Teachers' Experiences of the Integration of 21st Century Learning in the Mathematics Classroom – The Bridge21 Model in Action

Aibhin Bray
Centre for Research in IT in Education (CRITE), School of Education and School of Computer Science & Statistics, Trinity College Dublin, Dublin, Ireland

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Abstract: Current research indicates a need for ongoing support and continuous professional development (CPD) for teachers in order to facilitate the development of 21st Century pedagogies and the integration of technology, as well as to scaffold their changing role in the classroom. This article describes a particular model of 21st Century teaching and learning and an associated approach to CPD, with a particular focus on mathematics education. A qualitative, case study approach has been taken in order to explore the teachers' experiences of using the model of teaching and learning, as well as their perceptions of the students' experiences. A total of 15 teachers who attended a Contextual Mathematics module on the CPD course provided consent for their data to be used in this study and a constant comparative analytic technique has been used to analyse their written reflections. Results indicate that the approach has the potential to address many of the difficulties associated with 21st Century teaching and learning identified in the literature review.

1 INTRODUCTION

There is no single, universally recognised definition of 21st Century skills or of the types of teaching and learning required to achieve them. However, in their comparative analysis of international frameworks for 21st Century competences, Voogt and Roblin (2012) identify a common recognition of the development of skills relating to communication and collaboration, problem-solving and creativity, as well as technological fluency, as being fundamentally important. Many of these skills can be defined as higher-order thinking and learning skills, or "life-skills", and they are seen as being transversal (not subject-specific) and multi-dimensional, impacting on attitudes and knowledge (Dede, 2010a; Voogt and Roblin, 2012).

Although a general recognition of the benefit of these skills is not new, an approach to education that emphasises the importance of acquiring them in an integrated manner throughout curricular activities, combined with the potential of technology to assist in their realisation, can be viewed as innovative (Conole, 2008; Dede, 2010a; 2010b; Voogt and Roblin, 2012). Meaningful incorporation of such 21st Century Learning (21CL) skills in mainstream curricula however, may require a change in pedagogic focus. Such a change would require a shift in teaching and learning approaches, de-emphasising the more traditional, procedural activities still common in educational practice, and increasing emphasis on the more complex skills that require an understanding of 'why' as well as 'how' the routine procedures should be used (Conneely et al., 2013; Dede, 2010b; Fullan and Langworthy, 2014; Voogt and Roblin, 2012). The role of technology in 21CL is perceived as important, in that it requires the development of specific competences regarding the effective use, management and evaluation of information across many different platforms (Martin and Grudziecki, 2006; Voogt and Roblin, 2012).

It is generally recognised that 21CL can be best supported through pedagogic approaches such as Inquiry-Based Learning (IBL), Problem-Based Learning (PBL), and collaboration, as well as a more formative approach to assessment (Conneely et al., 2013; Conole, 2008; Fullan and Langworthy, 2014; Voogt and Roblin, 2012). Some of these approaches as well as barriers to, and possible facilitation of, their implementation are discussed in the following sections.

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2 LITERATURE REVIEW

European research (Commission of the European Communitities, 2008; Euler and Maaß, 2011) has highlighted a need for appropriate structure, support and scaffolding in order to create opportunities for young people to develop key 21CL competences within the school environment. It is recognised however, that this is not a straightforward task. Indeed, the PRIMAS report (Euler and Maaß, 2011) has acknowledged that although many teachers wish to develop teaching and learning strategies that incorporate skills associated with 21CL, they are hampered by numerous factors outside of their control, including the restraints of current practices in curriculum and assessment, and a lack of relevant continuous professional development (CPD) for teachers.

Euler and Maaß (2011) identify three levels of problems associated with the implementation of a 21CL approach to teaching and learning: the overarching school system; a lack of resources including CPD; and teachers' beliefs. The macro-level issues identified by Euler and Maaß, relating to policies, curriculum, and assessment, while fundamental, are not addressed in detail in this research.

At the meso- and micro-levels, problems relating to classroom management and the difficulties that teachers may have in redefining their role, have been identified as contributing to the gap between the intended curricula, which tend to recognise the importance of 21st Century skills, and that which is actually implemented (Conneely et al., 2013; Euler and Maaß, 2011; Voogt nd Roblin, 2012). Not only are teachers expected to facilitate the acquisition of 21st Century skills among their students, but they are also expected to possess the skills themselves (Voogt and Roblin, 2012). Discussion alone is not sufficient to address these issues, rather a shift in the beliefs and practices of policy-makers and practitioners is required (Dede, 2010b). Educators need to be provided with adequate support and CPD in order to master the necessary skills and teaching strategies, but also to 'unlearn' the beliefs and assumptions that underpin the traditional industrial-model of classroom practice (Conneely et al., 2013; Dede, 2010b; Voogt and Roblin, 2012).

It has been suggested that an approach to CPD that presents teaching as a problem-solving activity, or 'research-in-action', may be particularly appropriate for linking teaching practice with children's learning (Commission of the European Communitities, 2008). This has clear links with the approach described in this research.

3 BRIDGE21 AND CPD

One of the findings that has emerged throughout the analysis of the literature, is a need for ongoing support and continuous professional development (CPD) for teachers in order to facilitate the development of 21st Century pedagogies and the integration of technology, as well as to scaffold their changing role in the classroom (Conneely et al., 2013; Dede, 2010a; Maaß nd Artigue, 2013; Voogt and Roblin, 2012). This paper describes the implementation of a structured CPD module that has been incorporated into a larger Postgraduate Certificate (PG Cert) course in 21st Century Teaching and Learning for post-primary school teachers, coordinated by the School of Education in Trinity College Dublin (Bridge21, 2014). This course began in September 2014 and the first cohort of teachers have recently completed the programme.

Bridge21 offers a structured pedagogic model for the integration of 21CL in classrooms, and supports an innovative approach to CPD, strongly influenced by the Japanese model of Lesson Study that uses an iterative cycle of goal setting, planning, teaching and observation, review, and revision (Lewis et al., 2009). Groups of teachers form communities of practice to engage in a process of systematic examination of their practice, with the goal of becoming more effective teachers and optimising their lessons (Maaß and Artigue, 2013; Takahashi nd Yoshida, 2004).

The initial experience for teachers engaging with the Bridge21 CPD model involves active participation in immersive and authentic activities, which enables them to understand the power of the approach at a personal level. Throughout the process, participants are provided with the resources, practical designs and collegial support that Donnelly et al., (2011) highlight as necessary conditions to motivate change amongst teachers.

The Contextual Mathematics module on the PG Cert requires each of the attending teachers to complete an assignment that involves the creation and implementation of a 21CL activity in their school, with a standard class. The activity should use the Bridge21 model of 21CL (Section 4) and a set of design heuristics (Section 5) developed for the creation of contextual, 21CL mathematics learning activities (Bray et al., 2013; Bray and Tangney, 2013b; 2014; Tangney et al., 2015). The written part of the assignment involves a description of the activity, highlighting the basic and transversal skills that are covered, as well as a reflection on their own, and the students' experiences of the process.

A total of 22 teachers attended the contextual mathematics module which forms the basis of this study. These teachers came from a wide range of schools and had levels of teaching experience ranging from 3 to 19 years. In a number of cases, two or three of the teachers came from the same school, which promoted greater levels of collaboration in the design and implementation of their activities, and also strengthened the communities of practice within the schools. Fifteen of the teachers provided consent for their work to be included in this research. This paper provides an analysis of their work, placing particular emphasis on their reflections on the process, and their experiences with it.

4 THE BRIDGE21 MODEL

Bridge21 (www.bridge21.ie) is a model of collaborative, project-based learning that has been developed at the authors' institution (Lawlor et al., 2010; Lawlor et al., 2015). Initially established in 2007 as part of an outreach programme, the Bridge21 model has been developed throughout the intervening years and is currently being trialled in a number post-primary schools as part of a systemic process of reform of the Irish education system (Conneely et al., 2015; Department of Education and Skills, 2012; Lawlor et al., 2015). The Bridge21 activity model is inspired by the concept of Design Thinking (Brown, 2008), and brings together many of the elements of 21CL in a structured manner, scaffolding teachers' introduction of the pedagogical approach. A Bridge21 learning experience involves a number of steps (Figure 1):

1. **Set-Up:** Ice breaker and team formation.
2. **Warm-Up:** Divergent thinking activity**.**
3. **Investigate:** Explanation of the problem context.
4. **Plan:** Group planning.
5. **Create**: An iterative process
   a. Exploration with resources.
      i. In the field.
      ii. In the classroom.
   b. Modelling and Calculation:
      i. Analysis and Synthesis.
6. **Present:** Competition and/or Presentations.
7. **Reflect:** Reflection and Discussion.

In addition to the activity process, Bridge21 observes a particular model of collaboration and group work influenced by the World Organisation of the Scout Movement (Bénard, 2002), which emphasises mixed-ability groups and individual, as well as group reflection. The role of the teacher is to act as a guide and mentor, scaffolding and orchestrating the learning. The physical learning space is configured to support an inquiry-based, technology-mediated, and collaborative approach to learning. The Bridge21 approach to CPD involves teacher participation in a full cycle of the activity model prior to the collaborative development of their own activities and their delivery in the classroom.

Figure 1: The Bridge21 Activity Model.

5 THE DESIGN HEURISTICS

In the Contextual Mathematics module, the use of a particular set of Design Heuristics for the creation of contextual 21CL mathematics activities is advocated. These heuristics have been developed and refined by the author over the course of the last three years. The theoretical foundations of the set of Design Heuristics were developed from an extensive literature review (Bray and Tangney, 2013a; 2014; Tangney et al., 2015). Particular attention was paid to the Realistic Mathematics Education, or RME (Freudenthal, 1991) approach to mathematics education, which, since its inception in the 1960s has become internationally influential in curriculum design (Clements et al., 2013).

In conjunction with the theoretical foundations stemming from the literature, an iterative process of activity design, pilot activities and in-school interventions were used to refine the Design Heuristics (Bray et al., 2013; Bray et al., in press; Bray and Tangney, 2013a; 2014). The primary concepts that underpin the heuristics can be summarised as follows:

1. "Activities should follow a 21CL model such as Bridge21: they should be collaborative and team-based in accordance with a socially constructivist approach to learning.
2. They should make use of a variety of technologies (digital and traditional) suited to the task, in particular, non-specialist mobile technology such as smartphones and digital cameras that students have to hand. Emphasis should be placed on the transformative, as well as the computational, capabilities of the technology.
3. Task design should prioritise guided-discovery, involving problem-solving, investigation and sense-making, and a move from concrete to abstract concepts. Tasks should be open-ended, allowing for different trajectories and solutions; they should have a "low-floor" and "high-ceiling", such that all students will be able to engage meaningfully with the problem, with the potential for more interested/able students to push its boundaries.
4. The context of the problem, and the learning experience, should be interesting and immersive/real, adapting the environment and class routine as appropriate;
5. Presentation, competition and reflection can be used for assessment purposes." (Bray & Tangney, In Press)

Activities designed in accordance with these heuristics, and implemented using the Bridge21 approach have been associated with increases in students' levels of engagement with mathematics, and their attitudes to using technology for its learning (Bray et al., in press; Bray and Tangney, In Press).

6 METHODOLOGY AND RESEARCH QUESTIONS

The work presented here is framed as an exploratory case study, which aims to investigate teachers' experiences of the creation and implementation of mathematics activities designed in accordance with the Design Heuristics and the Bridge21 methodology. The research design is a single case study, with multiple embedded units, each consisting of one of fifteen teachers' implementations of an activity in their school, and subsequent reflection on the process. The context is Post-Primary Education – Authentic Setting (the researcher is not an observer), and the case relates to teacher experiences and their perceptions of their students' engagement (Figure 2). The written assignments, which include a description and rationale for the design of the learning experience, content and skills to be covered, evidence to demonstrate student learning, and a personal reflection on the experience, form the basis of the data for analysis. As described in section 7, a constant comparative analytic technique was used to highlight the emerging themes (Strauss and Corbin, 2008).

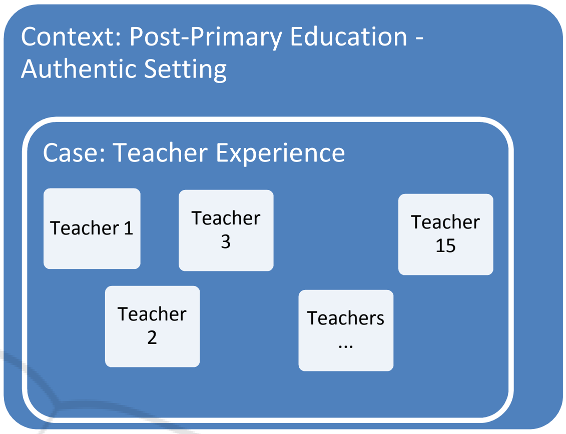


Figure 2: Case Study Model.

The specific aims of this exploratory case study are:

1. To explore the experiences of teachers in the creation and implementation of such activities, with particular emphasis on their perceived barriers to, and benefits of, the approach.
2. To explore the teachers' perceptions of their students' experiences with the activities.

The data that has been collected for this exploratory study is purely qualitative and comes from the written reports of the teachers. Not all of the teachers provided authorisation for their work to be included in this research - the total number of assignments that have been analysed is fifteen.

7 THE MATHS LEARNING ACTIVITIES

A number of the teachers worked collaboratively on the design of the activities, and joint implementation was permitted for teachers at the same school. In total, 11 different activities were created by the 15 teachers. The teacher-designed activities were conducted with students across four different year groups, ranging in age from 12 – 16. All of the activities were creative, contextual and transformative in their use of technology (Puentedura, 2006).

Table 1: Teachers' Activities.

Activity	Class	Description
Heights with Helium	Transition Year[1] (age 15/16)	A helium balloon and technology was used to find the measure of certain heights around our school. This meant dealing with only two variables, Height and Time and being able to use the free video analysis software Kinovea (*www.kinovea.org*) to obtain these variables and a Spreadsheet to graph the data.
Functions in context: analysing trajectory.	2nd Year (age 13/14)	Each team of students take video clips of attempts to throw a ball into a basket. They then use appropriate software to analyse the trajectory of a successful shot. Using a suitable graph, they compare successful and unsuccessful shots.
Distance, Speed and Time	3rd Year (age 14/15)	Students ask themselves "how fast am I running?" Based on their introduction to Kinovea and their knowledge of Microsoft Excel, they are asked to answer this question and illustrate their answers in the form of graphs and tables.
Statistics/ Height/Distance, Speed and Time	1st Year (age 12/13)	Working in groups, students are tasked with comparing the speed of the shortest and tallest members of their group over a specified distance. The data collected, and analysis of their findings, will be done using Kinovea.
Egg Drop Challenge	Transition Year (age 15/16)	Teams of four students work to design a method of safely dropping an egg from a first floor window. They use smart phones, digital camera and iPads to visually record the activity. They generate data from the activity and use a video App and maths analysis software to provide mathematical evidence for their approach.
Quadratic equations, functions and algebra.	Transition Year (age 15/16)	The students are asked to plot the quadratic function for the flight of their shot in a football crossbar challenge. The students are dived into groups of 3-4 students. Each group works with the tracker software to analyse the shot that is closest to hitting the crossbar. The students use the software Kinovea and excel to find and plot the flight of their shot. The students are asked to analyse the graph produced.
Children's Birthday Party	2nd Year (age 13/14)	Given an advertisement for a party hire company, the students use GeoGebra to explore different combinations of tables etc. to get the best value for money.
Speed, Distance, Time	Transition year (age 15/16)	The students are presented with the problem 'Who is the fastest in the class?' In their groups they must produce a method of experiment and a Microsoft excel presentation of their results.
Shoot a basket!	2nd Year (age 13/14)	In groups, the students develop different ways to analyse and make 'real' quadratic functions through group work and peer teaching and learning. Students learn to select, create, and use many new forms of technology, such as GeoGebra and Tracker (*physlets.org/tracker*). The groups will be briefly introduced to the programmes but need to decide if it will help answer the question, "What makes a successful shot successful?" As the students gain experience working with the programmes, they become more aware of the technology available around them.
Speed\Distance\ Time, Statistics	1st Year (age 12/13)	The students undertake a study to determine if the speed of the ball affects the chances of scoring goal.
Speed Camera	2nd Year (age 13/14)	In groups students are required to use technology to analyse the speed of cars passing by the school. They represent the data using an appropriate chart and come up with a hypothesis as to whether different coloured cars are more prone to breaking the speed limit based on their data.

[1] Transition year is a one-year school programme in which the focus is on personal, social, vocational and educational development, providing opportunities for students to experience diverse educational inputs in a year that is free from formal examinations.

The majority of the activities focussed on the mathematics involved in data collection and representation, patterns, and linear and quadratic functions. In all cases this was reported as being the first experience that the students had of generating their own functions using "real" data that they had collected empirically. Brief descriptions of the activities are provided in Table 1.

Of particular relevance to this research are the written reflections from the teachers' assignments, which provide insight into their experiences with the implementation of contextual mathematics learning activities and into the barriers to, and benefits of, the approach.

8 ANALYSIS OF RESULTS

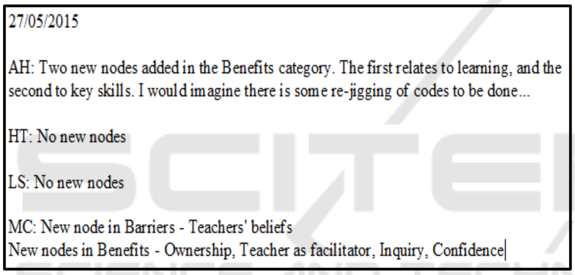
The results are drawn from a qualitative analysis of the teachers' reflections and a *constant comparative* approach to the analysis of the data has been taken. The steps in this process follow the procedure outlined by Glaser (1965) and Strauss and Corbin (2008). Constant comparison is a method of reducing qualitative data to codes emerging from within the original source, while retaining much of the richness of the original data. Thus, the results of the analysis can be used to create a rich picture of the teachers' experiences, potentially identifying any common themes or categories.

8.1 Generation of Initial Codes and Categories

NVivo10 software was used to facilitate the process of coding and theming. After the first five assignments were analysed, a total of 23 codes were identified. These fell into the two main categories of

Barriers, with five associated codes, and Benefits, with 18 associated codes. All segments of text associated with each of these codes were re-examined and compared before moving on to the next set of assignments, of which the next four led to the addition of five new codes, four under the category of Benefits, and one under Barriers. At this point, the process of *memoing* – keeping detailed notes on the thought process involved behind the coding – was very useful for highlighting areas that could potentially benefit from re-organisation (Figure 3). In particular, the codes associated with the category of Benefits seemed to be developing into a number of subcategories, some relating to teachers and some to students, some to the development of key skills, and so on.

The remaining six assignments only led to the generation of two more codes, leading to the tentative conclusion that a reasonable level of saturation of codes may have been reached (Strauss and Corbin, 2008).


27/05/2015

AH: Two new nodes added in the Benefits category. The first relates to learning, and the second to key skills. I would imagine there is some re-jigging of codes to be done...

HT: No new nodes

LS: No new nodes

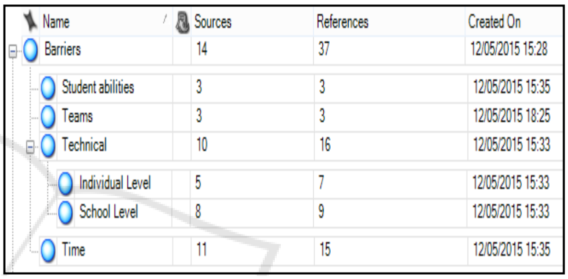
MC: New node in Barriers - Teachers' beliefs
New nodes in Benefits - Ownership, Teacher as facilitator, Inquiry, Confidence

Figure 3: Sample Memo.

All of the text was re-examined after each session of analysis, and particularly after the addition of new codes, in order to compare the coded text within their assigned nodes and also to identify whether they could be associated with any other codes. This process of constant evaluation and comparison has led to a rigorous association of codes and text.

8.2 The Reduction of Codes

Once the initial development of codes and categories was completed, the process of reducing and merging the codes, and developing sub-categories began. This involved an examination of the codes and the coded segments in order to determine whether there was any crossover of themes.



Name	Sources	References	Created On
Barriers	14	37	12/05/2015 15:28
Student abilities	3	3	12/05/2015 15:35
Teams	3	3	12/05/2015 18:25
Technical	10	16	12/05/2015 15:33
Individual Level	5	7	12/05/2015 15:33
School Level	8	9	12/05/2015 15:33
Time	11	15	12/05/2015 15:35

Figure 4: Barriers Category.

The Barriers category had significantly fewer references than Benefits, and included student abilities, teams, technical difficulties (at individual and school level), and time constraints (Figure 4).

Table 2: Matrix Coding of Task Design and Perceived Benefits.

Task Design v Perceived Benefits	Contextual	Cross-curricular	Hands-on	High Ceiling	Inquiry	Meaningful	Multiple Learning Styles	Open ended	Peer Learning	Student-led	sum
Ownership	1	0	0	0	0	0	1	1	2	7	12
Conceptual Understanding	5	1	0	1	1	3	0	2	2	6	21
Engagement	5	1	0	0	1	5	2	2	3	5	24
Teacher as Learner	1	1	1	0	1	1	0	0	2	4	11
Confidence	0	0	0	0	0	0	0	0	1	4	5
Communication	2	0	0	0	0	0	1	1	5	3	12
Teacher as facilitator	0	0	0	0	0	0	0	0	1	3	4
Collaboration	3	0	0	0	1	2	0	2	6	2	16
Technological competence	1	0	0	0	0	0	0	0	2	2	5
Problem-Solving	0	0	0	0	1	0	0	0	1	2	4
Flexibility	3	1	1	0	0	1	0	0	1	1	8
Creativity	0	0	0	0	0	0	0	0	1	1	2
Teacher Beliefs	0	0	0	0	1	0	0	0	0	1	2
Enjoyment	2	1	0	0	1	2	1	1	1	0	9
Organisation	1	0	0	0	0	0	1	0	0	0	2
Presentation	0	0	0	0	0	0	0	0	1	0	1
Sum	24	5	2	1	7	14	6	9	28	41	

(In Figures 4, 5 and 6, *Sources* refers to the number of individual teachers whose data were categorised at the related code, while *References* relates to the overall number of coded segments.)

The category of Benefits had a total of 295 references, in comparison to only 37 in the Barriers category. At this point in the analysis, a number of subcategories were confirmed in the Benefits category. These related to benefits to the students (key skills, other outcomes, associated task attributes) and benefits to the teachers (change in beliefs, teacher as facilitator, and teacher as learner).

8.3 Analysis of Relationships

The process of analysis of relationships used the coding matrix facility of NVivo10. Analysis focused on the relationships between the teachers' perceptions of the task design elements that had an impact on themselves and on their students, and their perceived *benefits*. No associations between task attributes and *barriers* were identified. Table 2, above, provides a numerical analysis of the number of times that segments of text were co-coded with a particular aspect of task design and a perceived benefit. The most significant elements (most frequently coded) of the *task design* columns and *perceived benefits* columns have been highlighted.

Using the ***sum*** functionality at the end of each row and column, it is clear that the fact that the tasks were student-led has had the most significant impact on perceived benefits, particularly on the sense of student ownership or autonomy, on their conceptual understanding, and on engagement. The student-led approach also seems to be significant in effecting a change in the role of the teacher in the classroom. Peer learning and the contextual nature of the task design appear to have had beneficial effects on the students and teachers, particularly in the areas of collaboration, communication and engagement.

In terms of perceived benefits, it appears that the task design has had most impact on student engagement, with the tasks set in contexts that were meaningful to the students and the student-centred nature of the activities appearing to have the greatest effect.

Conceptual understanding is highlighted as the second highest co-coded perceived benefit, and this seems to be related to tasks that are set in contexts that are meaningful to the students, as well as the student-led nature of the learning

9 FINDINGS

The findings that have emerged through analysis of the relationships between task design and the perceived benefits of the approach, go some way to confirm the link between the approach to mathematics teaching and learning and increases in student engagement emerging from earlier research (Bray et al., in press; Bray and Tangney, In Press). In particular, there is an apparent link between the student-led, contextual and meaningful approach to activity design, and a perception of increased engagement, conceptual understanding, and confidence. However, in addition to these relationships, a number of findings have emerged relating to the teachers' perceptions of the barriers to the implementation of activities of this kind, and also of the benefits that engagement with these tasks can engender.

9.1 Barriers

The CPD model presented here, has addressed some of the barriers to the integration of technology and the implementation of new teaching and learning strategies highlighted in the literature review, such as a need for a structured and supportive approach (Conneely et al., 2013; Dede, 2010a; Euler and Maaß, 2011; Means, 2010; Voogt and Roblin, 2012). However, many of the more systemic barriers remain, and have been identified by the teachers. The most significant of these relates to time constraints and the difficulty that implementing a project-based, inquiry activity in a series of 40 minute classes, which was identified as a problem in 10 of the 15 assignments (Note: teacher initials have been used to code quotations): "*Having a longer block of time would have been more productive, having to stop after 40 minutes and then pick up again a day or two later was inconsistent, especially when we were running into problems*" (AH)

Technical barriers were an issue for nine of the teachers, with five identifying personal difficulties with the technology, which would be easily rectifiable on a re-run of the project: "*The camera we were using ran out of battery power during the penalty shoot outs... More cameras would need to be made available, especially if more teachers were to start working with this approach*." (WMI)

Eight of the teachers identified technical barriers at the school level, which primarily related to inadequate access to the technology: "*Resourcing fully functioning laptops could be a challenge - I need to ensure that the limited number of laptops are* *available for at least three class periods*." (IS)

Other barriers that were identified by the teachers referred to lower than expected levels of students' technical expertise, and difficulties relating to the development of well-functioning teams.

9.2 Benefits

The perceived benefits associated with the approach far outweigh the barriers, and can be broken down into benefits for teachers and benefits for students.

9.2.1 Benefits to Teachers

The teachers perceived a number of changes to their beliefs and to their role in the classroom.

Name	Sources	References
To students	21	273
Key skills	19	107
Collaboration	14	22
Communication	10	15
Confidence	4	7
Creativity	8	10
Flexibility	5	8
Organisation	4	4
Presentation	6	6
Problem-Solving	7	9
Reflection	2	2
Technological competence	12	19

Figure 5: Key Skills.

Two of the teachers in particular discussed the impact that teaching in this way has had on their beliefs about mathematics teaching:

"After trying this, my eyes have been opened to the possibilities of covering the curriculum, but by changing the setting of the learning, you can teach a lot more effectively to an audience who are stimulated and engaged." (JPF)

"I will be honest that I found it more difficult to change my teaching style when it came to Maths. I was teaching the way I was taught, which was with very little understanding." (MC)

It appears that the role of the teacher in the classroom is significantly affected through the implementation of these activities. The change in role from transmitter of information to facilitator of learning was not a comfortable one for some of the teachers; however, in all cases, it was hailed as a positive development, empowering the students to take ownership of their own progress. "*I decided to tell the students of how this was as much of a learning curve to me as it was to them. This was because I really did feel that they would lose confidence in me if they felt that I was trying to teach them rather than facilitate them. This seemed to empower them as they felt that even though I wasn't part of their team, I was learning and teaching with them*." (MC)

In addition to the change in role from teacher to facilitator, six of the teachers also identified themselves as co-learners in the classroom, both in terms of learning about the technology with and from the students, and learning about how to make activities of this kind more successful in the future.

9.2.2 Benefits to Students

The benefits to the students have been deconstructed into the subcategories of 'key skills', 'other outcomes' and 'associated task attributes'. The relationships between the task attributes and the perceived benefits of the approach have already been discussed in section 7.3. This section will therefore focus on the perceived benefits of the approach to students, without dwelling on their associations with the task design.

The key skills subcategory is made up of the codes listed in Figure 5. It is clear from this figure that the most common skills that were developed relate to collaboration and communication, technological confidence and creativity and problem-solving. The students generally seemed to enjoy working in teams and learning with and from their peers. Many of the teachers recognised the potential that technology has to facilitate a deeper understanding of the mathematics involved in the activities, as well as increasing the students' technological skills.

"The resounding theme of the [student] reflection was that they could really engage with one another and more importantly that they could engage more with the abstract topics of maths because of their ability to use technology in everyday maths." (DR)

In addition to the development of key skills, a number of other beneficial outcomes emerged through students' participation in the activities designed by the teachers. These outcomes are listed in figure 6.

Name	Sources	References
Outcomes	19	89
Conceptual Understanding	11	20
Engagement	16	35
Enjoyment	13	20
Ownership	8	13
Prepared for 3rd level and w	1	1

Figure 6: Other Beneficial Outcomes.

An increase in student engagement relating both to how they felt about the subject (affective engagement) and how they behaved in the classroom (behavioural engagement) (Pierce, Stacey, & Barkatsas, 2007), was evident through the teachers' reflections. Comments such as those provided below, clearly illustrate the sense of engagement and motivation experienced by students and teachers alike.

"All the team members were fully engaged in the activity; their pride in and ownership of their learning was clearly expressed… It's really heartening to encounter such a level of motivation and commitment." (DD)

"Please let's do more of this stuff! It's brought Maths to life! I really get it now! J" (Student)

"This project was a thoroughly enriching experience for both the students and teachers assisting them." (DOC)

"After this contextual Maths workshop, they asked for a Maths club. To me that is success!" (MC)

There is a high level of cross-coding of segments of text coded as engagement and as enjoyment. However, a deeper analysis of the text coded at enjoyment indicates that this code is particularly closely related to affective engagement. Any segments that are coded at enjoyment and not at engagement relate specifically to the idea of having fun in the class, both from the point of view of the students, and the teachers:

"This project has highlighted one of the most enjoyable pieces of technology that I have used in my teaching career" (IB)

"I feel that the students enjoyed this realistic, contextualized activity and by taking part they have taken a step forward in developing their technological skills, becoming better problem solvers and gaining attributes in working as part of a team." (AH)

"The students also had fun, which they said that they thought they would never be able to say about Maths." (MC)

An increase in students' conceptual understanding and confidence was identified in nine of the analysed reports. This appears to be particularly closely associated with the contextual and meaningful nature of the tasks, a relationship that is clearly captured in the following: "*I am sure that none of these students will ever forget how they deepened their understanding of quadratic functions: the next time they video a friend kicking a football or teeing off in golf they will visualise that ball moving across the Cartesian plane, describing a smooth parabola*." *(DD)*

In addition, the open-ended task design and the student-led approach within the classrooms appears to have led to a deepening of the students' understanding: "*The open-ended nature of the activity produced a new energy in the teams: they were not working to find one answer (already known to me) but were engaged in a meaningful exploration of the topic.*" *(DD)*

Seven of the reports refer to the increased sense of student ownership of their work, leading in turn to pride, engagement and motivation.

"Students came into their own when given the opportunity to work as a group and they seemed to grow as individuals even in the short space of time while working in groups with their peers" (DR)

"Moreover, I feel that if I had taken over this aspect of the project… I would be impacting on their self-efficacy." (DF)

By handing the responsibility for the learning to the students, they were seen to develop as individuals and as members of a group, with the apparent increase in levels of motivation and pride in their learning leading to higher levels of conceptual understanding.

"All the participants felt that they had created their own quadratic function and understood that it could be mathematically analysed." (DD)

In summary, these findings provide a compellingly positive picture of the approach to the development and implementation of mathematics learning activities that correspond to the design heuristics described in this research.

10 DISCUSSION

The analysis of teachers' reflections described in this paper has provided an opportunity to explore various aspects of the participants' experiences of the Contextual Mathematics module on the Postgraduate Certificate, thereby addressing the research aims identified in section 5. In particular, analysis of the data has permitted:

- Examination of the experiences of teachers in the creation and implementation of such activities, paying particular attention to the barriers to, and benefits of, the approach.
- Exploration of the teachers' perceptions of their students' experiences with the activities.

These topics have been explored throughout this research. This discussion will explore aspects of the reflections that mirror concerns that emerged in the literature review, and will also set out the primary limitations of the exploratory study.

10.1 Addressing the Issues

Throughout the analysis of the teachers' reports, it was interesting to see that many of the problems associated with mathematics education that had been identified through the literature review, were also highlighted by the teachers taking part in this module. The predominantly formulaic approach to text-book questions (Boaler, 1993) was identified by one teacher as an area that the approach advocated in the CPD module, had the potential to address.

"These problems involved being given the function, algebraically or graphically, and all the information required to answer some fairly predictable questions. There was never any redundant information either: just enough and not too much to apply the usual procedures… I considered that setting the students the task of creating their own quadratic curve would give them a real sense of ownership and a greater insight into the nature of quadratic functions." (DD)

The teachers' reflections indicate a belief that this approach may go some way to address the fragmented, and de-contextualised nature that frequently pervades school mathematics (Albert and Kim, 2013; Dede, 2010a).

"It was useful for students to see different aspects of Maths used in one place rather than the disjointed treatment that they usually receive in a text book." (WMI)

In addition, as observed by Oldknow (2009), the use of personal devices, such a mobile phones, to generate mathematical models, contextualised the mathematics for the students, providing a relevance and meaning to the topic:

"For students, to discover that they can take their ubiquitous phone out of their pocket and create a mathematical model of an everyday event grounds Maths in the real world." (DD)

The issues surrounding teachers' beliefs and their changing role in the classroom can also be seen to be addressed through the structured, immersive and supportive nature of the CPD program. The provision of a specific pedagogical structure (Bridge21) and set of lesson design heuristics provide the teachers with an approach that has been tested and shown to work. The teachers all seemed to have been empowered by this, and were confident to approach their classes in a different way. The results appear to have been beneficial for both teachers and students.

"I have worked with this particular class group on two other 21st Century Teaching and Learning Assignments. Their development throughout the course of the year has been astounding. The flair with which they now competently and confidently use technology to gather and analyse information, and present their findings is very impressive. This project was a thoroughly enriching experience for both the students and teachers assisting them." (DOC)

10.2 Limitations

It is clear from this analysis that the approach to the creation and implementation of mathematics learning activities that has been developed in this research has the potential to address many of the issues that were highlighted in the literature review. However, it is important to identify the limitations of this study.

Firstly, the sample that is used in this exploratory study consists of teachers who have opted to be a part of the research, and who are participants on a CPD course that they have chosen to attend. It is therefore a self-selecting sample and cannot be seen as representative.

Another point that needs to be highlighted is that the reflective pieces provided by the teachers were all submitted for assessment purposes. There is a possibility that the participants therefore emphasised the positive aspects of their experiences more than the negative. This is a limitation of the study to date, which future work will aim to overcome through interviews with participants and their students and non-participant observation of the classes.

Another drawback of this exploratory study is its small size. The analysis of fifteen teachers' reports is unlikely to permit the generation of any substantive theory. However, the consistency of the results do allow the generation of hypotheses and research questions to follow up on the initial, very promising, findings.

11 CONCLUSIONS

This study will require further expansion in order to fully examine the emerging themes. It is a very encouraging however, to see such positive results emerging from the work with teachers. In particular, the following quote from one of the attendees on the Contextual Mathematics module highlights the teachers' understanding of the intention behind this research.

"The importance of 21st Century teaching and learning and indeed the B21 model can be seen by Green and Hannon who state, "In an economy driven by knowledge rather than manufacturing, employers are already valuing very different skills, such as creativity, communication, presentation skills and team building. Schools are at the frontline of change

and need to think about how they can prepare young people for the future workplace" (2007, p. 15). As such a huge emphasis is being placed on STEM subjects/activities in schools, RME in conjunction with the B21 model helps to contextualise maths for our students, increasing their engagement and allowing them to use technology in a meaningful way." (MC)

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