AN INTEGRATED APPROACH TO THE TEACHING AND LEARNING OF SCIENCE AND MATHEMATICS UTILISING TECHNOLOGY – THE TEACHERS' PERSPECTIVE

By

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ABSTRACT

The concept and importance of curriculum integration in Science and Mathematics has come to the fore in the recent years (Czerniak, 2007). Ireland's Science and Mathematics performance is well documented and extensively reported in the media and elsewhere (e.g. Expert Group on Future Skills Needs, 2008; Task Force on the Physical Sciences, 2002). Concern primarily lies with the post-primary students' underperformance in science and mathematics, coupled with a failure to make a successful transition to third level scientifically and mathematically orientated undergraduate courses. The aim of this study was to design, develop, implement and evaluate an integrated approach to the teaching and learning of Science and Mathematics in second level schools in Ireland. This was undertaken through the integration of a handheld graphic calculator known as 'TI-NspireTM' into first year classes (age 12 -13 year olds) of science and mathematics. This integration was assisted by the development and implementation of a unit of learning on distance, speed and time, with specific lesson plans which integrated the teaching and learning of both subjects by utilising the TI-NspireTM. The methodology of this research project was an exploratory year-long case study of three second level schools in Ireland and their implementation of the unit of learning in their respective schools. This paper focuses on the teachers' perspective of the integration of mathematics and science teaching and learning utilising technology. The study was qualitative in nature and was evaluated through a teacher's perspective where a teacher focuses on group interviews and independent lesson observations. The key finding emerging from the data is that the integration of mathematics and science was lost in coping with the technology demands required in implementing the unit of learning.

Keywords: Technology, Integration, Science, Mathematics, Second Level Education

INTRODUCTION

The concept and importance of curriculum integration in science and mathematics has come to the fore in the recent years (Czerniak, 2007). In nature and the real world, mathematics and science integrate on a daily basis. Therefore, it is reasonable to promote the concept of integration in the teaching and learning of these subjects. However, in the Irish context both subjects are treated in isolation from one another in the National second level curriculum (approximate age is 12-18 years). Increasing the uptake and the performance of second level students in mathematics and science, especially higher level mathematics and physical sciences, has been identified as a national priority in Ireland (NCCA, 2008; Expert Group on Future Skills Needs (EGFSN), 2008). In the OECD (Organization for Economic Co-operational and Development) PISA (Program for International Student Assessment), (2006), Ireland ranks 14th and 16th respectively out of 30 OECD countries in terms of scientific and mathematical literacy (Educational Research Centre, 2007). 'Modest levels of attainment in mathematics at junior second level are feeding into poor performance and low levels of interest in higher level mathematics' (NCCA, 2008, p.17). Concern primarily lies with secondary students' underperformance in mathematics and science subjects, coupled with a failure to make a successful transition to third level through scientifically and mathematically orientated undergraduate courses. The Task Force on Physical Sciences (2002) highlighted the serious concerns about mathematics and science uptake and the low intake into the Science, Engineering and Technology courses at third level education. Also of note is the major curricular reform taking place in the Mathematics syllabus at second level education. 'Project Maths' is a mathematics syllabus introduced into both the Junior and Senior Cycles of second level education since September 2010. A much greater emphasis is now being placed on the students understanding of mathematical concepts and an increased use of contexts and applications that enable students to relate mathematics to everyday experience. Therefore, given the focus within the new mathematics syllabus on increased understanding of concepts and use of real life applications this research project on the integration of science and mathematics is timely and relevant in the Irish context. Moreover, data on trends in technical, scientific and business occupations support an impression of a population ill-prepared to meet the needs of a growing knowledge economy requiring graduates with mathematical, scientific and technology skills (EGFSN, 2008). Clearly, there is a need to address the teaching and learning of both subjects at second level education in Ireland.

The authors propose that one of the causes of underperformance and low uptake in science and mathematics may be attributed to students' perceptions of the lack of relevance of mathematics and poor mathematical skills to support scientific learning. In particular, the authors of this study strongly feel that integrating the teaching, learning and assessment of science and mathematics at post-primary education can contribute to an enhanced learning experience for students and contribute to the development of conceptual understanding and accordingly improve engagement with the subjects in the long-term (Furner and Kumar, 2007; McBride and Silverman, 1991). Therefore, the aim of the research project was to investigate the potential of the integration on science and mathematics utilising technology at post-primary education in the Irish context. The primary rationale for this approach is to demonstrate the mutual relevance of subject areas, to develop connections and understanding, to aid the development of student criticality, and to engage teachers and students in both subject areas (Czerniak, 2007; Pang and Good, 2000). Technology was chosen as the vehicle to facilitate the integration between both subjects as it allows for the transfer of learning between both science and mathematics classes, it can assist changes in pedagogies in the classroom to a more student-centred approach and support the development of understanding (Niess, 2005; BECTA, 2003).

For the purpose of this research, the project involved a case study of three schools with science and mathematics teachers working in collaboration to implement a unit of learning on distance, speed and time, with a focus on technology to support integration of the subject areas. The National Centre for Excellence in Mathematics and Science Teaching and Learning (NCE-MSTL) led the research project and was central in designing the integrated unit of learning, providing the training in the use of the technology for the teachers participating in the study and coordinating the implementation of the project in schools. It was a topic-driven, evidence-based research. The research question for this project was 'What are teachers' perspectives of the integration of mathematics and science teaching and learning utilising technology at post-primary education?' This paper reports on some key literature in the area of mathematics/science integration and technology, the research study itself, and key findings and insights emerging from the data collected.

Key Literature

Mathematics and science have long been seen to be inextricably linked disciplines (Orton and Roper, 2000). Science can provide students with concrete examples of abstract mathematical ideas, while mathematics can enable students to achieve deeper understanding of science concepts by providing ways to quantify and explain science relationships (McBride and Silverman, 1991). Mathematics and science integration is therefore critical to motivate and engage students in meaningful learning (Furner and Kumar, 2007). While science and mathematics may be integrated in nature, as school subjects they can be very separate (Orton and Roper, 2000). Integration of science and mathematics deals with bridging the gap between the subjects in a variety of ways such that the natural links are obvious, relevant and meaningful for teachers and also for students.

Integration of science and mathematics is said to have a number of benefits for students. It can help students to think critically, which can make the curriculum relevant to them, and can help them make connections between important concepts (Czerniak, 2007). Rationales for integration have included that mathematics and science are similar attempts to discover patterns and relationships, that they are based on interdependent ways of knowing and that they share similar instructional processes such as inquiry and problem solving. When they are connected to real-life situations, students learn and appreciate how different subjects together can solve an authentic problem (Pang and Good, 2000). Czerniak (2007) noted that a number of studies indicate that the integration supports student learning, understanding and motivation as well as helping to build their problem-solving skills. Venville et al. (2004) here reported that teachers observed several benefits of integration for their students, including increased motivation, engagement and application of mathematics and science concepts.

Given the move towards the increased use of online and information technologies in all aspects of life in the 21st Century, education must also incorporate an increased use of technology within different subject areas. This is not just teaching about technology, but also with technology (Niess, 2005). Technology can give teachers the tools that permit their students to perform complex tasks that are similar to those in the real world. For example, when they use technology to integrate data from science experiments and fieldwork into their mathematics class. Additionally, the use of technology can cause change in teacher pedagogies, including the usage of a more student-centred approach, showing a greater willingness to experiment and raising the expectations of students (BECTA, 2003). The use of technology can enhance the integration of science and mathematics for teachers and for students. In a case study where science and mathematics teachers worked collaboratively to use hand-held technology, there were a number of positive outcomes. Mathematics teachers found that using data from science and other subjects helped them to enrich the mathematics curriculum. Both science and mathematics teachers found that, working collaboratively helped them to expand their knowledge of both their own and the other subjects. The cross-curricular nature of the collaboration helped to increase the discussions between departments, and helped to support teachers in their confidence in using technology in the classroom (Ransom, 2000).

However, the research does not indicate that technology has radically changed teaching and learning, possibly because historically, teachers have had little experience of using technology as learners themselves, and because they had little hope in designing and developing technology implementation plans (Niess, 2005; Hennessy et al., 2005). In a review of the literature, Bingimilas (2009) found that barriers to the integration of technology in education are many, and can be classified as teacher-level barriers and school-level barriers. Teacher- level barriers related to the individual include lack of confidence, lack of competence and resistance to change in integrating technology. School-level barriers include lack of effective training in solving technical problems, lack of technical support, lack of access to resources and lack of time. These barriers are interrelated. So, for example, in case of a teacher lacking in competence in technology, it is probably because they have never received training, and therefore lack confidence to integrate it into their teaching. Resistance to change usually indicates that something else is amiss, for lack of technical support or time for planning lessons or incorporating the technology. An important issue in relation to training is that teachers are provided with pedagogical training to use technology, rather than simply being trained in the use of the technology tools. Technical problems are a major barrier for teachers, for example, waiting for websites to open, failed connections, malfunctioning equipment, etc. These impede the flow of the classroom activity, preventing teachers from using technology (Bingimlas 2009). In addition to those factors, Bingimilas (2009) acknowledges that adaptation and innovation are costly in terms of the time needed to develop new practices, and the working context in which teachers find themselves that they assist or impede their efforts in integrated technology. The wider community in which teachers operate, including the organizational culture, the attitude of school management, pressure to deliver a content laden curriculum, etc., will have an effect (Hennessy et al., 2005).

Teaching and Learning Approach to Facilitate Integration

This section discusses some of the key concepts underpinning the design and implementation of the integrated unit of learning. Research has highlighted the importance of building the development of scientific concepts and skills on concrete experience (Rosenquist and McDermott, 1987). The lessons were designed to engage the students in the active use of concepts in concrete situations. Everyday objects and experiences from their everyday lives were used in these lessons. The teaching and learning approach was designed to help the students and close the gaps in their knowledge through repeated exercises that were spread out over time and were integrated with the subject matter of both the science and mathematics syllabus. Arons (1990) states that for a learner to assimilate abstract concepts, they need to engage in the active use of the concepts in concrete situations and the concepts must be explicitly connected with immediate, visible, or kinaesthetic experience (Arons 1990). Arons (1990) also state that, the learner should be led to confront and resolve the contradictions that result from their alternative ideas or misunderstandings. There are several learning difficulties that are involved in the development of the concepts of distance, speed and time.

The mathematics lessons were designed to promote a teaching for understanding approach through the use of rich mathematical tasks which provide students with the opportunity of specializing and generalizing in the mathematics class (Mason, 1999). Mathematical tasks that are referred to as 'rich' are those that are most likely to engage students positively and effectively with their mathematical learning. By employing rich mathematical tasks, it allows students to find something challenging and at an appropriate level to work on (Swan, 2005). Within the mathematical element of this project, authors are also concerned with how students approach problem-solving. Mason (1999) emphasises the central core of mathematics as Specializing (constructing particular examples to see what happens), and Generalizing (detect a form; express it as a conjecture; then justify it through reasoned argument). Specializing involves trying specific examples in order to develop an understanding in relation to what a mathematical concept is proposing. Therefore, the purpose of specializing is to gain clarity as to the meaning of a question or statement, and then to provide examples of which have some general properties in common which is known as the process of generalizing (Mason, 1999). Generalizing has to do with noticing and describing properties common to several mathematicals questions/problems. The mathematics teacher should employ questions which encourage students to think deeply about the problem/examples presented. By looking at the examples, the students have to complete, and they should try to see what is common among them, guided by what the problem or text asks for or states. Generalizing is more difficult, because it involves noticing or stressing things that are common to numerous examples, and ignoring features which seem to be special to only some of them (Mason, 1999).

The Integrated Unit of Distance, Speed and Time

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

Science Lesson 1

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

- Identified the quantities needed to measure speed (distance/time).
- Described how to measure speed.
- Built and tested balloon rocket cars
- Demonstrated the ability to measure the speed of the balloon rocket car.

Mathematics Lesson Plan 1

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

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

Science Lesson 2

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

Mathematics Lesson Plan 2

The purpose of the second mathematics lesson plan was to develop further students' understanding of graphical concepts in relation to the travel graphs. Key student learning outcomes from the lesson included the following,

- Stating the scale/units being used.
- Developing an understanding of speed - straight lines correspond to motion with a constant speed; the slope of the line indicates the value of the speed.
- The steeper the slope, the faster the speed; a horizontal line shows the object at rest – indicates no movement at all (slope = 0 = speed).
- Lines with a positive slope indicate movement away from the starting point.
- Lines with a negative slope indicate movement back towards the starting point.

Mathematics Lesson Plan 2 also incorporated the use of data generated from the previous science lesson to draw distance-time graphs, while also encouraging discussion and explanation of variations in their findings in relation to the key concepts developed.

Science Lesson 3

The final double science lesson involved the students to actively act out their motion using the TI-NspireTM and the motion probe. In the previous mathematics lesson, students examined questions in relation to the direction of the motion and the slope. The active experience of acting out this motion helped the students to connect the graph on paper to actual motion. For example, being able to distinguish between positive slopes, negative slopes, no motion etc., was possible through all concrete experiences. Thus, they developed further the relationship between distance, speed and time by predicting and acting out the motion of the graphs.

Mathematics Lesson Plan 3

The overall aim of the lesson was that students themselves would generate the average speed formula through the completion of mathematical rich tasks concerned with speed, distance and time. These tasks incorporated real-life applications, which make the material relevant for student learning.

Mathematics Lesson Plan 4

The last mathematics lesson plan was concerned with students' further understanding of the concept of average speed through engagement in the different sets of distance, time and data they had collected in the science lesson. Students were required to demonstrate key learning outcomes acquired from the previous science and mathematics lessons, while appreciating the application of mathematics in science and real life applications.

Methodology

This section presents the selection of methodologies and methods used in this study including the context of the study, the design of the project and the data collection and analysis. A case study was the research strategy and the methodological approach taken in this study was qualitative methods. According to Cohen et al. (2000), a case study is a unique example of real people in real situations, enabling readers to understand ideas more clearly.

Context

This innovative project was implemented in three second level schools in the Southwest of Ireland. These schools were purposely selected for this project on the basis of location and willingness to get involved in the project. The number was limited to three schools due to the quantity of technology made available and feasibility due to the resources available. One mathematics teacher and one science teacher worked in collaboration with each other and with the NCE-MSTL team, in each of the participating schools. In two of the schools, both a science and mathematics teacher worked collaboratively on the project, and in the remaining school, one teacher (who taught both science and mathematics) implemented the project. The following is a description of the 3 schools. Pseudo names are used to protect the schools identity. The study focused on 1st year students at second level education (approx. aged 12-13 years old) and this influenced the selection of teachers participating in this research project. Post-primary schools in Ireland are also known as second level schools. There are three types of school in Ireland: which are Secondary Schools, Community and Comprehensive Schools, and Vocational Schools. The differences are mainly due to the management structure and ethos of the schools. All schools follow a National curriculum in all subjects.

School 1: St. John's Secondary School

The rural coeducational vocational post-primary school offers full-time education from first year to Leaving Certificate level (final state examination at second level), ranging in age from twelve to eighteen years. Currently, it is one of the fastest growing post-primary schools in Ireland, the school has built up a national reputation in the delivery of a high quality and progressive educational programme, particularly with its emphasis on the sciences, languages, information and communication technology and overall commitment to innovation. Technology plays a major role in this school with every student owning a laptop and the availability of wifi and data projectors in every classroom. There were 824 students enrolled in the school (413 boys; 411 girls). The participating first year mathematics and science class had 27 students. One male teacher took part in the study from this school.

School 2: St. Ann's College

This school is a secondary post-primary school which offers full-time education to girls from first year to Leaving Certificate level, ranging in age from twelve to eighteen years. The school has developed a reputation of providing education for girls from a variety of social class backgrounds in the city. The school is committed to deliver a high quality teaching and a holistic learning experience. There were 252 girls enrolled in the school. The participating first year mathematics and science class had 24 students. This school lacked basic technology and there were two to three laptops available for the teachers to share amongst approximately 20 teachers. The science laboratory contained a data projector. Two female teachers took part in the study from this school.

School 3: St. Patrick's Secondary School

St. Patrick's is a co-educational vocational post-primary school situated in a large town 25 minutes drive from city 'A'. It offers full-time education for first year to Leaving Certificate level. There were approximately 450 students enrolled in the school. The participating first year mathematics and science class currently had 24 students. This school had basic technology, the science laboratory contained a data projector and both mathematics and science teachers involved in this study owned their own laptop. One male and one female teacher took part in the study from this school.

The Design of the Project

This research project was one school year in duration. The NCE-MSTL was central in leading, designing, implementing and evaluating the project. The NCE-MSTL facilitated professional development in the use of technology (TI-NspireTM handheld graphic calculator and data logging equipment) and in supporting integration in the implementation of the unit of learning. The teachers participated in in-house professional development (2 days), followed by in-school support by the authors in the individual schools as required. The following considerations are applied as given by,

- Every student in the classes of the three selected schools along with the teachers were provided with a TI-NspireTM handheld graphic calculator and data logging equipment.
- The integrated unit of learning on distance, speed and time was developed by the authors, with the support and feedback of the participating teachers.
- Continuous support was provided for all teachers involved in the research project.

Data Collection and Analysis

This study is qualitative in nature and centred on eliciting the teachers' experiences of participating as active researchers in the classroom. The following is the list and description of key data collection tools employed in this research project:

Teacher's Reflective Journal

This required teachers to respond to specific questions on the lesson plans, organisational aspects, student learning and development, the use and integration of technology, and an overall reflection on the lesson as a whole. Teachers were required to reflect on each relevant lesson during the period of implementation of the integrated unit of learning (approximately three weeks).

Observation of Lessons

All lessons, in each of the three schools, were observed by an independent NCE-MSTL staff member. All observers were provided with specific templates for evaluating each of the lessons which included key questions in relation to learning outcomes, implementation of the lesson, technology, integration of subjects, the teacher's role, and students' concept skills development.

Focus Group Interview

All teachers participated in a semi-structured focus group interview on completion of the project. The purpose of the focus group interview was to elicit teachers' perspectives on the integration of science and mathematics as a unit of learning, the use of technology and their participation in such an initiative.

There are four reflections from each of the teachers who taught the mathematics component and three reflections from each of the teachers who taught the science component of the integrated unit of the learning, giving twenty-one teacher reflections in total. There are twenty-one independent lesson observations (twelve mathematics observations, nine science observations). The focus group interview was approximately one hour in duration. This interview was recorded and transcribed. The interview transcription, the teachers' reflective journals and lesson observations were then coded into nodes, followed by recoding again so as to gain further insights and to facilitate the interpretation of the data gathered. Final nodes included technology challenges, ownership and design of the unit of learning, time, integration of mathematics and science, value of learning, teaching approach, and implementation. It is important to note that the selection of nodes when coding the data rests solely with the authors, as the extent of the searches made, relationships established and the interpretation of the data. Therefore, for the purpose of this paper, the primary focus of analysis was on teachers' perceptions in the integration of science and mathematics utilising technology.

Findings

As opportunities to engage in research projects are limited in second level education in Ireland, this was the first time for all participating teachers to engage in such an initiative. The teachers embraced the project with commitment and a willingness to learn. The teachers enjoyed the challenge of such a project and acknowledged their students' enjoyment and engagement throughout the process. Overall, the teachers were very accommodating and open in their approach and involved in this research project throughout the entire school year.

A number of key insights emerged from the data gathered in this research project. The key finding emerging from the data is that the integration of mathematics and science was lost in coping with the technology demands required in implementing the unit of learning of distance, speed and time. Table 1 summarises the key findings presented in this section, which are centred on teacher perspectives in relation to technology challenges, integration challenges and student learning.

A number of technology challenges emerged from the study and accordingly impacted on the teachers' ability to implement the integrated unit of learning. Primarily the teachers' own confidence and competence in the use of the TI-NspireTM handheld graphic calculator and data logging equipment impacted significantly on the implementation of the lessons. In particular, the teachers felt that they needed 'more hands on experience to be completely confident' in integrating technology into their science/mathematics and would first do some of the tasks by hand on the whiteboard, copybook, etc. and then repeat the same activity using the TI-NspireTM (John, Reflective Journal/Lesson Observation, Science Lesson 2). This was the teachers' first time using such a technological equipment in their classrooms and the authors acknowledge that they had underestimated the teachers' competence in implementing the technological requirements of integrated science and mathematics lessons. Therefore, it was not surprising that teacher reflections were primarily concerned with their own use of the technology and dealing with issues, 'often with difficulty' (Rachel, Reflective Journal, Science Lesson 2). All expressed an interest in further training to become more competent in the use of the technology in the classroom.

Technology Challenges	Integration Challenges	Student Learning
Teachers' confidence and competence	Time and timing pressures of sequence of lessons	Didactical style of teaching evident in some lessons
Lack of experience	Impact of technology and lack of teacher capability	Implementation of a teaching for understanding approach/individual tasks done well in some lessons
Physical and time consuming aspect of using technology in the classroom	Significant technological requirements in order to facilitate integration	Some key concepts not developed in the lessons
Need for further teacher training	Lack of ownership of the unit of learning by the teachers	Lack of use of mathematical and scientific language
Willingness and commitment demonstrated by the teachers	Lack of awareness by the teachers of the value of technology to facilitate learning	Students competent and confident in the use of technology
		Students engaged and enjoyed the unit of learning

Table 1. Summary of Key Findings

All teachers felt the pressure of getting material completed in their particular lesson so as not to impact on the next lesson. Therefore, time and timing was a significant factor given the challenges they encountered with utilising the technology. For example, in Mathematics Lesson 2, Anna had to get her students 'to enter data manually which took time as the data had not been collected correctly in the previous science lesson (Reflective Journal, Mathematics Lesson 2). The integrated element of the unit of learning was designed to be facilitated by the technology. Therefore, the teachers' inability to cope with the technological demands of the individual lessons impacted on facilitating the integration element of the lessons. Similarly, the practicality aspect of utilising technology in the classroom was also a significant factor in the (un)successful integration of science and mathematics. The teachers were very vocal about the technology being 'time consuming' and the need for 'extra hands' in the classroom to manage distribution of technology, setting up the technology (e.g. motion probes), replacing equipment parts (e.g. flat batteries) and dealing with student queries (Focus Group Interview). In general, the teachers felt that the time factor required in implementing such lessons developed in the unit of learning require more time than 'one would have in "the real world of teaching"!' (Norma, Reflective Journal, Mathematics Lesson 2). Technology challenges were also dominant in the observers' logs, in earlier lessons in particular, 'the teacher had his hands full helping and guiding the testing' (St. John's, Observers Log, Science Lesson 2).

Output of some minor input into the unit of learning from the participating teachers, the ideas of thought processes behind the integration was done by the authors. Thus, this led to the teachers to implement the unit of learning as distinct separate lessons and not looking at it as a whole. It became obvious that the teachers' lacked confidence in their ability to adapt and utilise the technology and lessons in the appropriate manner for their classroom context and felt compelled to implement it as it was presented on paper. Accordingly, the lack of adapting the lessons to suit the individual contexts was an issue and hindered integration and added to the complexity of utilising the technology. Similarly, the teachers felt that there was too much time between the specific lesson plans (a week on average) and they felt that it would be better if they were closer so as to facilitate reinforcement of previous learning.

From the mathematics and science teachers' reflective teaching, it is evident that the teachers thought the tasks incorporated into the lesson plans were appropriate and consistent with the learning outcomes stated and consistent with syllabi requirements. However, they strongly felt that there were too many tasks per lesson requiring the use of technology which had repercussions for time management and facilitating the integrated teaching approach. Teachers regularly expressed a desire in their reflections to remove some of the technological requirement in the lessons. The authors strongly feel that there was a lack of an awareness or an understanding by the teachers of the value to learning or the potential that this form of technology could have added to their mathematics and science lessons if incorporated in an appropriate manner. Equally, the authors acknowledge that by not being part of the design and the development of the unit of learning, key learning opportunities were missed by the teachers. The observers' reflections on the mathematics/science lessons undertaken by the teachers reinforce the impression of didactical style of teaching taking place in some of the classrooms. Some lessons were dominated by teacher talk as opposed to the student-centred approach promoted by the lesson plans. There was limited time or no time at all given to discussion in the observed lessons. For example, as noted in one of the science observations, 'No time spent on the development of the lesson – how to measure speed' (St. Patrick's, Observers Log, Science Lesson 1). This is a core concept that needed to be developed through discussion and exploration with the students. It was evident that the teachers were caught up in the 'doing' of the lesson as opposed to the thinking behind the lesson. 'Students were not given time to attempt the problem themselves or in groups, all teacher-led with questions, probably due to time constraints' (St. Ann's College, Observer Log, Mathematics Lesson 2). Other observers commented on the teachers' student-centred approach as 'The teacher ensured 'teacher talk' was at a minimum, while ensuring the students were kept busy with as much activity as possible'.

The observations also expose that the mathematics and science teachers missed out on some key concepts within the lessons. Similarly, there was poor use of 'mathematics language' at times by the teachers and there appears to be a lack of confidence in their students' ability to cope with mathematical terminology and concepts. For example, 'slope was referred to as 'going to' when positive and 'coming' when negative. No relationship between these terms and positive and negative was made' (St. Ann's College, Observer Log, Mathematics Lesson 2). Observers also commented on the type of language used by teachers, at times, in the lessons 'Scientific terms and ways of explaining was quite colloquial' (St. John's, Observers Log, Science Lesson 3). However, there were some positives identified by the observers, in the final science lesson in particular, 'through the calculator/graphs, students could see that the distance/speed/time were related and the shape of the graph varied when the distance/speed/time varied' (St. Ann's Observers Log, Science Lesson 3).Naturally, this has been the repercussion for students' learning and understanding for both mathematics and science. On an encouraging note, some tasks within the lesson plans were done very well by individual teachers and this is a positive aspect to take forward. The observations also noted that the students responded positively to those tasks when done well. 'One of the students, on leaving the classroom stated that it was 'the best lesson ever sir' (St. John's, Observers Log Science Lesson 3).

Conclusions emerging from the observations portray a lack of awareness/understanding by the teachers in adopting the teaching for understanding approach proposed in the unit of learning but when done well, student learning and understanding was enhanced. Moreover, some of the teachers did struggle with the technology aspects of the lessons, but the students were competent and confident in utilising the technology, while engaging them in learning and applying knowledge. In general, the teaching for understanding approach to facilitate the integration of the science and mathematics lessons was not adopted as expected by the authors. Teachers found it difficult to give the students enough time to respond and come up with their own ideas and the lessons tended to be teacher-dominated rather than student-centred. 'This class of students seemed to show more concrete evidence that they had grasped the concept, but some more assessment/questioning would have been beneficial to reiterate the points and the key concepts' (St. John's, Observers Log, Science Lesson 3).

Some very positive insights emerged from the data collected. Both the science and mathematics teachers involved in this research project found positive outcomes for student learning and understanding. The teachers' reflections portray students as engaged, interested, responding well and enjoying the mathematical and science activities. In particular, engagement was highly correlated with building, designing and personalising the balloon rocket car, while working collaboratively with peers. Norma recognised the impact on student engagement and learning due to the fact that they 'owned' the car/data (Reflective Journal, Mathematics Lesson 4). Similarly, the students responded well to the introduction of technology into the teaching and learning of the subject areas, ensuring relevance to their elevated use of technology in their personal lives. During the Focus Group Interview, Norma felt strongly that this research project demonstrated to her that it is 'good for students to see teachers using technology' and personally it was 'good to be challenged and see it from their (students') perspective'. The teachers recognised that the students had engaged with the integrated approach and the use of technology. Norma commented that her students found the integrated unit of learning as 'real fun, which made more sense, and know that maths/science link a lot' (Reflective Journal, Mathematics Lesson 4). Moreover, the teachers felt that the integrated approach helped to develop students' understanding of the relevance of mathematics for science and science for mathematics. At a professional level, the teachers enjoyed the collaborative element of working with another colleague and 'building up links with other teachers and sharing ideas' (Rachel, Focus Group Interview). This was the first time for all of the teachers to engage in such a research project and they recognised the importance of collaboration in future practices.

Discussion

The importance of incorporating 'rich mathematical tasks' into the teaching and learning of mathematics has been highlighted by many researchers (Boaler and Staples, 2008). Science is an ideal source of rich tasks (the design and testing of balloon rocket car and the use of motion probes to explore concepts of distance, speed and time). Those rich tasks are characterised as activities where students make mathematical decisions, discussing and communicating their mathematical ideas, ask questions, reflect and interpret on their ideas and enjoy mathematics, among other things (Ahmed, 1987). At the same time, in science class, students are exploring concepts about motion and its related graphical and algebraic representations which Arons indicates to be a difficulty for many students (Arons, 1990). Research has demonstrated that mathematics and science integration can motivate and engage students in meaningful learning(Furner and Kumar, 2007).Insights emerging from the data presented in this paper demonstrate that students enjoyed the linkage between science and mathematics lessons and it assisted with engaging the students in curricular subject areas. Thus, there is value in teachers collaborating and planning cross-curricular linkage between both subject areas to improve the teaching and learning experiences of the students at second level education. However, this study demonstrates that, while technology could enhance the integrations of science and mathematics, this is a difficult task until teachers are sufficiently comfortable with the use of such technology in the classroom. The significance in terms of criticality, relevance and connectivity is an important consideration and justification for the integration of both subjects (Czerniak, 2007).

In this project, the use of handheld 'TI-NspireTM' graphical calculators was intended to enhance the integration of science and mathematics. However, the teachers' lack of confidence and competence with the technology were major barriers to the achievement of the goals. Apart from two well-documented teacher-level barriers, lack of time for dealing with the technical problems also came into play (Bingimlas, 2009). Additionally, the teachers did not initially appear to be aware of the value to the learning of integrating technology. Teachers felt there were too many technological tasks in the lessons, at the expense of the integration aspect. The importance of technology and the potential to improve teaching and learning has been well documented. However, the emphasis and focus needs to shift from coping with technology to actually teaching with technology (Niess, 2005). Altogether, the findings indicate that the need for teachers to have more training in pedagogical use of the technology, as well as having a greater input into the development of the technology requires the lesson plans. Once teachers have mastered the technology requirements, it is anticipated that, they would demonstrate greater engagement with implementing the integration element of the unit of learning with a teaching for understanding approach (BECTA, 2003).

The barriers presented by the technology also contributed greatly to the teachers' didactical approach in the lessons, as they were clearly anxious and lacked confidence to depart from the lesson 'script'. The integration of science and mathematics, therefore, did not flow as well as expected from the mathematics and the science lessons. It would be hoped that once the teachers become more familiar with the technology, the science and mathematics integration would also proceed more smoothly. The lesson observations indicated that the teacher's pedagogical content knowledge in their use of mathematical and scientific language, where they appeared to underestimate their student's capacities to grasp technical language, was a barrier to the integration of science and mathematics. The authors acknowledge that the method of presenting the teachers with an almost finished integrated unit of learning impacted significantly on how the teachers made the lessons on their own. The instructions and guidelines given by teachers were rigid and not presented in a flexible/adaptable manner. Therefore, teachers should be given more opportunity to have input into the design of the lesson unit, along with more support in implementing the ICT (Information and Communication Technology) aspects of their lessons. This should also assist the teachers with adopting a more student-centred approach in the lessons, as they will be more in tune with the concepts and language involved, and have a greater sense of ownership of the lessons.

Nonetheless, the data from the perspective of the teachers indicates that the project was very positive in other ways. The teachers reported that the project enhanced their students' enjoyment, learning and understanding of both science and mathematics. They acknowledged that the use of technology engaged their students in the lessons, and helped them make connections to their usual world. Additionally, the literature indicates that it is not easy to achieve science and mathematics integration, even without the added complication of integrating technology. Teachers often have little experience of it, and may lack sufficient content knowledge in the other subjects (Stinson et al., 2009).This project presented the teachers with the opportunity to collaborate with colleagues who had the content knowledge in the other subjects. The teachers found the collaboration as a very productive and enriching aspect of the project. They may not have fully achieved a fluent use of the technology in their lessons. However, their later reflections indicate that after they moved through the past technical issues, they experienced a change in attitudes towards technology, by the value of ICT for themselves and their students. These small positive findings augur well for integrating science and mathematics utilising technology, with some adjustments to the model used here.

Recommendations and Conclusion

The teachers involved in this research project were highly committed and demonstrated excellent engagement in the project throughout the academic year. All expressed an interest in taking part in the second phase of the project. Preliminary findings have shown that the integration of science and mathematics teaching and learning at post-primary education facilitated authentic learning experiences for the students and teachers involved in this pilot study. Difficulties arose with integrating the technology into the classroom, as well as in adopting a new approach to the teaching and learning of mathematics and science at post-primary education. Moreover, the pilot study confirmed the value of collaboration between mathematics and science teachers within schools and the need and willingness of teachers to engage in continuous professional development to enhance their students' learning experiences

From the in-depth analysis of the data, the author findings indicate that in order to develop this research, three key elements need to be investigated further. The authors suggest the following recommendations given by,

- Design and develop the integrated units of learning with the teachers, and let them experience what their students will experience, building on the teachers' understanding of integration. This would give the teachers an opportunity to engage with mathematics or science colleagues, engage in the technology challenges and discipline challenges, before facing those challenges in the classroom.
- Continue to work with the same participating teachers, building on their understanding of the integration of mathematics and science utilising technology, as such they will be starting with an excellent foundation from the first phase of the project. Further support for the teachers in developing their technological pedagogical content knowledge is needed.
- Re-examine the design of the integrated unit of learning; more flexibility and adaptability are needed.

From the study, it is evident that, further research in this area is warranted. In particular, insights generated in relation to student engagement and participation through the integration of subject areas utilising technology demonstrates the value associated with such an approach for student learning and the teachers' professional development.

Acknowledgements

The authors would like to acknowledge the support of the NCE-MSTL and Texas Instruments, who supplied the technology equipment, in carrying out this research project. The authors would also like to thank the schools and teachers who participated in this research project.

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