On the other hand inquiry based learning in its various levels described in (Bell, 2008) brings several benefits for pupils, e. g. deeper understanding of concepts and their relations, developing their inquiry abilities, curiosity, openness to new ideas, critical thinking etc.

In the paper we describe an inquiry activity presented in form of card guessing game. The activity is aimed at discovering and understanding the principles of information encoding, the code length dependence of the quantity of states, unambiguity of encoding, the use of binary trees in encoding, binary searching algorithm etc. Based on the teaching experience of this game in various target groups (elementary school pupils, lower secondary school pupils, pre-service and in-service computer science teachers) we provide our findings and methodology comments. As teacher trainers we consider implementation of more inquiry approach in pre-service and also in-service computer science teachers' education to be very important.

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IMPLEMENTATION OF INQUIRY BASED SCIENCE EDUCATION (IBSE): IS SUPPORTING THE TEACHERS SUFFICIENT TO BE SUCCESSFUL?

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The European Community wants science education to change in the direction of IBSE (Rocard Report). Today several large projects involving many countries are addressing this challenge. The main focus is on preparing and supporting teachers by providing them with innovative curriculum materials and teacher training activities (as well pre-service as in-service).

In this presentation I will analyze the process of implementation and identify key factors that have decisive influence on the level of implementation. Also some design criteria for effective in-service training will be discussed.

This analysis will be based on two cases of innovation in The Netherlands, and a comparison with experiences in other countries:

- the implementation of a new part in the curriculum of Physics: Physics Informatics, and
- the implementation of the integration of ICT in Science Education

We have known for a long time that ICT might stimulate and enable Science Education in a direction that brings (high school) students in a similar position as researchers in science. The powerful tools available (from measurement with sensors, advanced video-analysis to numerical modeling) facilitates realistic and authentic research projects by students.

INQUIRY APPROACH IN LEARNING SELECTED COMPUTER SCIENCE CONCEPTS

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Many computer science concepts and their relations seem difficult so some teachers prefer more transmissive ways of instruction in which pupils receive knowledge in ready form. However, inquiry based learning brings several benefits for pupils, e.g. deeper understanding of concepts and their relations, developing their inquiry abilities, curiosity, openness to new ideas, critical thinking, etc. In this paper we describe an inquiry activity presented in the form of card guessing game. The activity is aimed at discovering and understanding the principles of information encoding, the code length dependence on the quantity of states, unambiguity of encoding, the use of binary trees in encoding, binary search algorithms, etc. Based on our own teaching experience in this game in various target groups (elementary and secondary school pupils, pre-service and in-service computer science teachers) we present our findings and methodology comments. As teacher trainers we consider implementation of more inquiry approach in pre-service and also in-service computer science teachers' education to be very important.

INTRODUCTION

Computer science (Informatika in Slovak) is quite a new school subject in comparison with mathematics or other science subjects. A school reform that brought some changes to the teaching of computer science started in the Slovak Republic in 2008. A new subject called computer science was introduced at both elementary and lower secondary school levels and the time allocated to computer science was increased at higher secondary level. On each level (from age of 8 to 19) the subject matter covers five areas: Information about us; Communication through ICT; Procedures, problem solving, algorithmic thinking; Principles of operation of ICT; Information society.

The reform emphasizes the development of key competencies of pupils and a two-level curriculum (basic requirements, extended requirements) enables more freedom for schools to create their own specific school educational programmes. If we want to bring up a new generation with developed key competencies is impossible to educate them in an old-fashioned, mainly transmissive way of learning and without involving digital technologies. There is a great variety of modern approaches to learning (problem-based learning, project-based learning, inquiry-based learning, discovery learning) oriented to the pupil, their engagement and activity, solving authentic problems, involvement of higher-order thinking, developing pupils' curiosity, critical thinking, etc.

Many of our computer science teachers are familiar with these modern approaches to learning and accept them. However, they do not exploit them in their teaching. They mostly argue that there is no time to let pupils think more deeply, further develop their ideas, and simulate way of thinking of scientist/researcher.

In this paper we would like to show and persuade computer science teachers that it is worth spending time with inquiry-based activities because of distinct benefits for both pupils and teachers themselves. The activities presented in the paper follow the methodology of inquiry based learning on structured or guided level of inquiry stated by Bell (2008). We have modified the methodology by using Socratic style dialogue as in Garlikov (2006) and by taking into account the pupil's Zone of proximal development (ZPD) mentioned in *e.g.* Kozulin (2006). In our methodology we exploit the BSCS 5E

Instructional Model (BSCS, 2006). In the beginning we demonstrate a card-guessing game (magic with cards) and ask questions (engagement stage). Then we let pupils play the game in pairs to find out the best way of card guessing with little or no help from the teacher, e.g. Socratic questions, using teaching aids (exploration stage). Then pupils discuss their results, compare their findings, the teacher gives explanation for pupils' findings in scientific language (explanation stage). Then pupils apply their conclusions to solving a related or more general problem and the teacher specifies or further extends these conclusions (extension stage). In the end the teacher asks high-order questions to pupils and assesses pupils' understanding of the concepts (evaluation stage). If the methodology is to be used with various target groups, it requires some adaptations to each particular group of pupils, e.g. simplifying or omitting some tasks of the activity.

CARD GUESSING GAME

Teacher's information

Main problem:

- Find and describe as well as possible how to guess one card chosen from a deck of 32 cards.

Further problems:

- Find and explain as effective way of calculating the amount of information necessary for finding the chosen card as possible.
- Find and explain the relationship between the length of encoding (number of digits), logarithm and depth of N-ary tree.

Topics:

- Information encoding.
- Calculation of information quantity.
- Binary searching of elements in an ordered sequence.

Learning aims:

- Applying (discovering) binary search algorithm to guessing cards/numbers.
- Explaining that the amount of information necessary to determine a chosen card depends on the total number of cards and also on the manner of questioning (the number of different answers to the questions).
- Explaining that after each answer to a question more and more information is acquired, after a binary question 1 bit of information is acquired, (after ternary and decimal questions 1 trit and 1 dit of information are acquired respectively).
- Giving reasons that for a clear determination of one chosen card from a deck of 32 cards we need to ask 5 binary questions (for one from 27 cards we need to ask 3 ternary questions, in general for determination a card from a package of N cards we need to ask $\log_K N$ K-ary questions at most).

Prior knowledge:

- Calculating with various positional numeral systems (writing the successor of a number, conversion of number notation between various bases).
- Using logarithmic and exponential functions.

Target groups: upper secondary school pupils, university students – pre-service teachers)

Used materials: a deck of 32 cards, dataprojector, (interactive) board.

Time requirement: 1 lesson

The course of solving the guessing problem

Solving the whole card guessing problem can be divided into several phases:

- In the first phase a teacher demonstrates the card guessing game and encourages pupils to play the game in pairs, they take turns to guess cards.
- In the second phase, by means of Socratic debate with a teacher (or independently of a teacher), pupils discover a sophisticated way of determining the chosen card.
- In the third phase, after playing the card guessing game, pupils will study information encoding by means of binary numbers, calculate the amount of information and use a binary tree for searching, information encoding and showing the unambiguity of encoding.
- In the fourth phase pupils are encouraged to solve further problems leading to generalization and exploiting various ways of encoding information in solving some practical problems. Finally, the teacher assesses pupils' understanding of the concepts.

In the first phase a teacher motivates pupils to discover the best way of guessing a card chosen by a classmate. Only yes/no questions can be used by those who guess. Before the pupils' experiments start, it is important for the teacher to warm up their thinking by asking some questions, for example. "Do you know cards? What kind of suits (colours) and values are there? How many cards are there in a complete deck?" Clever pupils can carry out the activity without touching the cards, only using their imagination and thinking. Pupils are encouraged to play the game several times taking different roles and also to record the number of questions for each card guessing. The first phase is concluded with questions, such as "How many trials did you need to guess the card? Who was better? Did you ask random questions or did you use a sophisticated way of guessing the card?"

In the second phase of solving the problem the experience acquired in the first phase is exploited and by means of Socratic debate we try to analyse pupils' random guessing and to come together to a systematic way of guessing a card – binary search algorithm. During the dialogue the teacher can ask well-considered sequence of questions, such as "Considering asking questions randomly, can you guess the card at the first trial? How many questions do you need in the worst case to guess the card? What can be said about the set of cards containing the searched card after each question? How will the set be reduced question by question? What question should you ask in order to reduce the set containing the searched card by more than only one card? How large will the set be after answering the question regarding the card's suit? What question should you ask to get equal chances for further guessing regardless yes/no answer? What will be the next question concerning the suit of the searched card? How many questions do you need for guessing the card from a deck of 32 cards?"

In the dialogue it is very important for the teacher to give pupils some affirmative and encouraging information, e.g. "Perfect. You are right. When asking questions it is really important to find and formulate a convenient attribute by which the set containing the searched card will be reduced". The teacher can improve pupils' learning by means of some teaching aids, e.g. card decks, diagrams with 32 cards, binary tree with binary numbers. For more detailed information on modeled Socratic dialog see the paper (Snajder, 2012).

After pupils' discovering the way of questioning, the teacher leads a dialogue to generalize the solution to the problem. Pupils can very easily discover the fact that for guessing a card out of 64 cards it is necessary to ask 6 questions, and for 1024 cards 10 questions are needed. Then the teacher shows that for $N=2^K$ cards the sequence of cards containing the searched card is decreasing as follows: 2^{K-1}, 2^{K-2} ... $2^{K-K} = 2^0 = 1$. From this sequence pupils can conclude that for guessing a card from a deck of 2^K cards it is necessary to ask K "yes/no" questions. On secondary school level pupils, who are familiar with logarithmic function, can express that for guessing a card from N cards it is necessary to ask $\log_2 N$ yes/no questions. They can also discover formula for $N \neq 2^K$ cards.

In the third phase the teacher leads pupils to understanding the relationship between the total number of elements (e.g. numbers, cards) and the number of bits necessary for encoding all the elements and also the number of binary questions for finding out a searched for element. There is a binary tree that is considered to be a very useful tool for understanding several concepts.

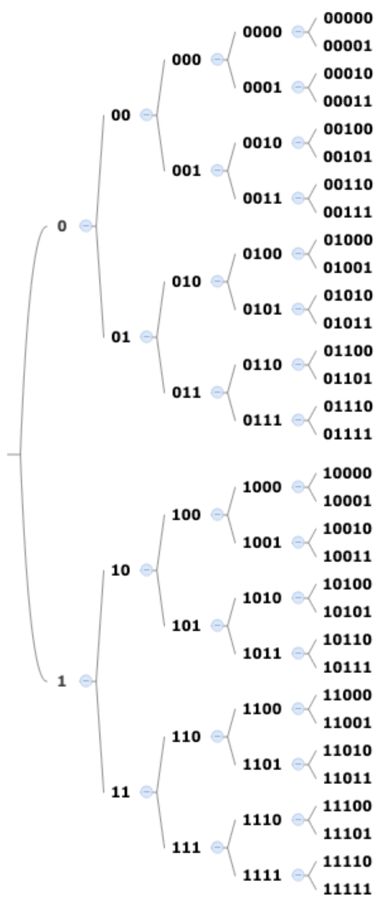

Fig 1. **Binary tree with depth 5 and $2^5 = 32$ leaves assigned by binary numbers**

Let's create a binary tree (Fig. 1) starting with an empty root vertex. From the vertex we draw two edges leading to two sons' vertices. Let's assign the left son vertex with the value from the father's vertex adding digit "0" to the right side, and the right son vertex with the value from the father's vertex adding digit "1" to right side. This procedure can be applied to each vertex. It is clear that in K_{th} depth of binary tree there are vertices that are assigned by numbers with K binary digits. If we would like to find an arbitrary number with K binary digits we need to know answers for K binary questions. In other words, for representation of a number from 2^K numbers we need K binary digits or acquire K bits of information. In the guessing card game we can receive one 5-bit information (e.g. red king) to know definitely all about searched card, or one 2-bit information about the colour (e.g. red) and one 3-bit information about the value (e.g. king), or five 1-bit information, etc. Previous consideration, which can be easily rewritten in the form of dialogues, shows the relation between bit as a binary digit and also as a binary information unit.

In the fourth phase pupils solve further problems to learn to generalize the acquired knowledge and exploit various ways of encoding information in solving some practical problems, e.g. guessing a card from a deck of 27 cards laid in three columns, guessing a number from 1 to 26 using special treated double sided cards, encoding two or more coloured pictures by binary (K-nary) numbers, finding a bag of fake coins using single weighing only, etc.

From binary numbers we can move on to K-nary numbers. For guessing one of 2^{10} numbers we need to ask 10 binary questions and by this we acquire 10 bits of information. For finding out one of 10^3 numbers we need to ask 3 decimal questions (value of 1st decimal digit, 2nd decimal digit, and 3rd decimal digit) and we acquire 3 dits of information. For determining the card chosen from among 3^4 cards organized in a square with 9×9 positions, we need to ask 2 nonary questions or 4 ternary questions. In general, for determining one of K^L elements we need to acquire L K-nary information. Examining K-nary tree, pupils can deduce that K-nary tree with depth L has K^L leaves, and also that depth of K-nary tree is closely related to logarithmic function (with base K) and number of digits of a K-nary number. Finally, the teacher assesses pupils' understanding of the concepts by assigning a solving task that requires higher-order thinking.

DISCUSSION

Proposed methodology is based on the teaching experience in various target groups (elementary school pupils, gifted pupils from secondary schools, pre-service and in-service computer science teachers) and on assigning various problems (looking up a word in a dictionary, guessing integer number from 1 to 16 (or from 1 to 26) using binary spiders (or special treated cards), guessing one of 32 (or 27) cards obtaining binary (or ternary) answers, encoding two coloured pictures by binary numbers etc.)

Of course, for different target groups we have achieved different ranges and depths of subject matter comprehension. Pupils from 3rd class of elementary school have discovered a better way of looking up a word in a dictionary than browsing the dictionary page by page. They understand that "spider" (binary tree) is a very good aid for guessing integer numbers in a few trials.

Gifted secondary school pupils very quickly discovered a principle of effective guessing a card using binary (or ternary) questions. They were very active, asked many questions, created and verified hypotheses, were very consistent and critical (they verified the card deck to make sure that it had not bee specially treated). Only some of them knew how to work with other than decimal numbers, but after using the above described Socratic debate and experimenting, all of them understood the principle of representation of numbers in other than decimal numeral system.

Pre-service and in-service computer science teachers appreciated the magic with cards as a very appropriate activating teaching method which fosters understanding of selected computer science principles and at the same time they found it interesting and enjoyable. During a lecture to a group of pre-service computer science teachers a lively discussion arose. The teachers repeated the magic with guessing a card from 27 and more cards several times. They were surprised to guess the card from a deck of 30 cards after 3 ternary exchanges. After explanation of this issue with regards to probability students understood the whole problem.

Teachers can devise special decks of cards (e.g. cards with computer devices, binary numbers, animals, fruit), which could be more appropriate for younger pupils and would help to remember selected notions of computer science, too, or which would have a closer relation to other school subjects. For inquiry approach it is also very helpful to use computer animations, demonstration videos and interactive applets (Edkins, 2006; Snajder, 2010; Wolfram, 2012).

CONCLUSION

We believe that we managed to inspire both computer science and mathematics teachers and encouraged them to exploit inquiry approach in their teaching. From the point of view of teacher trainers, i. e. ours, both proposing and testing inquiry methodologies of computer science teaching as well as preparing pre- and in-service teachers for exploiting inquiry approach in their teaching are important.

The proposed methodology was developed within ESTABLISH and LPP-APVV 0057-09 projects.

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INQUIRY BASED CHEMISTRY EDUCATION - PILOTING THE UNIT "EXPLORING HOLES" IN SLOVAK SCHOOLS

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The teaching of chemistry based on scientific inquiry according to the project Establish started to implement these lessons in Slovakia in the academic year 2010/2011. The verification showed that Subunit Visible holes complies with the State Educational Programme for chemistry of primary schools in Slovakia – the proposed activities are appropriate for the 6th class for the topic Mixtures and chemical substances and for the 7th class for the topic Physical and chemical processes. Verifying the lesson Invisible holes revealed that not all proposed experiments can be incorporated into chemistry teaching in Slovak schools as not all of them comply with the State Educational Programme and such chemicals are used in them which a teacher must not work with for safety reasons. Lesson Exploring holes has been tested at basic and grammar schools on the sample of 250 pupils and 150 students, the total of 12 teachers. The teachers and pupils answered a questionnaire after the teaching unit had been completed. It has come out of verification that pupils found the activities useful, entertaining and interesting. The teachers appreciated the fact that pupils do not get ready information but by carrying out practical tasks and by mutual communication they acquire knowledge that will be long-lasting. Pupils learn to perform scientific activities, be responsible, work in teams, be tolerant, communicate, express their opinions. The disadvantage was seen in the fact that it is rather demanding for a teacher because they have to prepare trials and it is also time-consuming in the class.

INTRODUCTION

The European Union is making an effort and devotes significant means to support innovation in scientific and mathematical education. By means of the seventh general plan for research and international projects it supports the ESTABLISH project (www.establish-fp7.eu), in which P.J. Šafárik University in Košice participates as a partner. Within the project the partners develop inquiry-based activities for teaching chemistry, physics and biology. For teaching chemistry the *Exploring Holes* lesson was to be created first. Our aim was to transform the unit into the State Educational Plan for chemistry in Slovakia and test the lesson in class. The total of 50 chemistry, physics and biology teachers have taken part in further education in active scientific inquiry methodology. The teachers who participated in the training implement the activities developed within the project in teaching science at primary and secondary schools. The efficacy of the method is tested by means of tools developed within the project. The paper will analyse and discuss the contribution of this educational method mainly to motivating students towards science school subjects and to their becoming aware of the significance of science and technology for the society development.

TESTING THE UNIT "EXPLORING HOLES" AT SLOVAK SCHOOLS

Motivation:
The need to separate one substance from another is as old as mankind itself. Who would not know the story of Cinderella as an example? She, in order to dance at the ball, had to separate lentils from peas. If she had known what we know today about holes, she wouldn't have needed the help of pigeons and would have coped with the job much faster and without worries and wrinkles.

The unit *Exploring Holes* was tested with 12 teachers, 250 primary school pupils and 150 secondary school students in Slovakia from 2010 to 2012. The aim of the test was to find out whether it was possible to incorporate the unit *Exploring Holes* into the chemistry chapters of the State Educational Plan. We tried to find out if the different activities are suitable, age-appropriate and feasible at Slovak schools with respect to the schools' facilities.

Incorporating the unit "visible holes" into the state education plan for chemistry in Slovakia
After comparing the contents of the unit's inquiry-based activities with the State Educational Programme for chemistry in Slovakia, it can be stated that the activities can be incorporated into the following chapters:

1. mixtures and chemical substances in the 6th class of primary school
2. physical and chemical processes in the 7th class of primary school
3. organic substances in everyday life in the 9th class of primary school
4. mixtures, separating mixture constituents in the 1st year of grammar schools

Chapters a-c are part of the State Educational Plan (SEP) ISCED 2 for 2nd grade of primary schools and chapter d is part of SEP ISCED 3 for grammar schools.

Testing the efficiency of inquiry-based activities of the unit *Visible Holes*
Testing the efficiency of inquiry-based method was carried out by means of evaluation tools prepared within Establish project. It was carried out after teaching the unit *Visible Holes* at 5 primary schools. Ten teachers and 173 pupils aged 12-14 participated in the research.

Evaluation of teachers' questionnaires:

1. Do you think that the finished learning unit has a positive impact on students, especially on their perception of science?

Figure 1 shows that as many as 75% of teachers strongly agree that an inquiry lesson has a positive influence on pupils, particularly on their perception of science. The remaining 25% agree with the above.

2. If you agree, do you think it will have the positive impact in the long term, i.e. it will take several months or a year or more?

The graph implies that 50% of teachers strongly agree that inquiry lessons will have a positive long-term influence on pupils and the remaining 50% agree with the above.

3. Do you think that this learning unit can support the development of students´ knowledge and skills? If you agree, please write down briefly what are these knowledge and skills concretely:

- A pupil will be able to use basic terminology correctly, present their knowledge, experience and skills in an intelligible way.
- They will be able to apply the acquired knowledge in everyday life.
- They will be able to work in groups, advise and help one another.

4. Do you think it can support the development of students´ attitudes? If you agree, please write down concretely and briefly what are these attitudes:

- My pupils‘ attitude to work in the carried out experiments has changed. Pupils do not get ready information but look for solutions in problem-solving tasks, co-operating efficiently in a group and being aware of their responsibility in the team.
- They use creativity and independence in researching and carrying out problem-solving tasks.

5. What are the main advantages and disadvantages of this learning unit over the „usual teaching and learning“?

Advantages:

- Pupils do not get ready information but by carrying out practical tasks and by mutual communication they acquire knowledge that will be long-lasting.
- Pupils learn to perform scientific activities, be responsible, work in teams, be tolerant, communicate, express their opinions.

Disadvantages:

- It is rather demanding for a teacher because they have to prepare trials and it is also time-consuming in the class.

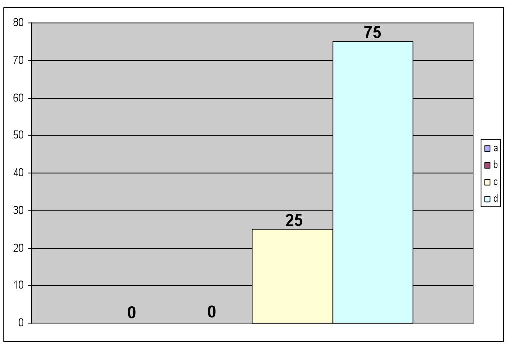


Figure 1: Graph evaluating question 1

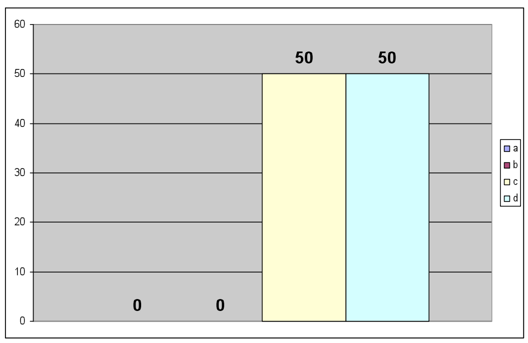


Figure 2: Graph evaluating question 2

Evaluation of pupils' questionnaire:

After completing the whole unit pupils filled out a questionnaire. The results show that the majority of pupils find the activities important, useful and interesting, and at the same time entertaining and beneficial. There were, however, pupils who considered the activities to be boring (2%) or claimed the activities pointless (4%). On the other hand, more than 10% of pupils considered the activities absolutely beneficial and useful to such an extent that they would like to do them again.

The following graphs show pupils' answers to selected questionnaire questions.

Question 6: I believe, doing these experiments will be conducive to me.
Question 3: It was a fun what we were doing.

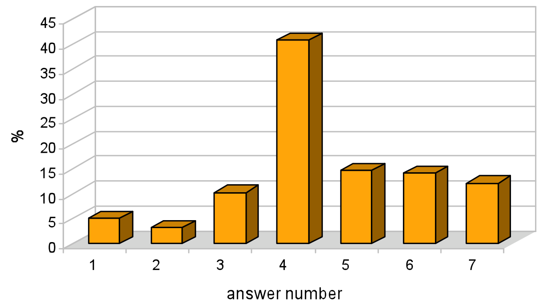


Figure 3: Graph evaluating question 6

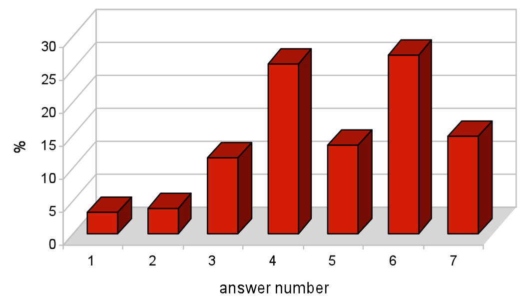


Figure 4: Graph evaluating question 3

INCORPORATING THE UNIT INVISIBLE HOLES INTO THE STATE EDUCATIONAL CHEMISTRY PLAN IN SLOVAKIA

Incorporating the unit *Invisible Holes* into the State Educational Plan in Slovakia is very difficult. The topic Polymers, which the subject matter is connected with, is not included in the SEP in Slovakia. Organic chemistry only includes PVC and its properties. The topics Dialysis and Osmosis are only incorporated into the optional biochemistry topics. That is why some activities of this subunit were tested in chemistry club classes.

In implementing unit *Invisible Holes* we had difficulty with using suitable foils as it was difficult to get semi-permeable foil. Activity 2.2A focusing on diffusion was the most popular with pupils.

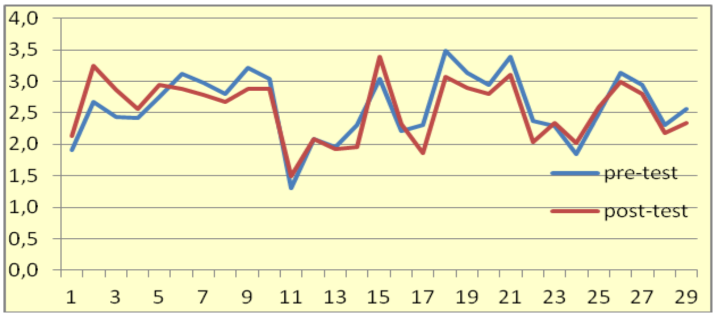
INCORPORATING THE UNIT INTERESTING HOLES INTO THE STATE EDUCATIONAL CHEMISTRY PLAN IN SLOVAKIA

The activities can be incorporated into the chapter "Hydrocarbons Derivatives important for everyday life, their properties, use, and impact on living organisms and the environment" in the 2nd year of a grammar school. The lesson was tested in optional classes. The students were very interested in the experiments that enabled them to find answers to the following questions: Why does a disposable diaper not soak as soon as the one made of cloth? Why do they always talk about the change of liquid into gel in sanitary pads advertisements? Why is a human eye lens wet? Why is it possible not to water plants for a longer period if you put hydrogels under their roots?

TESTING THE EFFICIENCY OF INQUIRY-BASED ACTIVITIES OF THE UNIT EXPLORING HOLES BASED ON EVALUATION TOOLS OF ESTABLISH PROJECT

Testing was carried out following the scheme - pre-test, carrying out a lesson (here teachers could choose any activities that could be carried out within 3 lessons), and post-test (at the end of teaching units). The testing tool consisted of three parts in which pupils stated to what extent they agreed with the statements about science subjects and expressed their attitude to science and technology.

It turned out from testing that inquiry-based activities had a positive influence on pupils. To the question 2 – if science subjects are interesting - many more pupils answered yes in post-test than in the pre-test. The post-test results also revealed that science subjects were not particularly popular with the pupils and that scientific jobs did not appeal to them either. Neither had changed their perception of science and technology and their impact on eliminating world's poverty. Pupils continued to believe that science and technology are the reasons of ecological problems.



x-axis: questionnaire XY questions

y-axis: allocation of points

Figure 5: Graph of pre-test and post-test results

CONCLUSIONS

Testing the unit *Exploring Holes* by an inquiry-based method revealed both its advantages and disadvantages. Among the advantages doubtlessly belongs the development of critical thinking in pupils, developing key competences – communication in mother tongue, development of logical and mathematical thinking, ability to solve problems, deeper understanding of chemical phenomena. In order to obtain really positive results it is necessary to teach teachers to use the method, to use it simultaneously in several subjects at one school and increase time allowance for science subjects.

ACKNOWLEDGEMENT

The paper has been written within the project KEGA č. 027UPJŠ-4/011 financed by Ministry of Education Slovak Republic and within the project ESTABLISH (7th General Programme of EU, FP7/2007-2013 based on the n° 244749 agreement).

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INQUIRY-BASED VERSUS PROJECT-BASED METHOD OF TEACHING THE TOPIC PLASTIC

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The paper points out the significance of implementing inquiry-based activities for pupils' project work. Within the national project KEGA č. 027/2011 on the web page kekule.science.upjs.sk we are making accessible the digital library for doing chemistry projects of pupils. The digital library provides both teachers and pupils with such educational sources needed for doing projects as learning texts, experiment proposals on particular topics, proposals and outputs of projects and inquiry-based activities. Plastic and plastic waste has been prepared as a pilot topic with inquiry-based activities. Project-based teaching based on implementing inquiry-based activities represents the method of teaching in which a teacher manages a pupil in a way similar to the one common in real research. The research characteristic of the teaching is manifested e.g. in the activity "Properties of plastic materials" in which pupils design experiments, formulate hypotheses, make conclusions and links with reality on their own. In these inquiry-based activities a supervised type of research is mainly used. We have tested the digital library with inquiry-based activities in ten teachers of basic and grammar schools. The teachers claimed the library represented a useful digital aid for implementing projects. The accessible inquiry-based activities enable pupils to acquire necessary knowledge of plastic and plastic waste and at the same time develop their skills and competences stated in the State Educational Programme. According to the teachers pupils acquire more permanent knowledge and their interest in chemistry increases due to such an active approach to learning.

INTRODUCTION

Project and inquiry-based education methods are currently ranked among the main methods leading to increased efficiency of science education. In our research we focused on building a digital library for project and inquiry-based education methods for teaching the topics Plastic and Plastic Waste. The library should serve for teaching chemistry as well as interdisciplinary topics "Setting up a Project and Presentation Skills" and "Environmental Chemistry" of the State Educational Programme (SK) and General Educational Programme (CZ). The library should provide chemistry and other science teachers with methodological educational resources needed for setting up interdisciplinary projects such as learning texts, proposals for experiments on a particular topic, proposals for and outputs of projects as well as inquiry-based methods. Inquiry-based activities are accessible because project-based education has the character of inquiry-research and because inquiry or research activities of pupils within a project represent a unique educational method. We would like to point out common features and significance of an inquiry-based method in project-based education.

DIGITAL LIBRARY STRUCTURE

The library can be found at http://kekule.science.upjs.sk. It has been created partly thanks to the finance from KEGA č. 027/2011 national project. The inquiry-based activities have been prepared within the Establish project. The library provides chemistry and other sciences teachers with methodological educational sources needed for creating interdisciplinary science projects. The digital library is currently available for the following topics: Water, Natural Substances – Proteins, Saccharides, Lipids, Energy, Plastic and Plastic Waste.

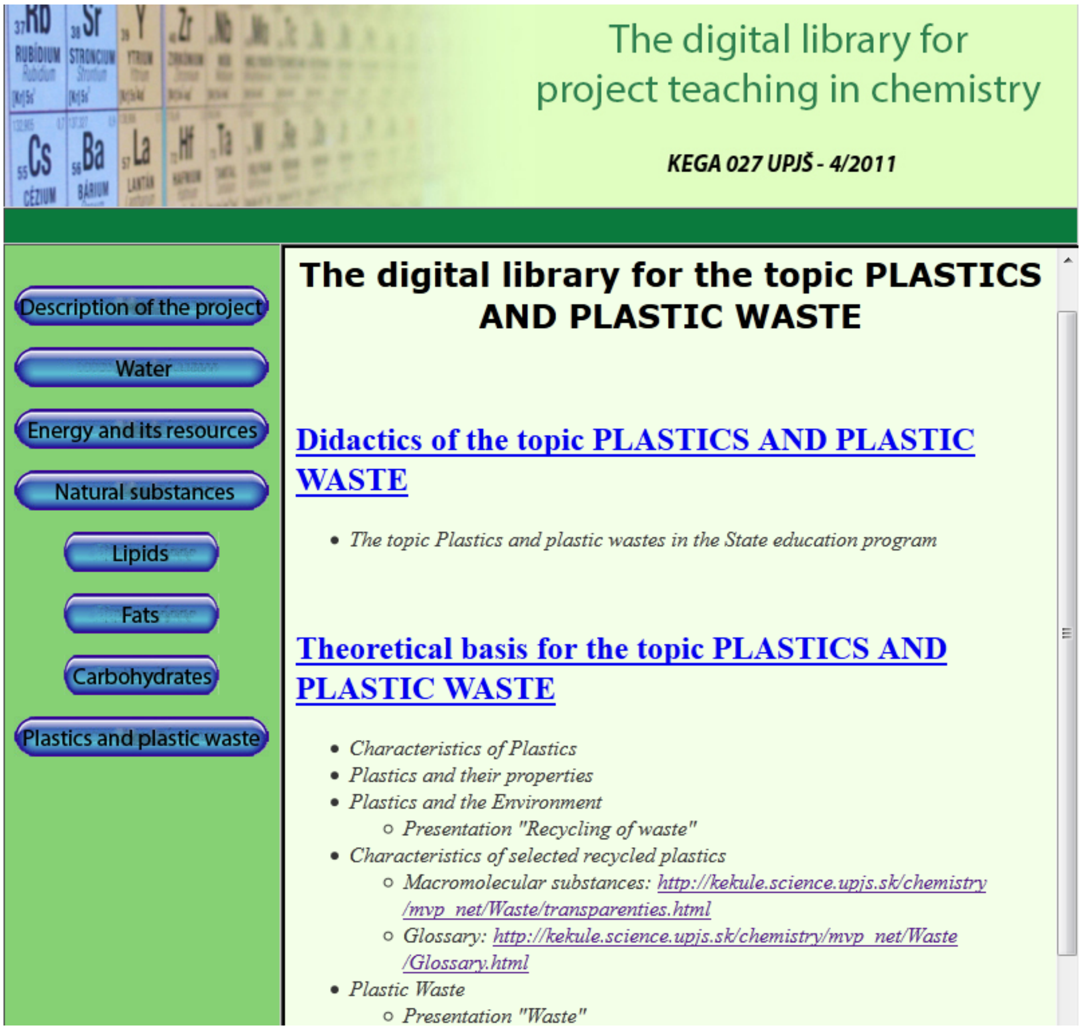

Figure 1: View of the digital library for the topics Plastic and Plastic Waste.

For each topic the library offers the following methodological means in a digital form: learning texts, presentations, experiments, model proposals of projects, inquiry-based activities for the above topics, school radio programmes and events proposals, etc.

In the following part the library available for the topics Plastic and Plastic Waste is depicted. The methodological means of the library for the topic Plastic have the following structure:

1. **Methodology of the topic Plastic and Plastic Waste** – presents the content and performance standards of the State Educational Programme in Slovakia for the 2nd grade of primary schools ISCED 2 and the State Educational Programme for grammar schools ISCED 3A for the topic Plastic and Plastic Waste.
2. **Studying material –** contains learning texts available for the topics: Characteristics of Plastic, Plastic Materials and Their Properties, Plastic and the Environment, Characteristics of Selected Recyclable Plastic Materials, Basic Terminology Dictionary, Plastic Waste. Presentations of teaching created by teachers in MS PowerPoint programme are also part of the library. The presentations contain selected theoretical knowledge.

3. **Experiments** – present chemical experiments such as Origin of Plastic, getting to know plastic, making glue from polystyrene waste, proof of polymers by means of a flame test.
4. **Implemented projects of pupils** – contain projects outputs, e.g. PowerPoint presentations of the topics “Is the Incineration Plant to Be Blamed?”, “To Recycle or to Throw away”.
5. **Inquiry-based activities** – contain activities focusing on determining properties of plastic materials, kinds of plastic materials and their labeling, recycling plastic, decomposition of plastic, etc. By means of these activities pupils study different plastic materials from their neighbourhood, get to know their physical and chemical properties, design experiments, formulate hypotheses and based on the acquired experience they try to guess the use of different plastic materials in practice and look for their existing and possible use. They get to know different kinds of plastic packaging materials, learn about possible separating of plastic in collecting bins and subsequent recycling of plastic.

TESTING THE DIGITAL LIBRARY ON TEACHERS AND PUPILS

Opinions of in-service chemistry teachers on using the digital library

The digital library for the topics Plastic and Plastic Waste containing inquiry-based activities was tested on 10 basic and grammar school teachers. The teachers said the digital library containing inquiry-based activities means a useful digital aid in implementing projects and at the same time it enables pupils to:

- do projects in an independent and active way, the library offers experience-based learning,
- develop key competences – pupils learn to listen to the opinions of their peers, think about a topic, reason and participate in a discussion,
- actively approach learning resulting in longer-lasting acquired knowledge and increased interest in chemistry

Opinions of pre-service chemistry teachers on using the digital library

Pre-service chemistry teachers studying at the Faculty of Sciences of the P.J. Šafárik University in Košice thought the library was particularly useful for beginner teachers who do not have experience in project-based teaching and that is why they found guidance and examples of projects very inspiring.

Opinions of pupils on using the digital library for self-learning

The library is an excellent self-learning aid for pupils’ project work. The pupils found the available learning texts very useful because of the correct, verified information they contain. The experiments were most liked by the pupils.

CONCLUSION

Inquiry-based activities as part of the digital library for pupils‘ project work offered pupils active as well as experience-based learning. They also created some space for self-learning and developing key competences. In implementing such projects as “Is the Incineration Plant to Be Blamed” and “To Recycle or to Throw away”, different forms of an inquiry-based method were used, such as experimental activity of pupils (determining properties of plastic), theoretical activity of pupils (kinds of plastic and their labeling, recycling plastic, decomposition of plastic, etc.). The findings of testing revealed that the activities were of a significantly motivating character, the interest in sciences increased in pupils and due to the topic their environmental awareness increased as well – they started to implement recycling of waste not only at school but also at home and in their neighbourhood. Advantages of implementing these methods were perceived by teachers as motivation, experience-based education, linking theory with practice, developing more advanced brain operations along with experimental skills. The disadvantage is mainly time-consuming preparation of education unit.

ACKNOWLEDGEMENT

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INQUIRY-BASED ACTIVITIES FOR THE TOPIC PLASTIC AND PLASTIC WASTE

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In the paper we focused on presenting created inquiry-based activities for the topic Plastic and Plastic waste within the Unit Polymers prepared in co-operation with The Faculty of Science of Charles's University in Prague. Subunit 1 consists of the following activities: Kinds of packaging plastic materials and their labelling and Properties of plastic material. Subunit 2 consists of activity Resolubility of waste in the environment, Separation of waste, Influence of acid rains on plastic products and Recycling plastics – using project-based method. In activity Plastic Properties, for example, pupils should determine combustibility of plastic, its thermal and electrical conductivity, reaction with acids, alkalis or with solutions of salts. Pupils write the results into tables by which way they improve the following skills necessary for research – data collecting and recording, data processing, carrying out experiments, stating hypotheses. In groups, pupils discuss conditions for conductivity of plastic, compare the conditions with conductivity of other substances. The activities were tested on the sample of 100 pupils of grammar schools and 50 pupils of primary schools. Verification revealed that the activities were very interesting for the pupils and at the same time they developed pupils' environmental awareness. That is why the activities can also be used within implementing the complex topic of Environmental education in the subject of chemistry. The pupils stated the following activities the most interesting: Properties of plastic material and Kinds of packaging plastic materials and their labelling.

INTRODUCTION

Plastic has a wide range of use in all spheres of human activities. In competition with classical materials, mainly metals, polymers have succeeded mostly because of their easy processing, low density and a convenient ratio of utility qualities and price.

The paper focuses on presenting created inquiry-based activities for the topic Plastic and Plastic waste within the Unit Polymers. The unit was prepared in co-operation with Charles's University in Prague. The whole unit Polymers consists of 3 subunits the first two of which will be presented to you as they have been both prepared and verified in Slovak schools.

The first subunit deals with getting to know plastic, its marking, separation, recycling and properties. Pupils acquire knowledge of plastic from everyday life and they will deepen it in this subunit. They will learn to identify symbols used to mark plastic and those on plastic packing and they will verify different properties of plastic by experiment.

Using plastic is closely connected with the issue of plastic waste disposal. Plastic does not decompose itself, therefore it accumulates in the environment.

Subunit 2 deals with plastic waste. Within different activities pupils have to think about the issue of waste disposal, discuss it with classmates and propose possible solutions.

Pupils should work out that recycling is an effective solution to the problem of plastic waste disposal. They should understand why it is necessary to recycle and realize that every individual can contribute to the improvement of the environment by correct and regular separation.

The lesson develops pupils' ability to look up information on the Internet, identify problems, create mind models, discuss, communicate with peers, propose hypotheses, distinguish alternatives.

By carrying out activities and work with worksheets pupils understand the substance of scientific research. The activities are designed in such a way that pupils work in groups, discuss, reason and propose solutions to the problems. Problems are stated either by a teacher or by pupils themselves. Thus mainly managed and restricted research is used in the activities.

INCORPORATING INQUIRY-BASED ACTIVITIES INTO THE STATE EDUCATIONAL PROGRAMME IN SLOVAKIA

These activities can be incorporated into chemistry of 9th class of primary school (14-year-old pupils) (the topic Plastic is incorporated into the State educational programme for the second grade of primary school in the Slovak Republic ISCED 2 – lower secondary education). At grammar school only PVC and its use is incorporated into the compulsory chemistry education for the topic Plastic. Other activities can be part of optional chemistry education (chemistry clubs) or that of seminars.

The topic Plastic is also a part of the cross section topic Environmental education.

The proposed inquiry-based activities can be also used in teaching other subjects focusing on environmental point of view of the topic, *e.g.* in biology pupils are supposed to give reasons for accumulating of waste and decide the significance of recycling waste (performance standard for 9th class).

CHARACTERISTICS AND DESCRIPTION OF SUBUNITS

Subunit 1: Plastic contains the following activities:

- Kinds of packaging plastic materials and their labelling
- Properties of plastic materials

Subunit 2: Plastic waste contains the following activities:

- Resolubility of waste in the environment
- Separation of waste
- Influence of acid rains on plastic products
- Recycling plastics – using project-based methods

The subunit *Plastic* focuses on getting to know plastic materials, their labeling, properties, separating, and recycling.

By doing the activity "Kinds of packaging plastic materials and their labeling" pupils learn about labeling plastic products and learn to identify different symbols on plastic packages. A teacher brings different kinds of plastic waste to the class and pupils examine it and notice symbols on it. They match the symbols to the names and gradually learn to use them. When examining the plastic waste they think about what further happens to it.

In activity 2 – *Properties of Plastic Materials*– a teacher states problems. The experiment that will enable to solve the problem is further proposed either by the teacher or pupils. Pupils are supposed to find out about combustibility of plastic materials, their thermal and electric conductivity, reactions with acids, alkalis and solutions of salts. The findings are recorded in tables whereby pupils improve the following skills necessary for research: collecting and recording data, data processing, carrying out experiments, formulating hypotheses. Pupils discuss in groups *e.g.* supposed conductivity of plastic materials and compare it with that of other substances. Finally, pupils prove their ability to apply the acquired knowledge in practice (*e.g.* the electric nonconductivity of plastic materials makes them believe that plastic materials can be used as insulators). A teacher asks questions enhancing creative thinking in pupils: *How can this property be used in practice? Where is this plastic material used? Have you come across this phenomenon in everyday life?*

An extract from a pupil's worksheet for the activity *Properties of Plastic Materials*:

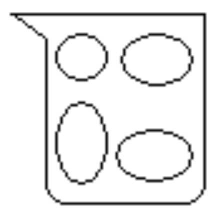
Determining density of plastic materials (PE, PP, PS, PVC) by comparing with water density.

Propose a procedure by which you can verify and compare the density of the above plastic materials with that of water. You can look up water density in the chemical tables.

<u>Findings:</u>

1. In the picture, there is the result of the experiment to determine density of different plastic materials of PE, PP, PVC, PS. Write the names of the materials into the bubbles in such a way that it complies with the findings of the experiment.

Picture:



2. Complete the text with the following expressions:

„floats on water"; „falls to the bottom of the beaker" „bigger, smaller"

The density of water is ________ g/cm3.

Polyethylene ____________, therefore its density is _________________ than that of water. Polystyrene ______________, therefore its density is ________________ than that of water. Polyvinyl chloride ____________________, therefore its density is _____________ than that of water. Polypropylene _____________________, therefore its density is ___________ than that of water.

Subunit 2 deals with plastic waste. While working on the activity Decomposing of plastic and different materials in soil, pupils acquire the basis of scientific research by reading books and information sources on the time of decomposition of organic substances, metals and plastic in soil, they explain prognoses, compare results, etc.

An extract from a pupils' worksheet for the activity *Tracing Waste*:

Tracing waste

In the following tasks try to find out what happens to different kinds of waste in the environment and how long they decompose. There is a wood in your neighbourhood where you like walking in, cycling, you go to pick mushrooms or rest in some other ways. You discover on one of your walks someone has started an illegal dump:

When investigating the rubbish more closely, you found: **juice box, cigarette end, used tissue, invalid credit card, used chewing gum, banana skin, flat mobile phone battery, marmalade jar made of glass, perforated bicycle tyre, plastic mineral water bottle, apple core, old magazine, aluminium tin**

You decide to watch how nature will cope with them itself. Here begins your investigation.

Task 1

You will come back to the dump in the following time intervals. Next to each of them write which of the things should have decomposed.

- One month later: ……………………………………………………………..
- Three months later: ……………………………………………………………..
- Two years later: ……………………………………………………………….
- Five years later: ……………………………………………………………….
- Ten years later: ……………………………………………………………….

Task 2

You are 100 years old and in perfect health. Which objects will still be at the dump? Next to each object write its time of decomposition.

- .... ……… years
- .... ……… years
- .... ……… years
- .... ……… years
- .... ……… years

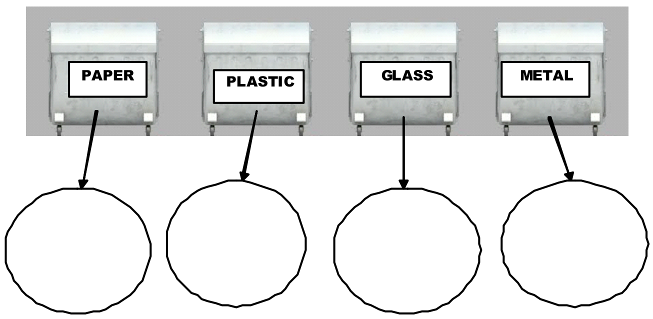
The activity *Separating Waste* begins with an introductory discussion in which a teacher finds out pupils' experiences of separating waste. Proposed questions for discussion: *Why do people produce such a big amount of waste? What are the reasons for separating it? Can you separate waste correctly? Why don't some people separate waste?*

An extract from a pupil's worksheet for the activity *Separating Waste*:

Waste Separation

The below-mentioned dustbins are outside your home. Decide which of the following things can be separated and which can't. Into the labels below the dustbins write the name of the thing you would throw into each.

A glass, milk cardboard box (tetrapack), electric bulb, cardboard, tin, plastic bag, porcelain vase, accumulator, mirror, shampoo bottle (clean), PET bottle, used batteries, magazine, yoghurt jar lid, toothpaste tube.



By means of the tasks pupils are supposed to understand that separating waste has its rules that must be kept. They are also supposed to understand why it is necessary to recycle waste and at the same time they have to become aware of the fact that every individual by means of correct and regular separating can contribute to improving the state of the environment. The output of the activity is the task in which pupils have to write as many reasons for separating waste as they can think of. The reasons are read at the end of the lesson and pupils together with the teacher draw conclusions.

The activity *Recycling plastics* gives space to communication, reasoning and stating explanations. Pupils tackle tasks focused on properties of plastic, its recycling, processing, separation of waste. A project-based method is used in this activity.

The different tasks are stated in such a way that their solutions could be outputs, eg. *How much waste do you produce per week? Collect all the waste all the day (eg. at the weekend), weigh it in the evening and multiply the weight by seven. What percentage of the waste did plastic represent?*

Or *e.g. In your neighbourhood find a plant in which plastic is recycled and find out what products are produced there and how. Focus on separated waste and try to answer the following question:"What happens to a PET bottle that you throw into a bin for separated waste?"*

Pupils turn the acquired knowledge and results into a poster or a PowerPoint presentation and present them to their peers.

VERIFYING PROPOSED ACTIVITIES IN TEACHING

The pilot verifying the activities for the topic *Plastic and Plastic Waste* was carried out with a sample of 100 and 50 pupils at primary and grammar schools, respectively. Verification revealed that pupils found the activities interesting – most interesting were the ones in which they examined different kinds of plastic materials and their labelling as well as the experimental activities in which they studied properties of plastic materials.

Teachers involved in verifying appreciated the inquiry-based activities for approaching the topic. They appreciated the activities more than the traditional teaching – approaching the subject matter mainly by means of theoretical knowledge. Most teachers agreed that after teaching the subunits a lot of pupils became interested in separating waste. They started separating waste at home and at school. Pupils realised that plastic accounts for a big amount of produced waste which, if not separated, will end up in incineration plants or landfill sites.

Further results of verification by means of Establish project verification tools are being evaluated.

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