Title	Maths mission: a case study of gesture-based technology in the mathematics classroom
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Publication Date	2016-05-04
Item record	http://hdl.handle.net/10379/5748

Maths Mission: A Case Study of Gesture-Based Technology in the Mathematics Classroom.

A THESIS SUBMITTED TO:

THE SCHOOL OF EDUCATION

COLLEGE OF ARTS, SOCIAL SCIENCES, & CELTIC STUDIES

NATIONAL UNIVERSITY OF IRELAND, GALWAY

IN FULFILMENT OF THE DEGREE OF:

DOCTOR OF PHILOSOPHY

By:

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– May 2016 –

DECLARATION

I, the Candidate, certify that the work in this thesis is to the best of my knowledge and belief all my own work and that I have not obtained a degree in this University or elsewhere on the basis of any of this work.

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Acknowledgements

I would like to thank the student from my preliminary study who named the game Maths Mission and express my gratitude to all the students, teachers and parents who gave consent and participated in this study. Without them, this study would not have been possible.

I would like to express the deepest appreciation to my supervisors. I wish to first and foremost thank Dr. Catherine Paolucci and Dr. Mary Fleming, who have given me great encouragement, support and understanding throughout this process as well as conveying opportunities in research. I would like to thank my committee members, Drs. Dolores Stewart and Tony Hall for their guidance during the Graduate Research Committee meetings. I would like to thank my examiners, external examiner: Dr. Kevin Burden and internal examiner: Dr. Máire Ní Ríordáin.

In addition, I would like to thank my parents who supported me throughout the PhD and who read through various articles, chapters and finally my thesis. I would like to thank my sisters and extended family for their patience and encouragement throughout the process. I especially thank Owen for his enduring support both financially and emotionally throughout this process and also for moving to Galway when I asked. This would not have been possible without your relentless support.

A huge thank you to all in the new Hardiman research building that I have been lucky to share an office with. These include those in the School of Education and many from the College of Arts, Social Sciences and Celtic Studies. In conclusion, I would like to express my gratitude to the scholarship committee for approving my Galway Doctoral Scholarship funding without which this research would not have been possible.

Abstract

Technology offers a new dimension to engaging students in the classroom. However, the complexities in an Information and Communication Technology (ICT) mediated environment can also bring challenges to the classroom (Chandra and Lloyd, 2008). Therefore, it is important to differentiate technologies and adopt them for specific uses within the classroom. The case study investigation is the first of its kind in Ireland on the design and implementation of a Gesture-Based Technology (GBT) game into the mathematics classroom. GBT refers to technologies that use the WiiMote, PlayStation Move or Xbox Kinect. Joining GBT and Game-Based Learning (GBL) characteristics together forms the foundational premise of this research. Three main questions were asked relating to the key design elements; the key challenges of classroom implementation; the potential of this game as a tool and the design features that informed the creation of a Gesture-Based game for the mathematics classroom. This research found that the WiiMote was the most practical device to develop a Gesture-Based game in terms of cost and benefits. In researching the design features a framework was developed – the ECG framework. The main design elements are engagement, enjoyment, relevance, confidence and collaboration. The potential of GBT integration directly depends on its ability to harness the fruitful benefits of engaging students in relevant, real world applications for the Maths curriculum in Ireland. The challenge lies in improving the ICT mediated environments to support the adoption of these technologies and maximise the benefits for the learners.

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Chapter 1: Introduction

1 Introduction

This chapter describes the background to this research and rationale for this case study research. The chapter subsequently describes games and Gesture-Based Technology (GBT) as tools within the classroom and discusses the possibility of using such technology in the Irish mathematics classroom. GBT includes the Nintendo Wii, Xbox Kinect and PlayStation Move and as a concept is discussed in more detail in the literature review. The chapter continues with describing the research aims and questions. Finally, the chapter concludes with an overview of the thesis and the researcher's biographical motivation for pursuing this case study research.

1.1 Background to the Research

Ireland has undergone significant changes and reforms in mathematics education following on the introduction of Project Maths at post-primary level as a pilot in 24 schools in 2008 and into all schools in the academic year 2010-2011. It is still debatable whether teachers are actively adopting the recommended constructivist teaching and collaborative practices. As far back as 2003 these approaches were encouraged by previous curricula (Lyons, Lynch, Close, Sheerin and Boland, 2003). This study examined the English and Mathematics classrooms specifically and shows the same issues that occurred in 2003 are happening in the recent report by Brosnan (2013). Even after the development and implementation of this new curriculum, designed specifically to promote constructivist approaches to teaching and learning, these practices are still not appearing in many Irish mathematics classrooms (Brosnan, 2013).

After the initial implementation of Project Maths, Brosnan (2013), having investigated the teaching approaches across Ireland, reported *'we tend to agree on constructivist approaches but there's a very low usage of them'*. A very low usage of the constructivist approach may mean teachers are still using traditional methods in their classrooms. In order to develop the constructivist approach, teachers are encouraged to learn from each other and engage in continuous professional development in order that the adoption of the curriculum has the desired effects on students. The desired effects on students being the connection within mathematics, and connection to applications in real life; these aims are presented in chapter 2, the literature review. Thus, teacher development practices such as lesson study are encouraged. These practices allow time for examination of different teaching strategies in order to teach particular topics. Despite the rhetoric, there are challenges to the adoption of the recommended new approaches to classroom practice and, as reported by the national coordinator, didactic approaches are still being used in Irish classrooms (Brosnan, 2013).

The introduction of the new curriculum has brought attention to the need for a change in thinking in terms of teaching strategies and approaches in the classroom. However, system-level contradictions still exist. Despite the fact that the value of rote learning is diminishing and the promotion of problem solving and 'real life' application of mathematical skills is increasing, the nature of the examination system remains unchanged with two written examinations being externally assessed by the State. Implementation of any curricular reform into the classroom carries with it an inherent need to consider the situational characteristics that may present some challenges when adopting new reforms.

1.1.1.1 Technology in the Curriculum

The curriculum has endorsed the use of computers in the mathematics post-primary classroom. Project Maths endorses the use of software such as GeoGebra[1] in order to engage students more deeply with the content and process of learning. A student compact disc can be downloaded with activities for home use on the Project Maths website.

Although these demonstrations and digital resources are very useful for student learning, they have not encompassed goal-oriented and peer learning tasks in and outside the classroom. The existing resources also do not illustrate the cohesive link between primary and post-primary levels nor engage students in collaborative learning strategies. Existing technologies also display mathematics without necessarily showing the link to real world

[1] GeoGebra is a dynamic software that graphically displays geometry, algebra and statistics.

applications of mathematics. However, these tools do make mathematics visually more appealing. It is generally agreed that there is a need to create a resource for students that is goal-oriented (Abuhamdeh and Csikszentmihalyi, 2012), and targeted towards peer learning. It is important to note that teaching and learning can be facilitated by technology as a tool for specified learning goals (TIMSS, 2011). Technology has the potential to facilitate goal-specific learning, and in particular, the use of digital games can bring such benefits. Adopting a goal-specific classroom may require students to work individually or with their peers. Working with peers through collaboration while using technology also brings additional and diverse challenges to the classroom. A game can potentially involve collaboration with peers and promote the desired learning in the mathematics classroom. As shown in the next section textbooks are still being used as the main resource for teachers and although these can aid the learning process, they may not envelope all the desired characteristics and learning strategies that capture real life.

In terms of teaching and learning tools, textbooks still play a vital role in classrooms. Often they can be criticised for not encapsulating the culture of the mathematics classroom and instead emphasising a disciplinary approach to the teaching and learning of mathematics (Conway and Sloane, 2005). Recommendations for textbooks to support the teaching and learning of mathematics involves the inclusion of resources that include problem solving, photographs, figurative representations, biographies, career information and narration about people. These include some of the insights from research carried out by O'Keeffe (2011). Heretofore, textbooks mainly supported rote-learning methods and with the adoption of new curriculum and strategies they have evolved to include problem-solving techniques and approaches. O'Keeffe (2011) recommends the use of resources to support the teaching and learning of mathematics and these involve opening up the classroom to use more than the textbook as a resource. Therefore, looking at the potential of other resources to provide support for the teaching and learning of mathematics needs to be explored in this context.

GBT and games can offer a useful resource for engaging students in mathematics and further research is needed in this area (Shin, Sutherland, Norris and Soloway, 2012). Current research offers evidence of the benefits of the use of GBT to engage students in different subjects. However, international research tends to focus on different subject choices such as English literacy (Homer, Kinzer, Plass, Letourneau, Hoffman, Bromley, Hayward, Turkay and Kornak, 2014) or lower levels of mathematics that aim to integrate such technologies at primary level (Isbister, Karlesky and Frye, 2012). Previous research also state the need to investigate GBT as another dimension to technology (Kenny and McDaniel, 2011) and its possibilities to engage students. The weaknesses of previous studies relate to investigations of already Commercial-Off-The-Shelf (COTS) software, where the main aim of the software is not necessarily educational. Heretofore, research has been conducted using COTS software, it is now the time to create software built for the purpose it is intended for, the mathematics classroom.

Game fantasy, learning support features and game-based pedagogy as well as a learning environment conducive to Game-Based Learning (GBL) can help trigger deep learning. Therefore, it is important to integrate a situated game story within the game, include supporting features and integrate game-based pedagogy while designing a game. Ke (2008) concludes by stating that there is a need for more research in game design for the mathematics classroom and a focus of games specifically for learning. Games often need to straddle between learning and game goals and this tends to break flow (Ke, 2008). As mentioned by Ke (2008) anything that is external to the game can interrupt the flow of the game.

1.1.2 Gesture-Based Technology (GBT)

Motion-sensing devices or Gesture-Based Technology (GBT) in the form of the Nintendo Wii, Xbox Kinect and PlayStation Move have not been explored in terms of GBL strategies in the Irish context or specifically within the Irish Mathematics classroom up to now. For the purposes of this study, GBT refers only to the Nintendo Wii, Xbox Kinect and PlayStation Move. The WiiMote is specifically intended to make these GBT devices more familiar to the non-game playing public by using it as a remote (Pearson and Bailey, 2007). The WiiMote is a one-handed remote control design that includes a sensor that is able to detect 3D motion. The Xbox Kinect uses the body as the controller and usually detects movement with hand signals. The PlayStation Move mirrors the WiiMote in that it is a remote that is detected via the colour of the top of the Move. This form of technology is novel compared to using more traditional and conformist technologies, such as an interactive whiteboard, in that it brings a host of innovative strategies and challenges for teaching and learning. It is a new venture in technology integration and the remainder of this section gives a brief insight into the existing research on the integration of these Gesture-Based Technologies into the classroom.

In terms of different disciplines, the Kinect and other motion-sensing technologies have shown promise in terms of promoting and supporting improvements in reading and subject disciplinary literacy. Research has indicated that reading and so literacy development using these devices can be interesting, engaging and support the acquisition of language and literacy of children (Homer *et al.*, 2014).

1.1.3 Other Gesture-Based Technologies

Other Gesture-Based interactive agencies are mobile devices and tablets. The potentail for the development and implementation of GBT games on or using these devices is not the focus for this thesis due to the short time frame for the case study. The process of development of the Gesture-Based (GB) games is extensive and the researcher has published previously on the potential for the integration of these devices into the classroom when she was employed in industry (McNamara, 2013, McNamara and Paolucci, 2014, McNamara and Paolucci, 2016). Development of suitable GB interventions can delay classroom implementation and are not guaranteed to be available through normal purchasing channels, such as the Apple, Windows or Google store.

1.1.4 Games in the classroom

Existing research shows that games give an opportunity to teachers to use different and innovative teaching strategies in their classrooms. With the rapid advancements of technology in the area, suitable and adaptable games are now available on a broad range of platforms. With the advent of mobile technologies, games can be offered on students' own devices, thus reflecting the continuous and rapid changes in both the technologies and their availability.

In a group of pre-service teachers, a study carried out by Kenny and McDaniel (2011) shows the positive effects the Nintendo WiiMote had on teachers in terms of adopting and integrating video game play into their classroom. It also adds another additional dimension within the Technological Pedagogical Content Knowledge (TPACK) framework[2] - this is described in more detail in chapter 2.

A recent unpublished thesis shows the need for research in the area of motion-sensing technology like the Wii or PlayStation Move to build on research in the field and show its influence on society and more specifically teaching (Bourgonjon, Grove, Smet, Looy, Soetaert and Valcke, 2013, Bourgonjon, 2015). In relation to mathematics, research shows that the Kinect can be used for kinaesthetic learning and offers a new mathematical learning experience for students (Ayala, Mendívil, Salinas and Rios, 2013). These technologies introduce novel ways of learning through their design elements and they have the potential to enrich, enhance and support student learning (Homer *et al.*, 2014).

1.2 Scope and Significance of the Research

As mentioned in the background to the research section above, mathematics curricula has undergone siginficant changes in recent years. From the above, it is evident that there is still a need to support the implementation of Project Maths and constructivist teaching approaches. More resources are needed to engage with real world problem solving. From a technology perspective there are still improvements that can be made to engage and encourage students in the mathematics classroom.

[2] TPACK encapsulates all three components (pedagogy, technology and content) and forms the basis of effective teaching while utilising technology (Mishra and Koehler, 2006).

In conclusion, there are many reasons for undertaking this research. These include: the recent curricular shift in the Irish education landscape, teaching development practices such as the promotion of constructivist approach to teaching and learning as well as an emphasis on the appropriate integration of technology as a learning tool within the classroom. In parallel, current digital and textbook resources lack a certain novelty in relation to their adaptability to goal setting and peer collaboration in the classroom. International studies show that games provide possibilities of engaging students in new and meaningful ways. These have yet to be explored using GBT in the Irish context. With the advent of Project Maths, providing resources that engage with real world problems and adopt a social constructivist classroom are needed in the mathematics classroom.

This research undertaken by the researcher addresses the problem that a purpose built game targeted at addressing the key challenges of classroom implementation along with investigating the design features that inform its creation. This research is exploratory and addresses whether GBT games have potential as a tool in the mathematics classroom. In the international field of mathematics education, this research contributes to the resources and potential for other resources for the mathematics classroom.

1.3 Aims and Objectives of the Research

The aim of this research is to develop a Gesture-Based game and investigate the key design elements, challenges, potential and design features that inform its creation. The following are the research questions for this case study research.

1.3.1 Research Questions

The research questions asked in this case study are:

- What are the key design elements of a Gesture-Based game and the key challenges for mathematics classroom implementation?
- What is the potential for a Gesture-Based game to be used as a tool in the mathematics classroom?

- What design features inform the creation of a Gesture-Based game in the mathematics classroom?

These entail investigating the development and design of a mathematical game while understanding the potential of this game as a tool for the Irish mathematics classroom. It is important to note that design also encompasses two meanings – firstly, the design of the game, which includes a focus on usability and human computer interaction, and secondly, the design of the game for classroom use which focuses on its application and use. In grasping the nature of design and development of the game – Maths Mission, this thesis undertakes development of a GBL solution that uses the Gesture-Based technology for use within the mathematics classroom.

1.4 Research Design

Recent changes in the curriculum and the encouragement to use constructivist teaching practices in the mathematics classroom has highlighted the need for resources. To establish its potential a proof-of-concept was initially developed in order to gain an insight into teachers' perspectives towards GBT and GBL. Research was carried out using a case study approach and adopting mixed methods. The study was split into four phases explained in more detail in chapter 3. The following sections describe each phase of this research project.

1.4.1 Phase one

Phase one demonstrates and examines the capabilities of GBT with a pilot game that envelopes Statistics, Integers and Probability (SIP). This pilot game known as SIP flight uses the WiiMote. It uses it to throw a dart at a dartboard. This phase provides results from a group interview and examines the feasibility of the overall GBT in the mathematics classroom in Ireland. Upon examining the capacity to build this proof-of-concept, phase two initiated the rest of this doctoral study.

1.4.2 Phase two

Phase two of the study begun as a result of carrying out phase one. Phase two focused on gathering students' perspectives towards mathematics and confirm understandings of their career interests. The design and theoretical framework was guided by Trends in International Mathematics and Science Study (TIMSS) and Expectancy-Value Theory (EVT) explained in more detail in chapter 3.

1.4.3 Phase three

Phase three focuses on the software development, software implementation phase of the study as this phase concentrates on the development of Maths Mission. The results are taken from the survey questionnaire and the literature review on GBL acts as design heuristics for the creation of Maths Mission. Phase three comprised of three stages. The first phase focused on design and learning, the second on identifying the best game engine and identification of learning outcomes while the third on the development of the game and classroom implementation.

1.4.4 Phase four

After the initial pilots in phase three, phase four of the study looks at the emergent cycles of improvement of the game. Phase four presents the data collected from each school visit and the continuous improvement of Maths Mission as an outcome of data collected from teachers and students in these schools.

The diagram (Figure 1) shows each phase and its successive phase along with each stage. Phase four is contains multiple stages similar to the others, however, this phase repeated classroom implementation in five schools.

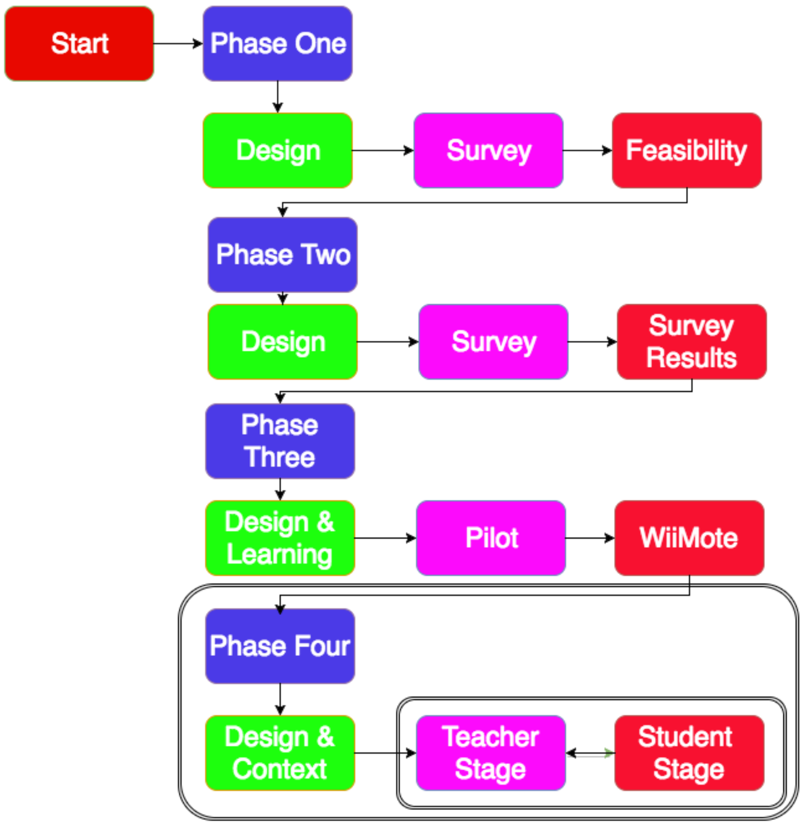

FIGURE 1 - AN OVERVIEW OF THE FOUR-PHASED RESEARCH DESIGN IMPLEMENTED IN THIS RESEARCH PROJECT

1.5 Theoretical Framework for Game Design

The theories used within this case study research enable the development of Maths Mission[3] as a GBT game. The framework was developed as part of the outcome of the literature review and is unique as it combines GBL strategies with design and theoretical framework. Overall the theoretical framework for game design is used as the design heuristics to develop Maths Mission.

The theoretical framework for game design draws on multiple theories including motivation, collaboration, flow theory and engagement. The framework used in this study relate to concepts of motivation, engagement, interest, expectancy to succeed and collaboration. Motivational theory is used to guide both the game development and the survey questionnaire. These theories include interest and achievement motivation which both consist of intrinsic motivation. The theories used for survey development draw upon TIMSS and EVT as mentioned above. Both of these theories guide the examination of the student context in terms of students' level of enjoyment of mathematics and perceptions of usefulness towards mathematics. Ultimately, TIMSS draws from interest, confidence and engagement with mathematics theories that cross over with EVT. The questionnaire sought to capture students' attitudes, motivations and perspectives and so sought to inform the game development at this time. GBL theories are used to guide the design of Maths Mission as these are needed to form a game. The characteristics of a game are summed up as having rules, goals, feedback, a challenge, a form of interaction and a narrative. Each one of these characteristics pulls from theories such as the growth mindset and flow. These theories are discussed in more detail in chapter 3 – theoretical framework for game design.

[3] The game developed as part of this doctoral research will now be referred to as Maths Mission for the rest of this thesis.

1.6 Research Methodology

This case study research aims to support the implementation of Project Maths by investigating the design and development of GBT games as a way to enhance collaborative learning in the Irish mathematics classroom at post-primary level. As mentioned above, there are many benefits to adopting games within the classroom – collaboration, constructivist learning and enhanced interactions. Therefore, this case study includes the development of the game from initial development to classroom implementation.

There are a number of different layers to this case study. The first is an investigation of the design of a purpose-built game for mathematics education. The second is an investigation of the application of a GBT game. The third is an exploration of the potential of the GBT game as a teaching and learning tool in the Irish mathematics classroom context.

1.7 Description of Terms Used Throughout the Study

Multiple terms are used throughout the course of this research. In an effort to aid the reader these terms are described in this section. An overview of mathematics at post-primary level is first described.

Mathematics is split into three levels at post-primary level, one of which cannot be used as a form of entry to third level. The three levels, foundation, lower and higher level are differentiated in terms of challenge and content. Within the central application system for University places, additional points are allocated to students undertaking Leaving Certificate higher-level mathematics[4].

Two examinations occur throughout post-primary education: the first state examination is taken after a student undertakes three years of study – the

[4] Each applicant's subject percentages are converted to points for the purposes of the Leaving Certificate examination. These points are then used as entry to third level where all the points across six subjects are added and this figure is used competitively with other applicants' points for entry into a preferred programme or course

Junior Certificate; the second state examination is taken after two further years of study – the Leaving Certificate.

- Junior Certificate

This examination is currently being replaced by a new principle-based curriculum - the Junior Cycle - with an emphasis on developing key skills, integrating technology and reform to existing methods of examination within the subjects. As Project Maths replaced the curriculum for mathematics in 2011, the mathematics examinations will not be updated to the new format immediately. It will still be examined in the older format with two examinations at the end of the three-year period. The Project Maths curriculum at Junior Certificate promotes and emphasises a linkage between the Primary Curriculum and Junior Certificate Curriculum. There is a need to establish a cohesive link between the mathematics learnt at primary school and the mathematics at post-primary school. A bridging framework is available to bridge the gap between primary curricula and post-primary curricula and establish links between the two curricula (Brosnan, 2008).

- Leaving Certificate

The second state examination is taken after another two years of study – the Leaving Certificate. The Leaving Certificate results are used for matriculation to higher education (third level) and application is through a central system for all Higher Education Institutions whereby the results are converted to points and entry to programmes is dependent on demand in any specific year.

- Game-Based Learning (GBL)

Game-Based Learning is a set of characteristics used within a game in order to engage players in the learning process. These characteristics are described in chapter 2.

- Gesture-Based Technology (GBT)

For the purposes of this thesis, Gesture-Based Technology refers to the PlayStation Move and Nintendo WiiMote. A detailed definition is given in chapter 2.

- Classroom implementation

Classroom implementation is when Maths Mission is being used in the mathematics classroom.

- Software implementation

The implementation of software is the development of the technical solution. This term refers to the final stages of software development after the initial stages of requirements gathering and design, implementation is the software development of the solution before verification and maintenance if you follow the waterfall software development model process. In terms of agile software processes, software implementation can be the integration testing phase of the cycle whereby design and development can occur together.

1.8 Overview of Thesis Chapters

Chapter 2: is a review of the current literature regarding GBT, GBL, technology in the classroom and the mathematics classroom. Throughout this chapter the researcher highlights the need for developing a Gesture-Based game for the mathematics classroom and show the plethora of benefits and challenges occurred by previous studies.

Chapter 3: defines the theoretical framework for game design and describes the theories used in the study. These theories include those that were used as design heuristics for the development of Maths Mission as well as TIMSS and EVT used in the survey development.

Chapter 4: describes the research methodology used in this study and the rationale for using the case study approach.

Chapter 5: provides an overview of phase one of the study. This chapter describes SIP flight, a proof-of-concept Gesture-Based game for the mathematics classroom and pilot studies carried out in order to test its feasibility. These preliminary studies consist of survey questionnaires and group interviews. The conclusion was to continue to develop the study further based on the results of phase one.

Chapter 6: describes phase two of the study. This chapter describes the survey questionnaire development using the TIMSS and EVT theoretical frameworks in order to confirm students' career interests.

Chapter 7: is concerned with the development of Maths Mission. This chapter presents findings regarding a cost-benefit analysis of technology, the development using the design heuristics and two classroom implementations.

Chapter 8: explores classroom implementations in five different schools. Findings per school are presented along with each school background context, which aids the reader gain an understanding of the classroom environment. It is important to consider each context as this shows the different landscape in which this study was carried out. In describing each of the schools, it also highlights the strengths and weaknesses of student engagement in each by showing the student survey questionnaire results.

Chapter 9: discusses the results that were gathered in the phases of the study. Each school contributed to the different key elements incorporated in Maths Mission. Maths Mission was continuously improved throughout each classroom implementation until the final school whereby it was tested several times.

Chapter 10: concludes the study by giving a brief summary, highlighting key findings and finally drawing the main conclusions of the research.

1.9 Biographical Motivation

Previously, the researcher worked in the area of educational technology developing digital resources for the Irish mathematics classroom. These resources are still currently on the market as part of the Project Maths curriculum and are sold with the textbooks for teachers use only. The researcher had seen a need for resources for students and observed the growing trend of educational technology in Ireland. Being the first person employed in the area of educational technology in a book publisher, it was evident that this was an important growing area of activity within the industry. The researcher observed the way in which digital resources were made for teachers' use and the deficit of student learning technology-based tools.

Upon gaining this insight the researcher put forth a research proposal to the School of Education with the intention of undertaking doctoral research. Having conducted research in the area of knowledge management at masters' level, the researcher was thrilled to be able to focus in the area that can make a difference in post-primary schools.

One of the key features of working with this technology in an area such as GBL is the ability to harness the technology for use in the area of mathematics education for the Irish post-primary classroom. With the advent of the new Project Maths curriculum that emphasises the mathematical discussion and justification of answers when problem solving, it was evident that there was a need for an innovative approach that could be used to encourage a positive and supportive engaging environment that encapsulates the desired learning and teaching approaches within the curriculum.

Chapter 2: Literature Review

2 Introduction

This literature review chapter outlines this multifaceted case study research. There are a number of aims for this chapter. These are to define Gesture-Based Technology (GBT) and what it is within the discipline of education, define GBL and look at its benefits, investigate technology in the classroom and factors that influence technology use. Overall the concluding section of this chapter ties together these aims and forms the reasoning for undertaking this research and the research questions.

The research questions are multifaceted and draw upon each of these aims discussed in this chapter. The following three questions are asked:

- What are the key design elements of a Gesture-Based game and the key challenges for mathematics classroom implementation?
- What is the potential for a Gesture-Based game to be used as a tool in the mathematics classroom?
- What design features inform the creation of a Gesture-Based game in the mathematics classroom?

The multifaceted nature of this research can be summed up in figure 1 below.

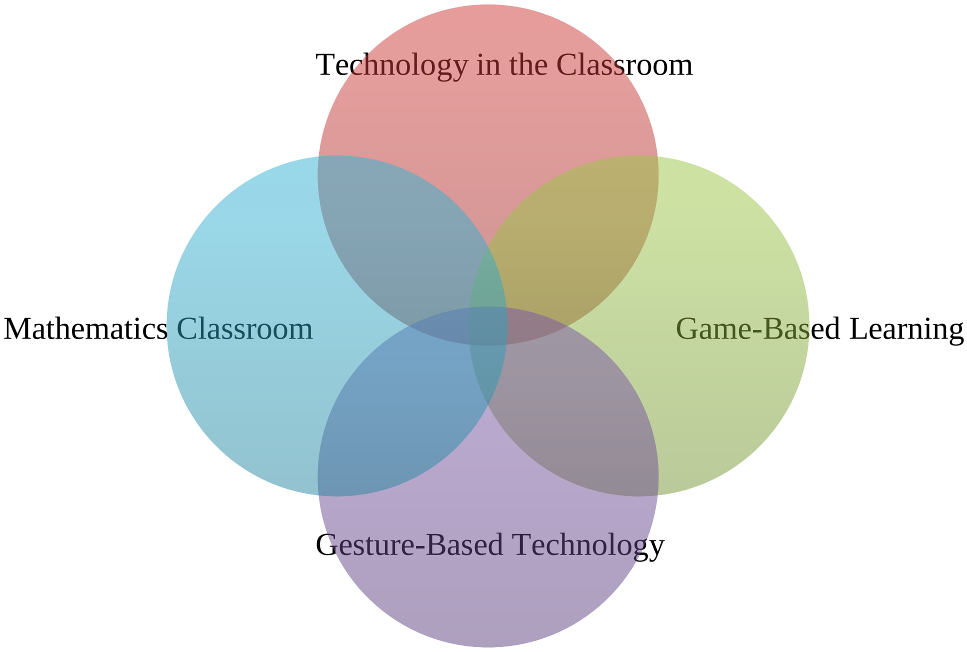

FIGURE 2 - MULTIFACETED RESEARCH

As shown within figure 2, the central focus of this research is the Gesture-Based game. This is not to be confused with GBT and GBL, both of which can be defined separately. On the one hand, GBT can be seen as the technology, the tools used for implementation within the classroom. GBL, on the other hand, can be both digital and paper-based and bring with it a range of advantages for classroom use. The subsequent sections define GBT and GBL.

2.1 Defining Gesture-Based Technology

GBT is technology that uses gestures as input to a computer or games console. GBT started as a concept from John Underkoffler, the Science Advisor, for films such as Minority Report. This film which was released in 2002 sparked the idea that computers could be controlled using a gestural input. Since then, much research has been done involving novel computer interfaces based on 3D motion capture. The Massachusetts Institute of Technology (MIT) released a video online in 2010 demonstrating a low-cost alternative and while developing the technology itself is not the purpose of this thesis, figure 3 below shows its potential. Students are able to manipulate objects on the screen without necessarily needing the objects within the classroom. As shown in figure 3, a coloured glove is placed on the student and no objects are on the desk. The student can then manipulate objects on-screen including assembling a wheel.

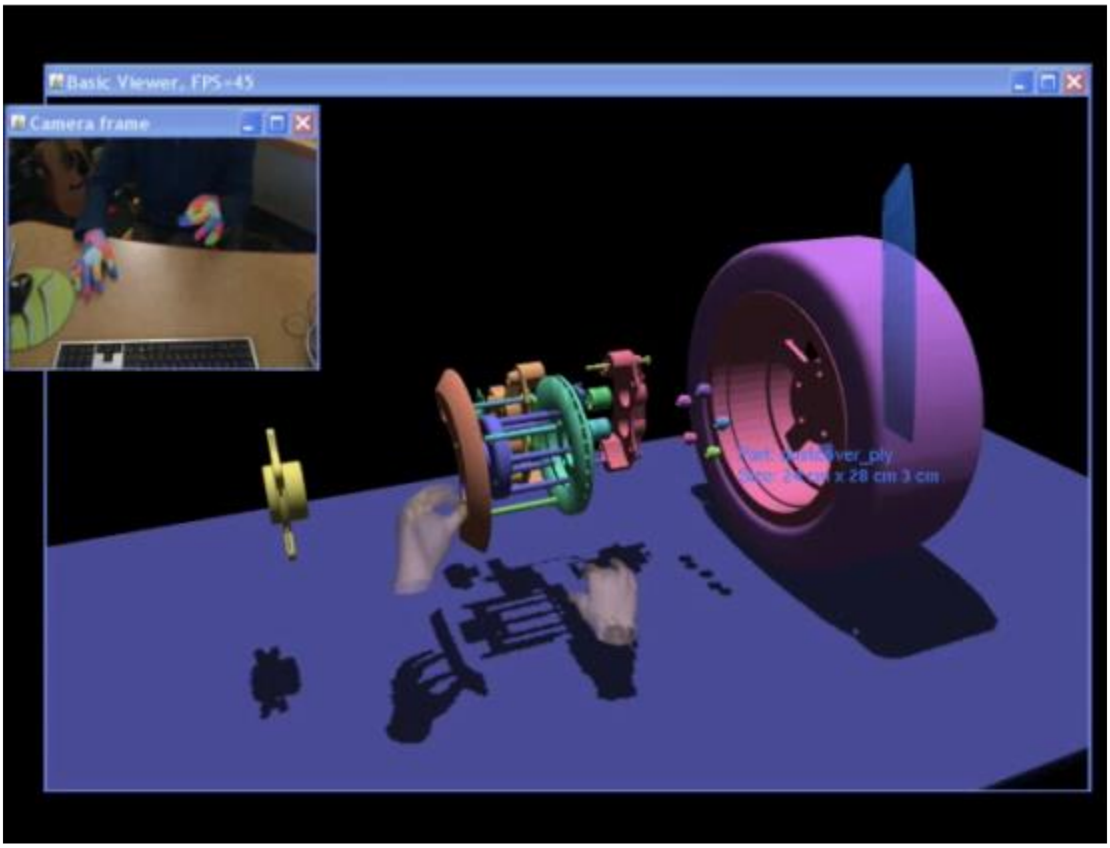

FIGURE 3 - MIT GESTURE COMPUTING - HTTP://NEWS.MIT.EDU/2010/GESTURE-COMPUTING-0520

In this research, three different gestural inputs are discussed including devices that allow these such as - the Sony PlayStation[5] Move, Microsoft Xbox Kinect and Nintendo Wii. The Nintendo Wii and Sony PlayStation Move both use handheld devices to detect this movement. However, the Microsoft Xbox uses the body as the main input device instead of using a handheld device. Figure 4 shows the two handheld devices used by the Nintendo Wii and PlayStation. These technologies associated with gestures through the use of the body either with a handheld device or otherwise fall into the realm of GBT, also known as Gesture-Based computing.

[5] The PlayStation refers to both the PlayStation 3 and PlayStation 4 as both of these are compatible with the PlayStation Move device.

FIGURE 4 - NINTENDO WII AND PLAYSTATION MOVE

In 2011 the Horizon report drew testimony its potential in education.

> *"Gesture-based computing has strong potential in education, both for learning, as students will be able to interact with ideas and information in new ways, and for teaching, as faculty explore new ways to communicate ideas. It also has the potential to transform what we understand to be scholarly methods for sharing ideas." (Johnson, Smith, Willis, Levine and Haywood, 2011, p.25).*

The Nintendo Wii went on sale in 2006 and this report was presented in 2012. As shown in the quotation above, GBT forms a way of interacting with technology in alternative means and facilitates new forms of communication. Communication is a foundational element of the required learning approach as advocated in the new curricular guidelines from Project Maths (Brosnan, 2008). GBT, when harnessed in the classroom correctly, may have the ability to aid the teaching and learning processes of the mathematics classroom. The technology has been around since 2006 and now is the time to test its capabilities within different settings. GBT was addressed again in 2012 in the higher education report noting that GBT 'has enabled students to learn by doing' (Johnson, Adams, and Cummins, 2012, p.7).

The WiiMote is specifically intended to make these GBT devices more familiar to the non-game playing public by using it as a remote (Pearson and Bailey, 2007). The WiiMote is a one-handed remote control design that includes a sensor able to detect 3D motion. The Xbox Kinect uses the body as the controller and usually detects movement with hand signals. The PlayStation Move mirrors the WiiMote in that it is a remote that is detected via the colour of the top of the Move. This form of technology is novel compared to the common learning tools today in classrooms, such as the interactive whiteboard, and brings a host of different challenges when being implemented into the mathematics classroom. The following section outlines existing research regarding GBT.

2.1.1 Existing Gesture-Based Technology

The Nintendo Wii has gained high esteem in the past as being the most successful games console ever to be sold (Nintendo, 2013). Nintendo released the Nintendo Wii in 2006 and has seen great success with the games targeted to people of all ages (Nintendo, 2013). In competition with Nintendo, Sony released the Sony PlayStation Move in 2009. Both devices use gestures as the user input. Microsoft also released a version of motion sensing GBT in the form of an attachment to their Xbox console. This attachment known as Xbox Kinect was released in 2010. The Kinect is different as it uses the body to control the games instead of a remote control carried by the player.

2.1.2 What Gesture-Based Technology is not

The New Media Consortium defines GBT and this is used to guide this research. The following quote taken directly from the report gives an example of how GBT is to be interpreted for the purposes of this research.

> *"Gesture-based computing moves the control of computers from a mouse and keyboard to the motions of the body, facial expressions, and voice recognition via new input devices. It makes interactions with computational devices far more intuitive and embodied. From the touchscreens on smartphones to the gesture and voice interpretation of the latest gaming systems (Xbox Kinect and Nintendo Wii) and virtual assistants, gesture-based computing enables users to learn by doing and facilitates the convergence of a user's thoughts with their movements. Large multi-touch displays support collaborative work, allowing multiple users to interact with content simultaneously." (Johnson, Adams and Cummins, 2012, p.8)*

As Johnson, Adams and Cummins (2012) states GBT moves the control from the mouse and keyboard to more interactive inputs. As they point out, GBT can enable users to learn by doing and support collaborative work with multiple users. Therefore, GBT for the purposes of this thesis is not simply the input/output of a device such as a mobile device. As this research focuses on gaming and GBL, it will focus on gaming systems as per the definition above, which include the PlayStation Move and Nintendo Wii. It is the need to engage the body and interact with the system in a novel way. Other such uses within education are described in the following section.

2.1.3 GBT and Education

Researchers purport benefits to using novel devices in the classroom, these include improved reading comprehension and improved attitude towards mathematics and school (Miller and Robertson, 2011). In a group of pre-service teachers, a study carried out by Kenny and McDaniel (2011) shows the positive effects the Nintendo WiiMote had on teachers in terms of adopting and integrating video game play into their classroom. This study showed that research in this area needs more attention and that the WiiMote is a psychomotor game with potential implications for learning. Kenny and McDaniel (2011) state that teacher-training programmes should not only include at least one technology course but also include a focus on how to integrate and evaluate the technologies as supporters of learning in the classroom. This might address some of the key challenges surrounding novel technologies being adopted within the classroom and the increasing demands on teachers to keep up with the growing trends.

While the purpose of this research is to develop a Gesture-Based game for the mathematics classroom there is scope for such technologies to investigate gestures in more detail and to recognise their support for a student's ability to learn. Gestures can play a significant role in our understanding of mathematics. Hostetter and Alibali (2008) note the visible embodiment of understanding of concepts. Gestures are also said to lighten the cognitive load when interpreting data and are seen as a central role in understanding cognition (Yoon, Thomas and Dreyfus, 2011). GBT games have been studied and positive claims have been made with regard to their potential in different aspects of learning such as improving literacy using games on the Kinect (Homer *et al.*, 2014). Their study suggested that the Kinect brought high engagement and interest in digital literacy for young children when using Kinect based activities and these can support language acquisition and literacy.

Using the Kinect may also impact upon memory performance. Embodied cognition is an area of learning science that focuses on the environment playing a role in cognitive processes. Chao, Huang, Fang and Chen (2013) found that when learning action phrases using the Kinect, the individuals did better than mouse-based activities and that physical interaction with real objects enhanced participants encoding of these action phrases. Another study using the Kinect for mathematics is Isbister, Karlesky and Frye (2012) as they focus on the potential of these technologies to reduce anxiety towards mathematics.

Isbister *et al.* (2012) showed that GBT in the mathematics classroom can be harnessed to reduce mathematics anxiety and improve self-confidence. The research carried out distinguished between physical movements that were traditionally confident postures and that GBT physically imposes these postures to the players who participate in the mathematics game. As described by Isbister *et al.* (2012), confidence is a remedy to anxiety.

The development of certain GBT using different devices such as the Kinect has led researchers to focus on areas such as kinaesthetic learning as a way to understand mathematical concepts. Ayala *et al.* (2013) explored ways of developing a GBT for a college mathematics course. They succeeded in developing a system that planned to improve students' learning of graphical concepts.

Kinect has also been explored through embodied interactions using software similar to that of GeoGebra for engaging junior and senior high school students (Johnson, Pavleas and Chang, 2013). The study helped participants to relate abstract concepts to physical movements and associate algorithmic equations with their graphical representations. The Kinect was used to help students interact with abstract objects, engage students' interest and enjoyment and demonstrate connections between algorithmic equations and graphical representation. Results have shown that the implementation has been positive, however, this particular study explored more relating to the interaction itself through observation. It was concluded that the Kinect provided a motivating opportunity for students learning mathematics.

The Nintendo Wii controller or WiiMote as it is referred to in this thesis has also been explored as a way to measure car speeds using GlovePie[6] technology. This method of applying this technology demonstrates one way of developing a game using the WiiMote. The next section defines GBL and where it is in relation to GBT.

2.2 Defining GBL

Games[7] started gaining traction in the marketplace in the 1980s and due to researchers looking mainly at its potential proposals were developed around how these could be used within the classroom (Gros, 2015). For games to be thought of as learning tools they need to encompass good gameplay, be social and have a goal (Beavis, 2015). Although gameplay is a key component of GBL there is no formal definition associated with gameplay (Kiili, 2005), however, play and games are both discussed in the section below. Therefore, it is important to look at how games are viewed as this novel technology was adopted into schools. Initially games focused on their affordances to the student and this aimed mainly at video games, Commercial-Off-The-Shelf (COTS) games that could be retrofitted or reverse engineered into a lesson plan. It took an increasingly diverse range of platforms and variation of games to make its way slowly into a classroom setting (Beavis, 2015). In stating this, this thesis focuses on the Gesture-Based Technology as the platform[8] used within this thesis. Educational games bring together both education and games for the purpose of supporting teaching and learning of a topic. It is still a new area and as shown by Hwang and Wu (2012), it is a growing field that incorporates many different levels of education, subject areas and contexts.

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[6] A software used to connect a computer to the WiiMote.

[7] For the purposes of this research games that are being referred to are only digital games and do not make reference to paper-based or traditional games.

[8] It is important to remember that platform is used to describe the technology used and can incorporate software and hardware.

Hwang and Wu (2012) examined educational games, also known as serious games, for their public effectiveness. The articles examined looked at a range of topics and little research covered GBL and mathematics education together. They examined 137 articles from seven major educational technology journals that indicate the distinct rise in GBL articles from 2001 to 2010. Studies examined looked at various topics across various levels of schooling from primary to University level. In these studies examined by Hwang and Wu (2012), they state that researchers generally accept that students were the main users of computer games and therefore teachers were rarely considered for the research samples. In terms of the most research with respect to public effectiveness, the top three countries were USA, England and Taiwan that are at the forefront of publications in the GBL domain. Hwang and Wu (2012) show the learning domain based on these articles and only one article was produced in the area of mathematics within the first five years. Although the purpose of GBL is to support teaching and learning of a topic with the use of video games, it draws upon many theories that are well known to educators some of which are discussed further in the following section.

As mentioned earlier, GBL focuses on gameplay and there is no formal definition for this (Kiili, 2005). There are also differences between play and games that needs to be explored. Play is an inherent part of early childhood education as children learn to manipulate different objects around them and research their boundaries. Play can be defined as

> *'a free activity standing quite consciously outside "ordinary" life as being "not serious", but at the same time absorbing the player intensely and utterly. It is an activity connected with no material interest, and no profit can be gained by it. It proceeds within its own proper boundaries of time and space according to fixed rules and in an orderly manner. It promotes the formation of social groupings which tend to surround themselves with secrecy and to stress their difference from the common world by disguise or other means'*
> *(Salen and Zimmerman, 2006).*

Huizinga did not differentiate between play and games as they evoke the same needs and psychological attitudes (Salen and Zimmerman, 2006). Klopfer *et al.* (2009) agrees with Huizinga in that play is free, however, focus on these freedoms draws on research in early childhood education. Play and freedom to fail is when a child might create stacks and knock them down. In another context this may be seen as failure. It is to be noted that an individual's play is not simply reproducing what they have experienced but a reworking of the experience into something that is understandable (Vygotsky, 2004). Klopfer, Osterweil and Salen (2009) reiterate the five distinct axes of play. These are the:

- Freedom to fail;
- Freedom to experiment;
- Freedom to fashion identities;
- Freedom of effort; and
- Freedom of interpretation (Klopfer, Osterweil and Salen, 2009).

Play invokes a form of investigation and Vygotsky (2004) describes play as a means to draw experience from the world around us and to experiment. Playful learning is an exploration through interaction and also reflection. Playful learning is also a must for creativity to occur (Sullivan, 2011). GBL may be considerd as a form of playful learning.

It is important to distinguish between GBL and gamification. GBL refers to using a video game in order to support the teaching and learning of a subject or topic. It can be a small fraction of an entire pedagogical model or a component of the overall learning process (Gros, 2015). It includes a goal, challenge, incentives and immediate feedback. Gamification, on the other hand, can refer to changing the instruction mode to incorporate features of games (Gros, 2015). When defining games as an immersive activity to achieve a certain goal with rules, there are certain characteristics of GBL aside from games and digital resources that need to be considered. A number of features resonate only with GBL. Prensky (2006) outline these as the following:

- Rules
- Goals
- Feedback
- Challenge
- Interaction
- Narrative (Prensky, 2006)

These features are necessary for a game to be a learning tool. Each of these features are now described briefly.

The rules imposed on a player can outline the boundaries of the game or they may also determine the necessary tasks that the player must undertake to accomplish a specific goal. Therefore, rules can be two-fold, one for the game in order to 'play' it and another that outlines how the game operates in order for the player to interact with the game, in other words, for the player to progress through the game and therefore potentially progress in learning.

Goals form the basis of a game and by their nature games can be collaborative and so appear to be a natural fit for the Irish mathematics classroom where collaborative learning is encouraged - this is discussed in the latter stages of this chapter. Collaborative learning encompasses goal-directed learning whereby students participate in an activity focusing on a defined goal/outcome, whereby students explore ways of getting to that goal in a group (Mascolo, 2011). Goals can be split into performance and learning goals (Grant and Dweck, 2003). Performance goals are related to ability and are said to be egocentric goals. These tend to validate one's ability and can be subdivided into performance approach and performance avoidance goals. Learning goals on the other hand relate to the acquisition of a new skill or more knowledge (Grant and Dweck, 2003). The former performance goal refers to how individuals attain success while linked to an individual's ability and is explicitly normative in nature, focusing on 'doing well' in the outcome. The latter refers to avoidance of failure, this is inherently negative, it is also ability linked and may serve as a predictor of lower motivation and performance (Grant and Dweck, 2003).

Each study carried out by Grant and Dweck (2003) examined the differences in how performance and learning goals were determined. The study looked at students and saw differences in terms of how these goals were understood. Performance goals were not effective for students who were not doing well. These goals were only effective when the student was already doing well. Learning goals predicted more active engagement of students and strategies used when interpreting a setback (Grant and Dweck, 2003).

Mastery and growth are the focus of learning goals. Learning goals refer to the development of growth and competence and are operationalised by emphasising the importance and benefits of learning some skill or knowledge. Learning goals can predict planning but is also attributable to effort associated with intrinsic motivation and mastery-oriented coping mechanisms.

Learning goals can be split into two subcategories 1) striving to learn and develop and 2) seeking to master challenges. Goal orientation can act as a source of motivation for the learner (Clark and Feldon, 2005). A person who is guided by mastery-orientated goals is not necessarily linked to comparison with others. Grant and Dweck (2003) argue that many studies conducted in the area of achievement motivation include discrepancies and it is difficult to draw comparisons between studies that do not show how performance and learning goals are determined. Feedback is necessary to accomplish a goal and facilitates the participation of the player.

Two types of feedback can be accommodated with a game; feedback to the player by the way of controls in terms of the technology being used correctly and feedback in terms of the learning outcomes. Feedback can be summative in the form of a score or result and formative in the form of verbal guidance to help the player progress through the levels of the game. All forms of feedback within a game can be immediate. The summative score or result can appear on screen instantly and the verbal feedback either visually or by audio happening instantaneously as the game is played.

Therefore, feedback is understood as information given to the student in order to proceed forward and accounts for learning feedback and technology feedback via the controls. Within DimensionM (Bai *et al.*, 2013), summative feedback was presented. The player in that study knew their score and the result from their mathematical equations during the game and was therefore able to proceed through the game and onto the next level.

In summary, GBL comes with its own characteristics and challenges. A definition of a game might be that of play with rules and competition. Games are also an immersive activity. An immersive activity that requires effort by the student to achieve a certain goal, usually with rules and is enjoyable, is said to be a game. Within a game there are usually rules, structure and a goal. Play can be free in form without the need to impose rules (Salen and Zimmerman, 2006). Therefore, it may be concluded that GBL brings feature of challenge, interaction and narration into the classroom.

2.2.1 Games and Mathematics

Ke (2008) purport the many benefits to GBL and highlight the value of situating activities within games that both challenge and scaffold learners. They discuss in particular the potential of computer gaming in mathematics and engagement of learning. Within this discussion they indicate that there is a distinct lack of connection between the curricula and computer games in mathematics and therefore a lack of uptake in its use. This also connects with the guidelines proposed by Project Maths, described in the latter sections of this chapter, where it is acknowledged that resources need to be in line with the learning outcomes in the syllabus. As mentioned in the introduction, Commercial-Off-The-Shelf (COTS) games are usually not intended to be educational and learning tools. A direct link to the curriculum is important; however, straddling the learning goal and the game goal can be challenging for designers and developers of games.

DimensionM was investigated by Bai *et al.* (2013) using Franken’s (1994) motivational theory, which looks at three important components: arousal, direction and persistence. Mission goals were set to arouse the curiosity of the learner. Bai *et al.* (2013) state that there were limited empirical studies that looked at the effectiveness of computer-based instructional games in mathematics education. The purpose of this study was to understand if DimensionM actually improved eighth graders' (this is the equivalent of second year in post-primary Irish education) algebra achievement scores. The study investigated if the game increases their motivation in mathematics learning. The study used a quasi-experimental design using 445 eighth graders in a public school district in the southeast of the United States with random assignment to each group. The experimental group (n=245) and the control group (n=192) were examined over an eighteen-week period. A high-quality testing instrument, a benchmark test was used as a pre and post-test. The second instrument used the Attention, Relevance, Confidence and Satisfaction (ARCS) questionnaire (Keller, 1987) to look at motivation. Relevance refers to students' perceptions of the activity while personal need and confidence refers to whether a student needs to succeed in that activity.

The findings were consistent with the literature, highlighting the advantages of game play on student learning and mathematical achievement. Results also showed the sustained motivation in students after using DimensionM. Driscoll (2000) states that learning can only happen when the learner's experience can interact with the real world. DimensionM offered an insight into an opportunity that students can gain a mathematical knowledge bank and absorb knowledge through interactions with real world problems.

DimensionM offered a promising supplemental instructional tool in the teaching and learning of mathematics. However, in terms of game design, interruptions in flow can occur when new screens appear in front of the player as well as mathematical procedures interrupting the game. This is the main concern of DimensionM as the mathematics does not necessarily interact with the game to show progress and the game focuses on procedural mathematics within a 3D environment. DimensionM also offers an insight into immediate feedback; however, there was also a separate screen that could interrupt flow for the player.

An example of immediate feedback to students for procedural mathematics can be found in a study conducted by Miller and Robertson in 2011. A brief description of this study follows. Miller and Robertson (2011), in Scotland, adopted the Nintendo DS into a primary school classroom that looked at drill and practice mathematical activities through a game called *braintraining*. This game is not particularly part of the curriculum, however, it does allow students to practice existing aspects of the mathematics curriculum. They sought to find out whether using the Nintendo DS in a randomised control trial could measure the self-concept and mathematical ability using quasi-experimental control groups in the primary classroom. The researchers noted that while there is limited research available in relation to games and learning, the results of their research supported a number of findings. The attitudes towards school in the experimental group were improved. The levels of attainment reflected an inverse relationship between the ability and gains in scores and finally it was observed that gender did not seem to be a factor. Overall, the less competent individual showed the greatest gains in scores (Miller and Robertson, 2011). This study also supported the researchers' claims in terms of students adopting positive perceptions of school. This claim can relate to more motivated students at primary level. The next section looks at GBL in general with other subjects.

2.2.2 Games and other subjects

Admiraal *et al.* (2011) investigate the relationship between GBL as an educational design to promote engagement and excitement and that of persistent educational problems such as underachievement. Underachievement is characterised by behavioural and emotional difficulties that may lead to school dropout. In their study, flow theory is used as a framework to examine the relationship between the process of gaming and the effects on game performance and student learning outcomes. According to Admiraal *et al.* (2011) flow is seen as having an influence on game performance; however, flow does not have an influence on learning outcomes. It seems reasonable that the study suggests that students are engaged more when they are less distracted. These distractions inevitably will have a bearing on student outcomes.

An individual's attitudes towards computer games may include being interested, competitive, cooperative, and results-oriented as well as being active in terms of seeking information and solutions. As stated by Admiraal *et al.* (2011), gaming can produce fruitful narrative experiences that merge location, contexts and meaning. Games' producing fruitful experiences is corroborated by Bourgonjon *et al.* (2010). Students need to find the computer game useful as well as easy to use as these are both predictors of acceptance of games, however, this is also dependent on the game's purpose. There follows an example by Admiraal *et al.* (2011) showing how a game can be used for the purpose of learning in history.

In the study conducted by Admiraal *et al.* (2011), a game was used to show Amsterdam in the Netherlands as a medieval town. Teams were divided up into city teams (CT) and headquarter teams (HQT). Each individual had to score enough points to gain citizenship in the city; however, this was dependent on the status of the individual either being a beggar or a merchant. Three assignments were given based on orientation activities, imagination activities and symbolic activities. Structured observations were used. Logs by participants and activities were split into game-play, competitive and indirect activities.

The results found the HQT was more engaged than the CT and CT was more competitive than the HQT. The results suggested that the more flow in game-play and the less distractive activities (navigation and technology), the better the performance of the learner. Flow, competition, group performance and student ability, distractive activities and motivation were all significantly related to student learning outcomes. The more engaged with competition, the less distracted learners were by technology. Scaffolding the activity to be accomplishable also showed how engaged students were in the activity. Scaffolding can be an effective enabler for students to challenge themselves.

Essentially, Admiraal *et al.* (2011) focused their study on the concept of flow and collaborative GBL. Both teams showed signs of deep absorption and engagement in the activity. One of the challenges of this study was that the students were distracted by the technology. It is not enough to incorporate technology and GBL into the classroom. The game itself has to be designed in such a way that it does not distract the students from the task at hand. The results regarding students' immersion with the learning activity negates solid evidence of increased conceptual understanding. These conclusions are similar to that of Annetta *et al.* (2009).

Annetta *et al.* (2009) investigates the impact of a computer-based game on understanding and engagement in learning genetics. Annetta *et al.* (2009) posit that participants' level of engagement increased by a significant difference when using a game. Annetta *et al.* (2009) postulates that because the computer-based game MEGA was developed by the teacher, teachers who develop their own game are, therefore, more likely to use it. Within the realms of the study, only student engagement and educational games were examined together instead of examining both individually as isolated characteristics. This led to investigating flow theory to examine student engagement. Games have the potential of engaging students in abstract and complex ideas in an immersive environment. Opportunities exist in terms of GBL to reach students that may not be academically strong in particular subjects. Annetta *et al.* (2009) also raise the subject of the *Net Generation* and facilitating a generation whereby their attention span is less than their older counterparts.

Annetta *et al.* (2009) examine both the cognitive load theory and the theory of multimedia learning and state that this could lead to limited capacity of working memory. Video games and challenges within games can play an important role in developing flow and therefore, student engagement. Cognitive processing may be affected by the rate of visual presentations given to the student. The study carried out by Annetta *et al.* (2009) investigated the difficulties of students learning and developing an understanding of genetics. The teacher developed a game for the students to play and involved a judgmental sample of sixty-six students across four classes. The elaborate storyline featured a couple that were deceased and the inheritance that was left for the family was stolen. Blood was left at the crime scene and three characters were in play, the butler (who briefly saw a robber), the investigator and the lab technician. The level of engagement was examined by a *Protocol for Classroom Observations* and taken using videotapes by two researchers; observations were made every two minutes, which resulted in a total of eighteen observations. The groups were divided equally among high and low achievers ensuring that one group was not an entire group of high or an entire group of low achievers.

Engagement was placed into three distinct categories, cognitive, emotional and behavioural. Cognitive engagement placed emphasis on mental investment, strategies and thinking. Emotional engagement focused on affective connections and connections to others. Behavioural engagement looked at the student as an active participant with attention, persistence and asking and answering questions all being observed in the behavioural engagement category.

Results of the study indicated that the experimental group was more engaged than the control group. One of the main drawbacks of this study was the focus on the game itself and potential lack of time on the content to be covered, namely genetics. The researcher postulated that the teacher might use this game more frequently if the teacher owned the game; however, the researcher overlooks the content and context of the game itself. It is also noted that the 'teacher effect' could have been at play when measuring the innovative intervention. Useful insights of the study were gained in particular with the different forms of engagement being measured and the use of an elaborate storyline. For instance, the elaborate storyline was to the detriment of the game design; that is, it led to possible student distractions. In this study the teacher provides information with regard to the game that was purposefully designed to engage students in learning about genetics. The students also participated in an examination of the topic after the game. Although the students did not show an increased level of understanding, the game may not have been targeted towards providing consistent and immediate feedback to the students in terms of genetics or whether it just presented the information through a game form with less interaction required from the students. Therefore, it remains to be seen whether students' flow in this game increased students' conceptual understanding.

While there has been extensive research conducted in relation to technology in the classroom, there has been less research conducted in terms of the relationship between technology, game playing and measuring the attainment of students (Miller and Robertson, 2011). Further research is needed to understand how the learners engage with technology-based games and if GBL improves academic achievement (Shin, Sutherland, Norris and Soloway, 2012, Chandra and Lloyd, 2008). Current research suggests that there is scope for integrating the type of games that are being examined and as suggested earlier their perceived advantages within different contexts. Some of which include engagement, enjoyment, collaboration, and goal-oriented learning.

In conclusion, there is an increase in GBL and mathematics education advancements in recent years with a growing number of journal articles being written (Hwang and Wu, 2012). GBL gameplay has no formal definition in research (Kiili, 2005). Play and games can be thought of as using the same psychological attitudes and were not differentiated upon by Huizinga (Salen and Zimmerman, 2006). Overall a number of features resonate with GBL and these include rules, goals, feedback, challenge, interaction and narrative (Prensky, 2006). Benefits of GBL include deep learning (Ke, 2008), sustained motivation (Bai *et al.*, 2013), adoption of positive perspectives of school (Miller and Robertson, 2011), engagement (Admiraal, Huizenga, Akkerman and Dam, 2011) and the engagement of the less academically strong students (Annetta, Minogue, Holmes and Cheng, 2009). Further to these, integrating technology in the classroom and its associated challenges are discussed in the next section.

2.3 Technology in the classroom

Technology in the classroom is a widespread topic that encompasses how to use particular technologies for the creation of a resource to be used within the confines of the classroom. It comes with its own challenges and from long ago technology has been debatable when it comes to its use within the classroom. Casting an eye back to an earlier time, technology within the classroom could have been viewed as the blackboard or the textbook; both the blackboard and textbook changed a student’s interaction with information. These, the blackboard and textbook, were two important developments to the classroom environment. The blackboard allowed for written word being presented on an on-going basis to the class. The textbook meant that information could be provided to students without the need for the teacher to prescribe it by writing it on the blackboard. It is not all that long ago when the blackboard was what students wrote on in order to complete their day lessons. Nowadays technology is in a pluralistic form. It can be anything from a software product to a hardware product that acts as a resource in the classroom.

It is posited that engagement and technology coincide as the resource is used to enact constructivist ideals in the classroom. Other such advantages include challenging students to apply themselves by utilising technology in such a way that promotes active and deep learning. Within these advantages posited by researchers is the use of certain technologies within the classroom.

Barkatsas, Kasimatis and Gialamas (2009) explored the impact technology has on engagement and specifically found high levels of achievement to be associated with high levels of mathematics confidence. Barkatsas *et al.* (2009) concluded that

> *"Students with high mathematics achievement demonstrated high levels of mathematics confidence, strongly positive levels of affective engagement and behavioural engagement are not confident in using computers, appear to have a positive attitude to learning mathematics with computers. It could be argued that their objective is to improve their performance via the use of technology."* (Barkatsas *et al.*, 2009, p.569).

Barkatsas *et al.* (2009) explored technology and its impact upon learning secondary mathematics. Engagement with the technology and confidence were investigated and Barkatsas *et al.* (2009) suggests that engagement, mathematics confidence, confidence with technology and achievement are all interrelated. Engagement is divided into two categories, affective and behavioural. Affective engagement as the name suggests focuses on how it affects the students by feeling. Behavioural engagement is defined as how the students behave in learning mathematics. Mathematics confidence spans two interpretations, a student's ability to handle a challenge and their perceived ability to attain good results. Confidence with technology is a student's belief regarding mastering a computer procedure.

Barkatsas *et al.* (2009) divided the study into seven clusters, each cluster included students with varying mathematical ability. These clusters focused on different aspects regarding the definitions in the aforementioned paragraph within the study. The overall aim of the study was to examine the definitions mentioned, these factors include: engagement, mathematics confidence, confidence with technology and achievement. The study found that students with a high achievement in mathematics appeared to have positive attitudes towards learning mathematics with computers. The students with excellent mathematics believed that the use of technology would not enable them to improve their performance. Further research is required for the group of students that have negative attitudes towards mathematics and positive attitudes towards learning mathematics with computers. In this research, there was a distinction between students having negative attitudes towards learning mathematics, however, positive attitudes towards learning mathematics with computers (Barkatsas *et al.,* 2009). Of course within these positive attitudes lies the fact that students were challenged and enjoyed the process. As mentioned, students that are actively engaged are also challenged and a balance to the activity needs to be achieved while guiding the student.

Abuhamdeh and Csikszentmihalyi (2012) investigate the relationship between challenge and enjoyment in two studies. The first study was a single activity and looks at Internet chess; the second study examined the enjoyment of challenge across a wide range of activities. Two factors were divided into four to investigate the relationship, activity moderation (intrinsically motivated, non-intrinsically motivated) and activity type (goal-directed and non-goal-directed).

Abuhamdeh and Csikszentmihalyi (2012) note that the more difficult the activity the more the enjoyment increases but only at an optimal level; if the difficulty is increased too much this affects the enjoyment and the enjoyment then decreases. The importance of challenge for the enjoyment of activities in intrinsically motivated and goal-directed tasks can only be examined in the context of these activities. Therefore, context plays an important role. As each person experiences games differently, there is a challenge to create games within a 'standardised context for learning' (Klopfer *et al.,* 2009).

Abuhamdeh and Czikszentmihalyi (2012) investigate both subjective and objective levels. Subjective levels are where the perceived challenge strongly predicts the predicted enjoyment and objective levels examined the games' opponents and how close the scores were to each other. Games that had superior opponents were more enjoyable and scores that were close were more enjoyable than inferior opponents. The classroom conditions impact on the enjoyment of activities' intrinsic motivation. Perceived challenges are said to have less relevance for enjoyment of non-goal directed activities.

The closer the games in terms of scores the more exciting they are, outperforming an opponent is also more enjoyable than being outperformed. Abuhamdeh and Czikszentmihalyi (2012) examine enjoyment, relative chess rating, relative performance, game outcome, perceived challenge and perceived skill in their study. Play was in real-time over a two-week period with 121 participants taking part. Opponents would enter a waiting room and get matched to their optimal opponent's skill level. Enjoyment is categorised into two different types, process-based and post-game enjoyment. As the name suggests, process-based is experienced during the game itself. Post-game enjoyment is experienced after the game has completed. Abuhamdeh and Csikszentmihalyi (2012) research focuses on the process-based enjoyment of activities while it is taking place and makes observations of students' learning experiences while playing a digital game as a teaching and learning tool for mathematics. This learning experience creates a form of flow and therefore, intrinsic motivation and the student needs to be actively engaged to accomplish this (Bressler and Bodzin, 2012).

Despite the specific learning advantages and benefits associated with the use of technology and games in the classroom outlined above, there are a number of different reasons as to why teachers are not adopting these and factors influencing their use. The following section outlines factors influencing technology use.

2.4 Factors Influencing Technology Use

While there are many benefits for adopting diverse platforms of technology to support the teaching and learning of subjects, there are factors influencing their use within the classroom. Dogan (2012) explored the extent of teachers' understanding of technological pedagogical content knowledge within the primary mathematics classroom. This relates to teachers' understanding of integrating technology within their classroom and understanding how to use it as an effective teaching and learning tool. Dogan (2012) addresses teachers' perspectives regarding computers and how these are construed as teaching and learning tools that affect students' learning and achievements.

One question that needed to be asked is to what extent do the teachers have a clear strategy and reason for implementing technology in their classrooms. From McDonagh and McGarr (2015) a study carried out between 2010 and 2011 stated that teachers have positive perspectives with regard to technology; however, they lack strategic vision of technology and tend to fluctuate with the evolution of technology advancements. Dogan (2012) did not explore deeply how the technology could be implemented and only scratched the surface of the complexity of an ICT mediated environment. Issues were raised with regard to experience, knowledge and accessibility of technology and the study was also limited in that it addressed pre-service primary level mathematics teachers only. Dogan (2012) did not state the types of technology he is referring to in the study and refers to using computers in general. This study was wide ranging in scope and did not address the effectiveness of a single application or function of a computer and leaves the definition and idea of a computer to the teachers participating in the study. However, an interesting useful insight that Dogan (2012) found was that increased use by teachers of computers affected their perspectives in terms of improved positive perceptions of computers as a way to learn and teach mathematics. A study that looks at specific technology and teachers’ understanding of adoption is in Kale and Goh (2012).

A study carried out by Kale and Goh (2012) in relation to Web 2.0 technologies examined similar areas to that of Miranda and Russell (2012) with regard to technology in the classroom. They explored the challenges influencing the use of ICT in the classroom. They highlighted similar factors including access, time, professional development and teachers’ feelings and beliefs about the technology.

Kale and Goh (2012) also offer criticism that education has struggled to sustain support for ICT software and hardware demands. Miranda and Russell (2012) address the issue of technology in the classroom being behind, noting that while technology has moved on greatly since 2008, education has found it difficult to catch up with the growing technology sector. They do suggest, however, that recent developments suggest that it is now *‘rapidly following suit’* as the availability of technology in classrooms increases.

The results of the study carried out by Miranda and Russell (2012) show that there is an association between teachers' personal experience with computers and their confidence using technology. Teachers' confidence and experience with using technology also affects the extent to which they perceive technology as being important for teaching. Teachers who are more experienced with technology will lead students to use technology more often than those who have less experience. Also, those who perceive technology as important for teaching appear to direct their students to use technology more often than those who do not have the same perception. This is a small-scale study and is not suitable for generalisations. It highlights factors such as the quality of the technology, the environment, engagement between students and teachers and the teachers' perceived benefits of using this technology as important for determining whether technology is used.

2.4.1 Successful Integration of Technology

Learning technology is still an emerging field Philips, Kennedy and McNaught (2012). It is important to gain an insight into how successful integration of technology as this is one of the key points of this doctoral research, therefore, a brief overview of previous studies carried out with regard to integration and adoption are described.

Kale and Goh (2012) found that integration of technology into the classroom could be influenced mainly by infrastructure and professional development. Understanding teachers' attitudes is an important component in the integration of Web 2.0, and plays a key role in technology adoption in the classroom (Kale and Goh, 2012). These findings are corroborated in other studies such as Keong, Horani and Daniel (2005).

Keong *et al.* (2005) examined the study of barriers to Information and Communication Technology (ICT) in Malaysia. They conclude that ICT in teaching mathematics can enhance a student's capacity to understand basic concepts and similar factors were barriers for teachers adopting ICT. Inadequate technological knowledge and professional development as well as the necessary infrastructure in terms of the technology and resource availability were both evident in the study. The barriers that were pinpointed were lack of time due to scheduling, insufficient professional support and development, inadequate technical support and lack of knowledge about integrating ICT into the curriculum, difficulty in integrating technology due to using different tools in a single lesson or unavailability of resources for students at home. The unavailability of resources for both students and teachers can be tricky to solve in today's society where there are constant upgrades in terms of technology. Again both Kale and Goh (2012) and Keong *et al.* (2005) draw upon the same aspects of technology as a whole without differentiating between the types of technology used within the classroom. This is a broad definition and could mean teachers use technology for the sake of using technology without investigating its full potential. ICT could refer to the use of presentation software and the content itself is the same as in book form, however, now on a screen. The levels of expectations then for technology to impact upon students or for it to be used as a teaching and learning tool are somewhat limited.

Oblinger and Oblinger (2005) agree that the rapidly changing external environment can influence a teacher wanting to use technology. The technology should address the needs of the teacher and students rather than being an obstacle for adopting particular classroom practices. Although research conducted many years ago state that technology is rapidly changing and technology should address the needs of the teacher, this still holds true today. Therefore, it is important to consider the successful practices to integrate technology as a new method that can inform classroom practices.

A study carried out in Finland has highlighted good practices for successful integration of ICT in the Finnish classroom. The successful integration of ICT in Finnish schools has involved ICT being a seamless part of the classroom learning experiences. Twenty different schools were examined as part of the national ICT strategy (2011-2016) across Finland. The study highlighted examples in which, from primary school, students are asked to work in pairs to write stories on the computer to improve their literacy. By the latter years of their schooling they have already become accustomed to using personal blogs and Flickr[9] accounts to post photographs and tell stories. The emphasis is on a curriculum delivery to allow for more integration of technology. In addition, school administrators and principals play an active role into sourcing different web-based activities for teachers (Niemi, Kynäslahti and Vahtivuori-Hänninen, 2012) however, it is important not to assume that students will be motivated by technology alone (Kiili, 2005).

Niemi *et al.* (2012) outline five principle components for successful integration of ICT in Finnish schools. These emphasise the students' active role in knowledge creation, active and participatory learning as well as adoption of formative assessment and self-evaluations rather than

[9] A photograph sharing software.

examinations and external assessments. These five main components include:

- having a strategic plan where the teachers make observations and make value assumptions for their own teaching practice,
- examining the methods used to integrate technology and to encourage and empower participation in the classroom,
- investing in video conferencing to share ideas among schools in regions in Finland,
- the principal is also encouraged to adopt a clear vision and set teacher objectives through leadership,
- these teachers are required to achieve and hold the capacity and commitment in terms of the overall ICT objectives (Niemi *et al.*, 2012).

The final component is emphasised in particular - the teaching staff's commitment to training and creation of activities using ICT. This commitment demands more of their time and requires a positive attitude towards integrating ICT in the classroom (Niemi *et al.*, 2012).

Shin *et al.* (2012) agrees with Niemi *et al.* (2012) stating that technology needs to be integrated seamlessly into the school curriculum as part of the routine learning activities for successful implementation in classrooms. Niemi *et al.* (2012) do not discuss any particular forms of technology; however, they offer guidelines for integration of all technologies and how they can be successfully integrated. It is important to note that Finland has a localised curricula and the adoption of technologies is therefore dependent on the prescribed curriculum in that area.

Although technology acceptance is one criterion, it is the teacher who is the leader and change agent in the classroom (Bourgonjon *et al.,* 2013). Studies on the integration of other forms of technology show that a classroom can be a complex environment. Chandra and Lloyd (2008) conducted a study looking at the differences between traditional and blended learning and came to the conclusion that *'the impact of information and communication technology (ICT) is evidenced differently in different groups'.* There was no global improvement in results. The scores of previously low achieving boys' scores rose while those of previously high achieving girls fell. This highlights the complexity of the ICT mediated environment.

This complexity should not be taken lightly; technology cannot be adopted for technology sake. There is insufficient evidence to show that technology promotes student learning (Shin *et al.,* 2012, Annetta *et al.,* 2009), even though, technology in its most general form has been adopted in the United States for over a decade. Professional development of teachers for technology use is also emphasised in Ke (2008) and in Mascolo (2011). Time is required to allow teachers to move their practice to a different teaching style, one that is more student-centred. This commitment demands more of their time and requires a positive attitude towards integrating ICT in the classroom (Niemi *et al.,* 2012).

Researching the integration of technology and games into a school can contribute greatly to the literature and findings in the field of educational technology. In this instance, it is not the remit of this thesis to establish the dynamics of the ecosystems of schools. It is well regarded that integration of technology including games in schools involves many factors including management, curriculum, infrastructure, training and development as well as support policies, school leadership and culture (Judge, 2013).

2.4.2 **GBL acceptance**

As well as the integration of technology generally, the factors relating to the integration of GBL specifically arise. Bourgonjon *et al.* (2010) examine acceptance of GBL by secondary school teachers. Bourgonjon *et al.* (2010) examine the factors that affect classroom adoption of video games. A number of factors influence adoption by students, students' perceptions regarding its usefulness, ease of use, learning opportunities and personal experience with video games. Some argue that the *net generation* has fundamentally changed in terms of how they gather information and how they are processing information (Bourgonjon *et al.,* 2010). However, there is a fundamental issue that has arisen relating to students' acceptance of video games for learning (Bourgonjon *et al.,* 2010). The Technology Acceptance

Model (TAM) and the Theory of Reasoned Action (TRA) are both models that study intended behaviour. TRA was the predecessor of TAM and looked at the individual's perceived attitude toward behaviour and social pressure to engage in a particular action as predictors of engagement in a particular behaviour. TAM utilised the TRA and focused on computer acceptance, positing that the easier technology is to use the more people will use it. In their findings, technology usefulness as well as learning opportunities and personal experience influences the acceptance of technology.

While there has been extensive research conducted in relation to technology in the classroom, there has been less research conducted in terms of the relationship between technology, game playing and the attainment of students (Miller and Robertson, 2011). Further research is needed to understand how the learners engage with technology-based games (All, Castellar and Looy (2015) and if GBL improves academic achievement. Shin *et al.* (2012), Chandra and Lloyd (2008) state that existing research seems to suggest that there is scope for integrating the type of games that are being examined at both primary and post-primary level. Current research states that positive claims have been made with regard to motivation and improved academic performance; however, teachers are the main change agents in the classroom and require information regarding the relevance of games in relation to the curriculum as this predicts acceptance of games in the classroom (Bourgonjon *et al.*, 2013).

GBL within the classroom is an aspect of the classroom; the context that it is in holds great consequence. It is within these conditions that students and teachers engage not only with technology, however, with a form of technology that implements GBL strategies within the classroom. Derived from play, games are more structured, create a goal for students to achieve, provide immediate feedback and generate an alternative assembly of the surroundings. GBL promises the freedom of play with inclusion of communication among students. Earlier on in this chapter, Huizinga's characteristics of play were mentioned including the freedom to experiment and interpret. This shows the environment where creativity can blossom. It is therefore, important to look at the context where GBL will be investigated within this study - the post-primary mathematics classroom in Ireland.

2.5 Mathematics classroom

International assessments that take place periodically give useful feedback on the current state of Mathematics education in Ireland. Trends in Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA) are two of these assessments and these report student achievement with a focus on the teaching and learning of science and mathematics. According to the TIMSS website (TIMSS, 2011a) TIMSS is described as:

> *"a globally cooperative enterprise, TIMSS conducts comprehensive state-of-the-art assessments of student achievement supported with extensive data about country, school, and classroom learning environments"(TIMSS, 2011a).*

Overall, TIMSS looks at the data of over fifty countries and these assessments make for comparable data regarding these data trends. In the previous 2011 TIMSS assessments, Ireland earned a score of 527, which is above average of these fifty countries. This also shows that a score of 527 was below high in terms of international benchmarks. This means that Ireland lies in the intermediate ability in TIMSS and students that sat the TIMSS mathematics assessment in Ireland are said to:

> *"Apply basic mathematical knowledge in straightforward situations." (TIMSS, 2011c)*

This is reasonably good; however, students lack the capacity to engage with complex mathematical knowledge.

The summary of international benchmarks for Ireland suggest that:

> *"...Ireland's reasonably good performance on TIMSS mathematics can be attributed to having few very weak pupils, and a reasonable number of very advanced pupils" (Eivers and Clerkin, 2012).*

Therefore, Ireland lies in the intermediate ability standard in terms of international benchmark comparisons. As Ireland undertakes the challenge of creating more careers in Science and Technology, it is important that improvement in this benchmark score is a priority. The commitment to improving Ireland's international standing from intermediate to high has been a point of interest for the government with the introduction of many initiatives to incentivise students to undertake careers in Science, Technology, Engineering and Mathematics (STEM). Some of these incentives include the introduction of a reformed curriculum with many rote-learning habits from the older curriculum being scrutinized and replaced.

The influence of the digital era on mathematics teaching has often been touted as requiring a change in the dynamics of the classroom. The milieu of adding technology shifts classroom practices as further implications arise for technology and teaching mathematics (Thomas and Palmer, 2014). Qualified teachers now need not only to focus on pedagogy for effective instruction but also incorporate different teaching and learning tools that are encouraged by the Project Maths curriculum. These include the use of technological teaching and learning tools. Therefore, integrating technology is an additional concern for the teacher. Introducing technology to the classroom brings its own challenges and the Technological Pedagogical and Content Knowledge (TPACK) explains this simply by the illustration below taken from Mishra and Koehler (2006).

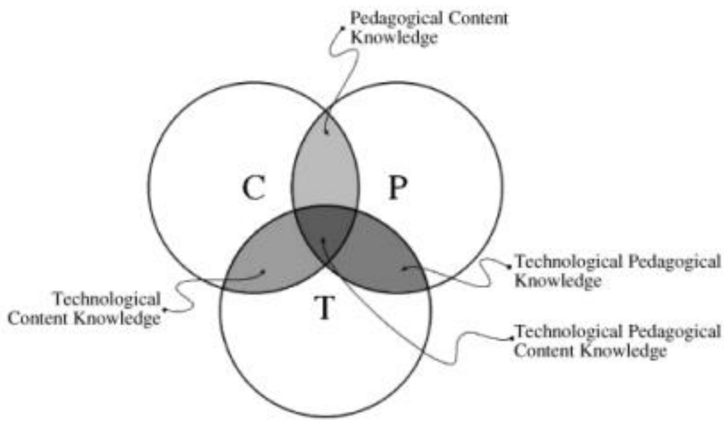

FIGURE 5 - TPACK FRAMEWORK

Without going into too much detail in this chapter, TPACK framework brings together technology, content and pedagogy and as shown in figure 5 above, it is all of these combined that make the technological pedagogical content knowledge. These form pedagogical content knowledge, technological pedagogical knowledge, and technological content knowledge and in the centre of the Venn diagram (figure 5) technological pedagogical content knowledge.

TPACK encapsulates all three components (pedagogy, technology and content) and forms the basis of effective teaching while utilising technology (Mishra and Koehler, 2006). While utilising technology is one element of TPACK, fostering new types of learning through the use of that technology is a whole other dimension. In the case of this study, both using technology effectively and using technology to promote GBL are areas of particular interest and concern especially with a shift in curriculum changes.

The mathematics classroom in Ireland has gone through major changes regarding the curriculum being presented to students. Since 2011 and the introduction of this new curriculum, Project Maths, it has garnered media attention in terms of its radical amendment in classroom practices. Classroom practices within Project Maths suggest the need for the introduction of communities of practice for improving the teaching and learning of mathematics. The curriculum supports constructivist ideals and advocates discussable topics for the classroom.

Some of the specific attributes of the Irish classroom and schools are described briefly in the points below:

- In comparison to Europe, Ireland has ‘the highest proportion of single-sex schools’, however, there has been a steady decline in these figures and schools are becoming co-educational (O'Connor, 2007).
- Textbooks are the dominant classroom resource (O'Keeffe, 2011).

- The mathematics course students undertake in school is part of the national curriculum and is taught across all post-primary schools. The curriculum content does not change based on locality or whether a school is private or public; schools have access to the same content.
- As well as the current Irish classroom context, implementing a curriculum of such magnitude often requires a change to teachers' traditional practices. The following section highlights some of the challenges facing teachers when adopting the Project Maths curriculum.

The Project Maths curriculum focuses on the learning of mathematics skills with a real life emphasis. This form of mathematics learning represents the practical aspects of mathematics. Project Maths also aims to adopt mathematical discussion within the classroom and move towards an open and encouraging environment for students to engage deeply in mathematical problems.

Changes occurred throughout all of the post-primary mathematics curriculum and assessments, including the main examinations, the Leaving and Junior Certificate due to the introduction of Project Maths. As shown in the citation below taken from the Junior Certificate 2015 syllabus, teachers are encouraged to engage students in the facilitation of discussions and support risk taking while also encourage inquiry.

"It is important that the learning environment engages students, facilitates discussions, supports risk taking and encourages inquiry"(Project Maths Syllabus, pg. 8) (NCCA, 2011b).

Encouraging inquiry and discussion is also encouraged at Leaving Certificate level, although, time restrictions on the curriculum can impact the teaching strategies employed. Teachers have less time to experiment in unusual methods of teaching with the risk of not covering the extensive syllabus material for the terminal examination.

Engaging students in order to facilitate discussion, support risk taking and encourage inquiry can be challenging. This challenge was acknowledged by the National Coordinator for Project Maths two years into its implementation in schools when she stated that 'what we think and what we do are at odds with each other', referring to the changing landscape of constructivist teaching approaches being advocated (Brosnan, 2013).

While she was discussing the curriculum, the coordinator also mentioned assessment. Assessment has also changed dramatically from a predictable terminal mathematics examination to an unpredictable examination where problem solving is paramount. This new reform requires a diverse range of problem solving skills in order to successfully complete the five-six hour examination. In enforcing these reforms the teaching strategy must move from teacher-centred to student-centred teaching with the adoption of relevant and appropriate resources to help engage students more deeply in problem solving. Therefore, the reforms have driven change across all levels of the mathematics classroom. An assessment can drive changes at the teaching strategy level of the classroom and also impacts on the content knowledge that is emphasised.

The Leaving Certificate is currently a high-stakes examination with entry to third level for many students determined by their mathematics results in particular. League tables, which rank schools based on the schools Leaving Certificate results and a student's ability to achieve his or her first choice of course, exasperate the situation. League tables have been highly criticised in the past, as they can support a preception of higher risks for teachers when experimenting with different teaching methodologies, especially those which involve the integration of less familiar technologies, such as games (Borooah, Dineen and Lynch, 2010).

The integration of any technology within the classroom is not to be taken for granted and as shown in the previous section is dependent on multiple factors. The mathematics classroom is still progressing in terms of integrating technology as well as affording the high expectations teachers have for revolutionising classroom practices (Drijvers, Tacoma, Besamusca, Van Den Heuvel, Doorman and Boon, 2014). As posited by Drijvers *et al.* (2014), the challenge is to disseminate the knowledge of how integration occurs in classrooms where technology has been successfully integrated and to further understand the mechanisms of how these practices can be adopted in different classroom contexts. A teacher's particular teaching style may affect his or her adoption of different technologies, and as discussed by Kale and Goh (2012), there is a positive correlation between teachers' use of technology and their teaching style. Central to any teaching style is the need for a teacher to link the lesson to the learning goals. In many cases teachers may often direct students to use technology in order to help them achieve these goals. A study by Miranda and Russell (2012) provides evidence that there are four main factors that contribute to the success of teacher-directed student use of technology (TDS). These include the following:

- Factor one: Teachers' experience with technology
- Factor two: Teachers' beliefs that technology is beneficial to meet instructional (learning) goals
- Factor three: Teachers' perceived importance of technology for teaching
- Factor four: Obstacles with integration of technology.

The study found that, while all factors are relevant, the belief that technology is beneficial and the perceived importance (factors two and three) are the most significant factors in adopting TDS in the classroom at elementary level. The researchers claim that it is essential for the teacher to believe in the benefits of technology and to perceive the technology as an important tool for teaching. Miranda and Russell (2012) did not mention the diverse range of technologies that could utilise these methods of TDS. Their research, however, contributes to understanding the factors influencing adoption within a classroom.

Miranda and Russell (2012) also raise the question of whether technology is really being integrated into schools. Teachers are becoming divided into two camps, integrators and non-integrators according to their beliefs on the value of the technology for learning

Teachers are being asked to connect ‘technologies, pedagogy and content’ and to integrate and apply their understanding of all of these to enhance students’ learning. As shown in the introduction, TPACK brings a new element and can be challenging (Mishra and Koehler, 2006). Kale and Goh (2012, p.4) postulate, *“Without positive attitudes, enhanced technology skills, and a strong pedagogy reflecting student-centred teaching style, they are unlikely to make such connections.”* These connections refer to the teacher connecting how to integrate such technologies. The teacher can observe and be trained in pedagogical skills as well as technology separately from one another. This separate training does not serve as a way to train teachers on how to integrate these pedagogical technological skills when each are taught in isolation from one another.

The research of Kale and Goh (2012) is at the heart of our understanding of teachers’ adoption of technology and their attitudes towards technologies such as Web 2.0 and 21st century teaching and learning strategies[10]. The 21st century classroom involves the use of technology and different technologies that harness students’ improved motivation and learning, technologies such as Web 2.0[11] the next generation of the Internet whereby the Internet is used as a platform for teaching and learning. Kale and Goh (2012) suggests that teachers’ pedagogical style was not a predictor to utilising such technologies. However, infrastructure and professional development that allowed teachers to focus on its use by making observations in other classrooms are predictors of application in their own lessons as well as age, self-efficacy, workload and teachers’ perspectives of the value of the technology-Web 2.0 (Kale and Goh, 2012).

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[10] Kale and Goh (2012) note this as students that are effective team players, innovative thinkers, active learners and problem solvers and are digitally literate.

[11] We are currently at Web 3.0 where there is semantic search and widgets. The advent of Web 4.0, also known as the mobile web, is on the horizon with intelligent agents, distributed search and ubiquity.

While we do understand some of the factors influencing teachers use and integration of technology, Kale and Goh (2012) fail to engage in a discussion regarding subject specific technologies and only refer to Web 2.0 in the general sense in the state of West Virginia, and with regard to the push for ICT in the public school system. However, understanding these teachers' attitudes still brings awareness into the existing role of any technology in their classrooms.

Teachers' attitudes towards technology influence whether a teacher adopts technology. It is also important to be aware of the benefits of certain technologies. These technologies can inform the basis for collaboration in the classroom and engagement with the subject matter. The following section discusses collaboration and the challenges encountered with marrying collaboration with different teaching styles.

Collaboration stimulates social interaction and students that socially interact with their teacher or a peer of higher ability are privy to the Zone of Proximal Development (ZPD) as theorised by Lev Vygotsky. The ZPD is *'the difference between what a child can do with help and what he or she can do without guidance'* (Collins and O'Leary, 2010, p.55). Vygotsky believed that social interaction is a key part of the learning. The development process includes social interaction with someone of a higher ability such as a teacher or peer that is familiar with the subject or topic (Rowlands, 2003). Therefore, in a classroom, students that are more familiar with the central concepts can interact with their peers to explain and support learning in mathematics. Essential to ZPD is collaboration and that forms the basis of effective instruction (Luckin, Connolly, Plowman and Airey, 2003).

Both Piaget and Vygotsky believed that peer interaction was key to cognitive development (Cole and Wertsch, 2002). Piaget believed that peers are more helpful in interaction as they can challenge each other's thinking. Vygotsky believed in co-constructed processes including that of, for example, losing a toy, the parent and child do not know where the toy is but the parent will participate in guided instruction the child with questions about ‘where did you last have it’ until a conclusion is reached by the child. Guided instruction can be encased in technology and the following section discusses scaffolding as central to collaborative activities.

2.5.1 Collaboration and Scaffolding Tasks

As mentioned by the Project Maths curricular guidelines, an activity also needs to be scaffolded. Scaffolding activities by a teacher can support the student in constructing their own knowledge through guidance (Mascolo, 2011). Scaffolding activities is a way to build upon students’ existing knowledge and create challenges for these students to reach their own potential. The task needs to be divided into manageable pieces. Developing a task to the correct level of the class can also mean that some students can be overwhelmed or not challenged enough. Adhering to the curriculum and splitting the activity or task into smaller chunks for students to follow from start to finish can accomplish scaffolding. This scaffolding of tasks can also include referring to a previous curriculum from the past year. This is beneficial for the students as they revise some topics that either they should know already or may not have been covered previously. Once the easier sections are covered, the students are then challenged while the easier part of the task equips them with deeper understanding of the subject matter at hand. Therefore, learning technologies in the classroom need to be scaffolded in a way that allows for the student to actively engage with an incremental challenging task. Also, in order for the task to be engaging, the task needs to be challenging enough. This requires the skill of balancing the challenge and being able to accomplish the task.

Kiili (2005) shows a diagram from Csikszentmihalyi (1965) that shows the balance between the ZPD, challenge and accomplishing that challenge. Therefore, when developing a learning technology it needs to present and create a students’ learning experience that encapsulates a challenge.

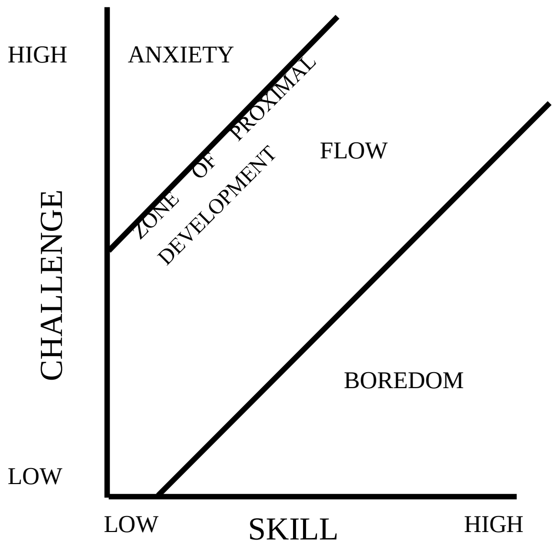


FIGURE 6 - THREE-CHANNEL MODEL OF FLOW

As shown in the three-channel model of flow above in figure 6, the challenge needs to lie in the realm of flow while skill needs to incrementally increase. While catering for all levels can be difficult, it is important to take into account students' prior knowledge as well as to engage students actively in the task. Engaging students means the task needs to be achievable although challenging at the same time. It also means that the learning experience needs to be positive and incorporate a skill. As one of the principles of the Zone of Proximal Development states, students can learn from each other through peer feedback and also guidance from a teacher.

2.5.2 Collaboration and learning experiences

Collaboration has the potential to enrich the learning experience in the classroom that is directed towards mathematical enquiry and discussion. Keong, Horani and Daniel (2005) postulated that technology and collaboration contributes to positive motivational learning experiences in the classroom. To adhere to a true representation of collaboration, it involves the synchronous ability to cooperate and engage with the activity and each other through discussions (Roschelle and Teasley, 1995). This adoption of collaboration needs a student-centred teaching style and in doing so technology may be needed to facilitate such collaboration (Scott, Mandryk and Inkpen, 2003).

The specific characteristics of creating a resource for the mathematics classroom includes being relevant and context-based among other more generic features as identified in the previous section. The teacher implementing these classroom characteristics needs to infuse student-centred teaching styles. The following section outlines some of the existing research carried out in the specific technology area of using a Gesture-Based game within the mathematics classroom.

2.6 A Gesture-Based game for the mathematics classroom

There is increasing interest in the field of digital games within the classroom as the promises of games are challenged and are researched more thoroughly (Beavis, 2015). Prior to this games mostly focused on video games without necessarily accounting for the diverse range of platforms and technologies for playing games or the genres that could be focused upon (Beavis, 2015).

The purpose of this study is to inform the design and integration of using a gesture based game within the mathematics classroom. As shown from the literature there are limitations in terms of design elements within games and challenges surrounding their implementation. There is also a need to look at their potential as teaching tools. In order to produce guidelines and disseminate the knowledge of successful integration this study also explores the core features for developing an effective GBT game for the mathematics classroom. In conclusion the following research questions guide the case study research and are formed as a result of carrying out this literature review.

- What are the key design elements of a Gesture-Based game and the key challenges for classroom implementation?
- What is the potential for a Gesture-Based game to be used as a tool in the mathematics classroom?
- What core features are important for an effective GBT game in the mathematics classroom?

In order to answer these questions, a number of key recommendations from the literature were gathered and presented in the next section.

2.6.1 Recommendations for Creating Technology for the Mathematics Classroom

Technology has and still goes through significant changes in this information age. Technology can also surpass all expectations for its use as a teaching and learning tool and yet the phrase 'learning is fun' is somewhat challenging for today's classroom. Another well known phrase by Sir. Francis Bacon is 'Knowledge is Power'. Today more than ever in the information age technology allows students access to a wealth of knowledge and therefore they are according to Sir. Francis Bacon more powerful than they have ever been previously. As cited in Reid (2005) Diamonds and Hopson (1989) carried out a longitudinal study regarding stress and environment. Their study postulates that an enriching environment for a student should have the following characteristics.

- A steady source of positive support;
- Provide a nutritious diet with enough protein, vitamins, minerals and calories;
- Stimulate all the senses (not necessarily at once)
- Has an atmosphere free of undue pressure and stress but suffused with a degree of pleasurable intensity;
- Present a series of novel challenges that are neither too easy nor too difficult for the child at his or her stage of development;
- Allow social interaction for a significant percentage of activities;
- Promote the development of a broad range of skills and interests: mental, physical, aesthetical, social and emotional;
- Give the child an opportunity to choose many of his or her efforts and to modify them;
- Provide an enjoyable atmosphere that promotes exploration and the fun of learning;
- Allow the child to be an active participant rather than a passive observer.

This environment promotes enjoyment, engagement and fun within the classroom and technology has been found in many studies to support many of these characteristics in both formal and informal ways.

Sugata Mitra has conducted an experiment using technology for disadvantaged children in India. He suggests that technology should be used to enhance the learning for children in disadvantaged areas as opposed to children with an advantaged educational background (Dangwal and Thounaojam, 2011). The study used computer software for students to self-instruct themselves and the so called ‘hole in the wall’ acted as a learning station. Learning stations are furnished with games and access to the Internet. An image of the learning station is below.

FIGURE 7 - HOLE IN THE WALL EXPERIMENT

Individuals in Mitra’s study showed improvements in students’ ability to self-regulate and use learning strategies as well as increased motivation. Although curiosity and hence interest is not explored in the study conducted by Dangwal and Thounaojam (2011) in great detail. The research did identify the importance of collaboration and creativity. Vygotsky tells of the importance of the process of creating with others within the learning process and as the study suggests the learning station encouraged social interaction, networking and creativity. In this environment there were also no barriers to integration, it was a free and natural process in this informal setting.

As suggested by Goos *et al.* (2002) collaboration is a learning strategy that incorporated discussion. Collaboration among students can allow them to experience a rich learning environment and elicit verbal communication

(Roschelle and Teasley, 1995). As stated by Dewey (2011) all communication is social. Collaboration assumes teachers use a student-centred teaching style in the classroom (Mascolo, 2011). Collaboration is understood as being a synchronous activity that involves joint cooperation, engagement and discussion (Roschelle and Teasley, 1995). It consists of 'conversation and data sharing' (Kearney and Burden, 2014). Collaboration is also highly influenced by the teacher (Goos *et al.,* 2002).

Within the Project Maths curriculum for the context of Ireland and creating a resource for the classroom. the guidelines note that digital resources should adhere to certain characteristics. For instance, 'the resource should be in line with the learning outcomes in the syllabus, account for students' prior knowledge, present concepts in an active and effective way, scaffold and engage students actively, cater for different levels of learners and facilitate mathematical discussion and enquiry' (Brosnan, 2008). As pointed out in the guidelines, discussion and inquiry should be elements of the use of a digital resource in the mathematics classroom. As mentioned in the introductory chapter, discussion and justification of mathematical problems are now emphasised as learning process elements in the curriculum for the classroom. When referring to similar reforms in terms of communication and justification in the classroom in Australia, Goos *et al.* (2002, p.194) stated that these are *'likely to require a major shift in the classroom practices of many mathematics teachers'*. Therefore, the recommendations need to be flexible apropos of the shifts in classroom practices as well as supporting social constructivist ideals being implemented.

Consequently, recommendations drawn from the literature show the qualities needed for the creation of a learning technology. The resource must have the following attributes. The game must:

- be relevant,
- be context-based,
- adhere to curricular guidelines,
- engage students and

- facilitate discussion through collaboration.

The conclusions that can be drawn from the literature review for proceeding to game design are illustrated in the figure below (figure 8).

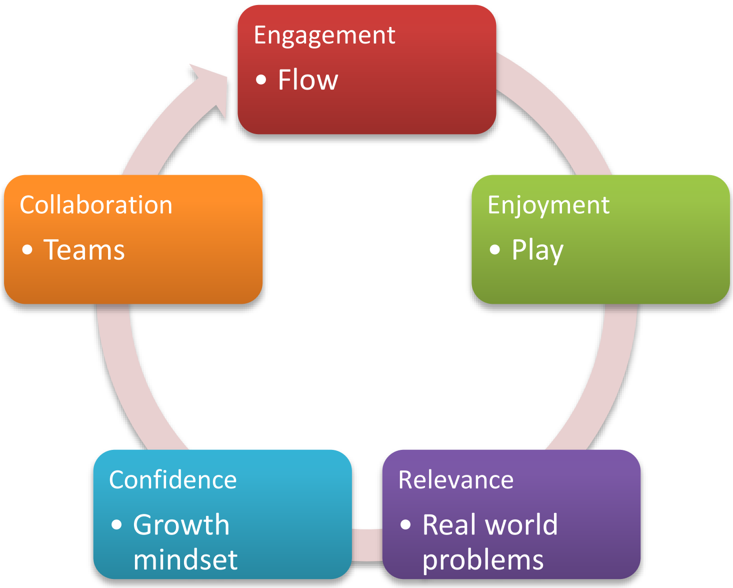


FIGURE 8 - GAME DESIGN FOR THIS STUDY

Creating technology for the mathematics classroom brings many challenges. Relevance, context, instilling confidence, focusing on more student-centred teaching styles and incorporating scaffolded tasks are recommended by the curriculum. There is also an need to incoprorate collaboration and discussion among students. In order to do this with technology, a change in classroom practices towards a more student-centred teaching style together with seamless integration of the technology is paramount.

Gesture-Based Technology (GBT) is a novel and innovative approach to interacting with a computer. GBT allows individuals to move their body as they interact with a gaming system and game itself, thus enabling a kinaesthetic dimension to the learning process. With appropriate integration GBT can harness the use of collaboration and, within collaboration, cooperation among students, mathematical discussion and justification as well as the employment of active learning strategies for students.

In developing an educational experience, there needs to be a balance between expectation, challenge and enjoyment. The difficulty level needs to be optimal with goal-directed activities and conditions and contexts impact enjoyment (Abuhamdeh and Csikszentmihalyi, 2012). More research is needed in terms of linking curriculum content and aims with computer games and these games need to eliminate external factors that break the flow of the activity (Ke, 2008).

The study undertaken by Bai *et al.* (2013) with DimensionM states that 3D games encourage student motivation and allow students to engage with the game in more depth. The game also needs to include real world games. As a result of the research carried out by (Bai *et al.,* 2013), it was stated that the game needs to be associated to real world problems, and goals arouse curiosity. Immediate feedback is also an important factor as shown in (Miller and Robertson, 2011) and the less competent players in the *braintraining* game gain the greatest gains in confidence.

Gaming needs to merge location, contexts and meaning for it to be a fruitful experience (Admiraal *et al.,* 2011). From that study girls are associated with liking narratology of games (story and themes) and boys are associated with liking ludology of games (rules and game play). However, Annetta *et al.* (2009) state in their study that skills-based tasks are more useful than an elaborate storyline. Ke (2008) also stated that there is a lack of links between computer games and curricula and this deficit should be addressed in the design of computer games.

2.7 Chapter summary

More research is needed in relation to GBL and the mathematics classroom. As a starting point Project Maths as a new curriculum in Ireland focuses on real life contexts and relevance to students; therefore, it was considered as an appropriate topic for this research project where the purpose and aim is to investigate the design and use of a GBT game in the mathematics classroom.

In terms of factors influencing its adoption and integration, Dogan (2012) states that increased use can lead to improved positive perceptions of computers in the primary mathematics classroom. A predictor of use includes teachers' attitudes towards the technology, their professional development and infrastructure in the classroom (Kale and Goh, 2012, Niemi *et al.*, 2012 , Bourgonjon *et al.*, 2010).

The next chapter describes the methodology used to undertake this research that explores the promotion of student engagement through GBT and investigates its potential in the mathematics classroom to be a teaching and learning tool.

Chapter 3: Theoretical Framework for Game Design

3 Introduction

The design and theoretical framework chapter outlines the theories used to develop this game – Maths Mission – as part of this doctoral research. The theories used within this doctoral research enable the development of Maths Mission[12] as a GBT game. The design and theoretical framework has been developed as an outcome of the literature review and is unique in that it draws on a combination of GBL strategies with design and theoretical framework. It is then used as part of the design heuristics for Maths Mission.

3.1 Description of the study

As mentioned in the introduction to this thesis, this study focuses on the development of a GBT game for the classroom to support and enhance mathematics education. This GBT game – Maths Mission – is part of an exploratory study and is designed to gain an insight into the potential of a Gesture-Based mathematical game as a teaching and learning tool for the new mathematics post-primary curriculum- Project Maths.

The research problem predicates the three main research questions as described in the next section. This case study research progressed through four phases towards the final GBT game design and its implementation into the classroom. Phases one to three may be described as design stages. These represent the design developments of an initial proof-of-concept (SIP flight), the development of Maths Mission and include a final refinement of Maths Mission as a consequence of piloting it in schools in phase three. Phase four then involved the development of the final GBT game as an outcome and consequence of visiting schools and classrooms with the prototype of Maths Mission. Phase four may be described as the teacher stage and student stage as it gathers their perspectives of Maths Mission as an actual teaching and learning tool in their classroom.

[12] The game developed as part of this doctoral research will now be referred to as Maths Mission for the rest of this thesis.

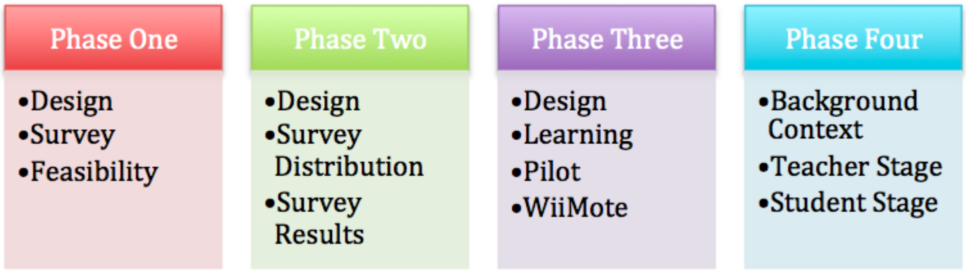


FIGURE 9 - PHASE SUMMARY

The illustration above (figure 9) shows each of the phases and the respective stages. These are explained in below.

3.1.1 Phase one

Phase one demonstrates and examines the capabilities of GBT with a pilot game that envelopes Statistics, Integers and Probability (SIP). This pilot game known as SIP flight uses the WiiMote. It uses it to throw a dart at a dartboard. This phase provides results from a group interview and examines the feasibility of the overall GBT in the mathematics classroom in Ireland. Upon examining the capacity to build this proof-of-concept, phase two initiated the rest of this doctoral study.

3.1.2 Phase two

Phase two of the study was initiated from the results of phase one and proceeds to carry out survey questionnaire. This phase seeks to understand students' perspectives towards mathematics and also confirm understandings of their career interests. These perspectives and career interests give a clear idea of what students' goals are and therefore act as a motivational goal within the game. In order to gain these perspectives and career interests, a survey questionnaire was designed based on the design and theoretical framework as described in chapter 3. Once the survey was designed, it was then sent out to a sample student population across Ireland. The result confirms the need for proceeding with the game and that an engineering focus would be an appropriate topic for the game's design.

3.1.3 Phase three

Phase three focuses on the actual development of the Maths Mission game by taking the results of the survey questionnaire and the literature review on

GBL as design heuristics for the creation of Maths Mission. The phase was split into different stages in order to accomplish this challenge. The first stage focuses on the design and learning stage. This includes both identification of the best game engine to develop Maths Mission and the identification of learning outcomes this game needed to accomplish. Phase three also includes the development of a pilot study and finally building the connection to the WiiMote on the game engine.

During this phase a key decision was the development of the game as a three-dimensional (3D) game instead of a two-dimensional (2D) game. The type of game engine was assessed that ‘best fit’ the research problem. Initial pilots informed further improvements of the game.

3.1.4 Phase four

After the initial pilots in phase three, phase four of the study looks at the emergent cycles of improvement of the game. Phase four presents the data collected from each school visit and the continuous improvement of Maths Mission as an outcome of data collected from teachers and students in these schools.

The diagram (Figure 10) shows each phase and its successive phase along with each stage. Phase four is encased as these were repeated for each school visit, while phase one to three only occurred twice.

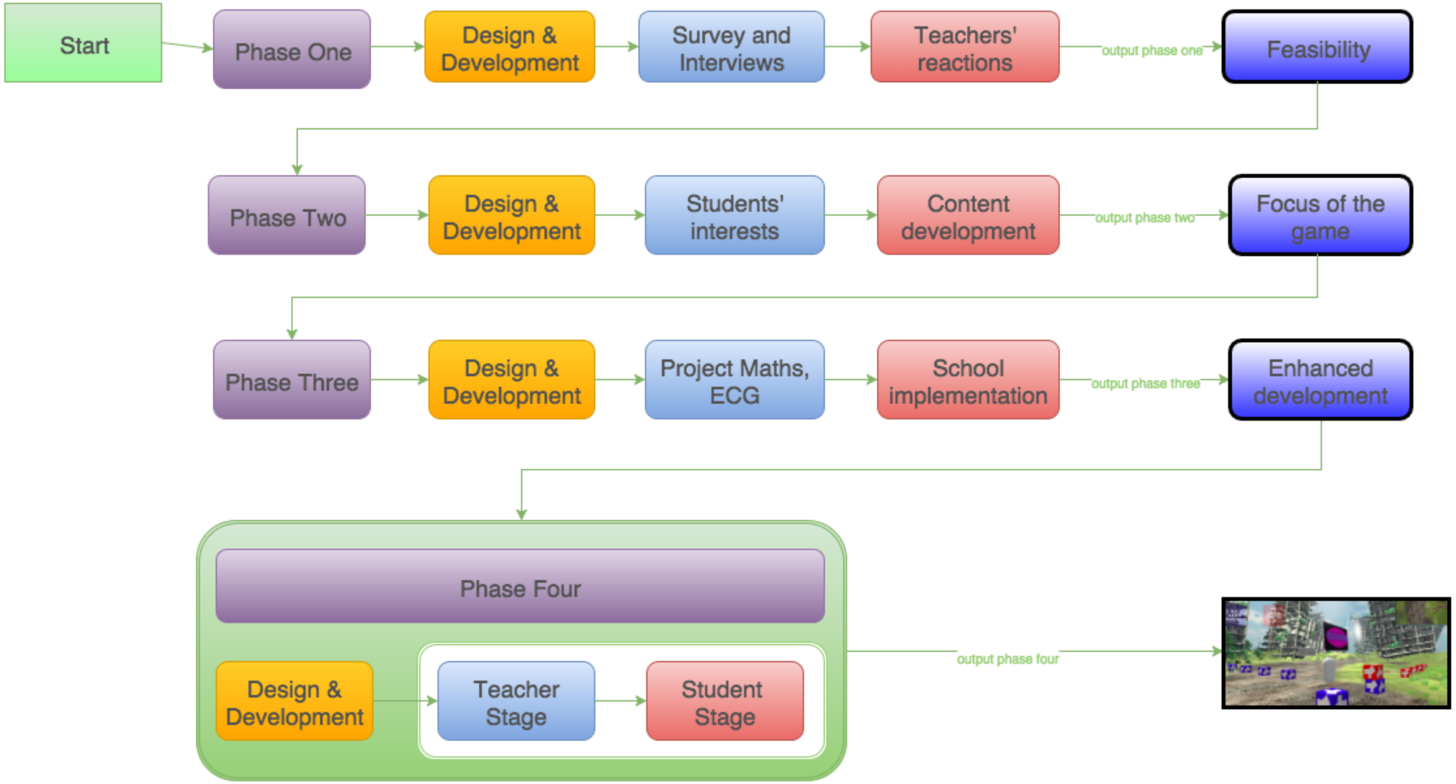


FIGURE 10 - AN OVERVIEW OF THE FOUR-PHASED RESEARCH DESIGN IMPLEMENTED IN THIS RESEARCH PROJECT

3.2 Research Questions

The study was motivated by the researcher's own reflections as a software developer when developing resources for the mathematics classroom. Initially the research focused on the proof-of-concept and whether it was technically possible to develop a low-cost Gesture-Based game (phase one) and further exploratory research, for understanding teachers' attitudes towards a low-cost Gesture-Based game (phase one). This is the first study on Gesture-Based games within mathematics education in understanding teachers' attitudes towards the potential of GBT in Ireland. Thus making a significant contribution to developing Gesture-Based games in this area of research. Phase one led to more in depth investigations at the primary and post-primary level so as to get a clear understanding of students attitudes (phase two). Phase two led to the development of Maths Mission and the pilot studies carried out in classrooms. Phase three then led to the classroom implementation of Maths Mission in different schools and following on from that led to phase four where teachers were interviewed and students were surveyed and observed while using Maths Mission.

Thus the case study research project evolved and was shaped by prior phases. The main phase of data collection (phase four) was guided by all prior phases as the creation of the GBT game (Maths Mission) took shape through feedback from teachers and students alike in order to fully answer the three research questions:

1. What are the key design elements of a Gesture-Based game and the key challenges for mathematics classroom implementation?
2. What is the potential for a Gesture-Based game to be used as a tool in the mathematics classroom?
3. What design features inform the creation of a Gesture-Based game in the mathematics classroom?

3.3 Design and Theoretical Framework

The design and theoretical framework forms an important role within this research to guide the development of Maths Mission. This framework is unique as it results in a culmination of motivational theories and theories surrounding GBL strategies. The framework used in this study relate to concepts of motivation, engagement, interest, expectancy to succeed and collaboration. Given the range of the exploration as this study straddles both games development and mathematics education, the diversity in range of the theories highlights the complexity involved with marrying these areas.

3.3.1.1 Motivation

Motivation involves a form of action and simplistically ‘being motivated to do something’ is usually associated with the word action. Motivation is derived from the Latin word ‘to move’, therefore, ‘in its basic form motivation is the study of action’ (Eccles and Wigfield, 2002). Motivation can be categorised into intrinsic and extrinsic. Intrinsic is when an individual **engages** in an activity because they enjoy and are interested in that activity, extrinsic is when an individual **engages** in an activity for an external reward or benefit (Eccles and Wigfield, 2002). If an individual engages in an activity due to enjoyment, intrinsic motivation becomes an important part of the design and theoretical framework in the design of Maths Mission.

3.3.1.2 Motivation and Interest

Motivation and interest are inherently linked. Regarding interest, it is one of the most important motivational factors when it comes to academic performance (Hidi and Harackiewicz, 2000). Interest is described as a relationship between the individual and certain aspects of the environment. Research has shown that interest facilitates a powerful effect on cognitive functioning (Hidi and Harackieqicz, 2000). Interest is bounded within enjoyment. It seems sensible that a person would not engage with something if they did not enjoy it. Therefore, ensuring interest is key within a GBL solution is imperative to motivating students and facilitating a powerful effect on their cognition.

3.3.1.3 Motivational Interest and Achievement Motivation

It is important to note a distinction between motivational interest and achievement motivation. Interest is when an individual places a high value on a specific subject and achievement motivation is when an individual generally wants to perform well for a specific reason without necessarily focusing on a particular subject (Schiefele and Csikszentmihalyi, 1995). In order for an individual to do well, the individual must value that specific subject. Students that tend to do well in mathematics lean towards valuing mathematics more (Middleton and Spanias, 1999). The benefits of motivations are described by (Middleton and Spanias, 1999) below.

> *"Motivations help guide children's activity; they help determine whether or not children will engage in future mathematical activity." (Middleton and Spanias, 1999 , p.67)*

As provided by Middleton and Spanias in 1999, research-surrounding motivation is important as it can inform an individual's engagement and interest with mathematics.

Middleton, Leavy and Leader (2013) carried out a study regarding motivational variables and achievement motivation. The results show that interest and usefulness can increase motivation as well as students' achievement. Attitudes regarding interest are an important component of learning and a poor attitude can mean neglecting the information from being taken in and perhaps jumping to conclusions because of this attitude (Dewey, 1933). The more interested a student is, the higher the learning outcomes (Admiraal *et al.*, 2011). Therefore, focusing on interest can increase learning outcomes and will be an important addition to the development of Maths Mission.

3.3.1.4 Collaboration

As Dewey states in his pedagogic creed, education is social (Dewey, 1933). Games, either board games or digital games, may invoke curiosity (Huizinga, 1955). Some educationalists regard them as being highly engaging and it is hoped that because of 'its highly compelling even addictive qualities that they can be used to help people learn effectively'

(Hainey, Connolly, Stansfield and Boyle, 2011, p. 2197). Gardner suggests that most schools have a ‘drill and response’ approach to schooling and that many of the individuals do not actually understand what they learn (Gardner, 1999). An individual’s perspective of schooling may be impacted by a ‘drill and response’ approach to schooling.

In terms of the Zone of Proximal Development (ZPD), an individual’s skillset development is greater when engaged collaboratively with others (Farris and Ylimaki, 2010). The fundamentals of the Vygotskian approach is that an individual constructs their own processes, development cannot be separated from the social context, learning leads to development and language plays a central role in cognitive development (Farris and Ylimaki, 2010, p.2). Vygotsky believed that social interaction is a key part of the learning and the development process including social interaction with someone of a higher ability such as a teacher or parent (Rowlands, 2003). Vygotsky believed that peer interaction was key to cognitive development.

Keong *et al.* (2005) postulate that technology and collaboration contributes to positive motivational learning experiences in the classroom. Engaging students on different levels can be challenging, this study aims to find out if GBT can support learning that encompasses all of these requirements of a teaching and learning resource in the mathematics classroom.

3.3.1.5 Flow theory

Flow theory is when a person is immediately immersively engaged in an experience (Eccles and Wigfield, 2002). Csikszentmihalyi (1990) states that when flow state is a form of deep concentration leading to an enjoyable experience free from distraction. This can lead to individuals working at full capacity such as an athlete working to their full potential when performing. Time may appear skewed to the individual as they are in full concentration when performing such tasks. Admiraal *et al.* (2011) describe the relationship between a challenge and the skills require to meet that challenge as interdependent. Concentration, interest and enjoyment are intertwined and must be experienced together for flow to occur (Csikszentmihalyi, 1997).

To ensure flow takes place, it needs to be an activity that is goal-directed. The activity or resource needs to trigger student engagement (Hwang, Chiu and Chen, 2015). Flow experiences need to adopt these characteristics and can be described in terms of a loss of self-consciousness with hyperawareness and the boundaries of your own self begin to expand (Gaffney, 2013). As illustrated, Gaffney (2013) indicates the eight characteristics of flow. The activity needs to have the following to facilitate flow:

- Requires skill and challenges you
- You concentrate fully on the task or problem
- Clear goals
- Clear immediate feedback
- Deep involvement removes awareness of daily worries
- Sense of control
- Self-consciousness disappears
- Sense of time altered (Gaffney, 2013).

The above list shows that games already have the first few characteristics including a challenge, goal and feedback. Engaging with a goal-directed activity deeply can diminish an individual's self-awareness. Students are in control of this task through the democratic or empowered teaching style in the classroom and are encouraged to make decisions to construct their own knowledge. Once the task is challenging enough an individual is enveloped, thus these individuals – the students – are not distracted by daily worries or being self-conscious. The game engages students in a method of enclosing students in the task itself and therefore time seems altered.

A central idea of games is the idea of flow, flow is when a sense of time is distorted and individuals become highly focused while being less aware of themselves (Murphy, Chertoff, Guerrero and Moffitt, 2013). Csikszentmihalyi has researched the idea of flow firstly in individuals of high intense sporting performances. These top athletes reported the loss of a sense of time and getting into 'flow'. Flow can be described as 'the state in which people are so involved in an activity that nothing else seems to matter; the experience itself is so enjoyable that people will do it even at great cost, for the sheer sake of doing it' (Czikszentmihalyi, 1990, p4.).

Conditions of flow	Explanation
Clear tasks	The task is understandable to what is needed to be completed.
Concentration/focus	There are no distractions and therefore this leads to an environment that enables an individual to focus fully on the task.
A balanced goal	The goal is challenging, however, within the realms of the individual's ability.
Characteristics of flow	**Explanation**
Control	Individuals control the task and therefore, control the outcome.
Less aware of oneself	An individual becomes part of the activity with less room for doubt.
A distorted sense of time	Perception of time is distorted. Time may pass extraordinarily quickly.

TABLE 1 - CONDITIONS AND CHARACTERISTICS OF FLOW

Table 1 shows the conditions required for flow to occur and the characteristics are the events that occur when an individual is in flow. Flow goes hand-in-hand with engagement and have become a hugely important aspect of game design (Murphy *et al.*, 2013). The conditions of flow are based around the game having clear tasks, allowing for concentration to occur the game needs little in the form of distractions and finally a balanced goal. The section earlier mentioned the challenge between the learning goal and the game goal that need to be aligned as a singular overarching and compelling goal (Ke, 2008).

In order to promote flow, a game designer needs to be aware of when designing a resource for learning should include the following:

1. Tasks
2. Feedback

3. Challenge
4. Distractions (Murphy *et al.*, 2013)

The tasks need to be clear. The feedback is directly to the player and provides feedback with regard to progression. The challenge needs to lie between accomplishable tasks that are short in length and finally, minimising distractions is an important aspect of flow. Minimising distractions ensure the player does not break the flow of the activity and continues to feel immersed in the activity at hand.

Admiraal *et al.* (2011) investigate the relationship between GBL as an educational design to promote engagement and excitement and that of persistent educational problems such as underachievement. Underachievement is characterised by behavioural and emotional difficulties that may lead to school dropout. Flow theory is used as a framework to examine the relationship between the process of gaming and the effects on game performance and student learning outcomes. According to Admiraal *et al.* (2011) flow is seen as having an influence on game performance, however, does not have an influence on learning outcomes. The study suggests that an individual is less distracted the more engaged they are in an activity, thus increasing concentration on that particular task. Abuhamdeh and Csikszentmihalyi (2012) denote the benefits of the flow experience in the literature review, however, there are certain characteristics in the flow experience that led to this immersive engagement.

3.3.1.6 Engagement

According to O'Brien and Toms (2008), engagement can be seen as something that keeps our attention, shares characteristics with flow and motivation; however, engagement can occur with a single use of an application in everyday life. It can be argued that the outcome of engagement is a sense of belonging and thus reduces school dropout, the focus can then be on engagement at a task level where the outcome is academic performance (Henrie, Halverson and Graham, 2015). This corroborates with Barkatsas, Kasimatis and Gialamas (2009) as mentioned in the literature review. The objective of engagement is to improve academic outcomes. Thus making this an important goal for GBL solutions that harness GBT.

Johnson and Sinatra (2013) investigated the connections between engagement, task values and conceptual change. One hundred and sixty-six undergraduate students were randomly assigned to one of three task values. Johnson and Sinatra (2013) point out that motivation can vary from individual to individual based on different career pursuits while also a student could be motivated to solely maintain a positive image without considering their career pursuits. Achievement motivation can be predicted by focusing on a subject's usefulness and this, therefore, activates engagement with the subject (Johnson and Sinatra, 2013). Therefore, the students engaging in tasks to better their educational development will engage in a task differently than those who engage in a task to enhance their career prospects. Finding something interesting and being intrinsically motivated was found by Johnson and Sinatra (2013) not to be as powerful a predictor to achievement as finding a task useful and placing importance on that task. These are usually known as utility values. Therefore, the more one places importance on a particular task, the more one values that task. Looking at a students' reason for placing importance on a task can ensure their necessary attention is drawn to playing Maths Mission. As pointed out by Wang (2012) there are opportunities to align career interests with students' educational experiences. Classroom experience can influence subsequent engagement in different activities as well as students' competence, interest and value and therefore students' future educational and career aspirations (Wang, 2012).

3.3.1.7 Expectancy-to-Succeed

As well as interest aligning to career aspirations, Wang (2012) states that students' classroom experiences predict student expectancies to succeed and their values. The relationship between expectancy and challenge is an integral part of developing a learning technology (Abuhamdeh and Csikszentmihalyi, 2012). The activity using the technology in the classroom must balance challenge, enjoyment and expectation. In doing so, a game is inherently social as individuals play with activities and explore boundaries (Huizinga, 1955).

The Expectancy-Value Theory (EVT) was developed in order to specifically target gendered enrolment in mathematics-related courses and mathematics achievement (Watt, Eccles and Durik, 2006). The model proposed that achievement-related decisions are based on two beliefs; the individuals' expectancy to succeed and the importance value placed on a task (Watt, Shapka, Morris, Durik, Keating and Eccles, 2012). Four components are operationalized within the study; expectancy to succeed, intrinsic value, attainment value, utility value.

The need to target motivation, interest and engagement specifically comes directly from the EVT. The EVT states that students' achievement is impacted based on the amount of the effort the student places on a task (Eccles and Wigfield, 2002). It also states that career aspiration is influenced by students' success expectations (Watt *et al.*, 2006). It is for this reason that the EVT acted as a learning theory to create Maths Mission.

3.4 Questionnaire Development

Two theoretical inventories: Trends in Mathematics and Science Study (TIMSS) and EVT, formed the basis for the development of the questionnaire during phase two of the study. TIMSS draws from interest, confidence and engagement with mathematics theories that cross over with EVT. The questionnaire sought to capture students' attitudes, motivations and perspectives and so sought to inform the game development at this time.

3.4.1 **TIMSS**

TIMSS was developed as a benchmark instrument between nations and gathered information through student context questionnaires, students' attainment tests, teacher context questionnaires and school questionnaires. The questionnaires are completed at school level and show the context of the school, the curriculum and summatively acts as a benchmark across all students at the age of fifteen. It is assumed that these students understand the questions being asked and, instead of a Likert scale questionnaire, it is shown as a four-scale questionnaire. This is purposely included so to avoid the middle response. This is called the Item Response Theory (IRT) and is a partial credit system whereby the statistical model estimates the probability that a person will respond in a particular way. It is outside the remit of this thesis to go into detail about the statistical models used within TIMSS.

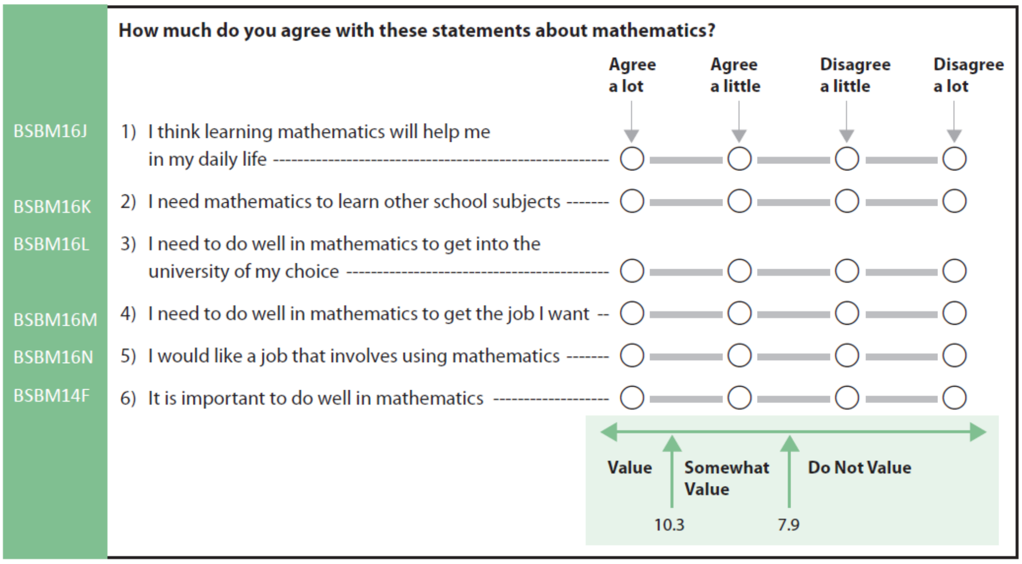
In this research, three TIMSS constructs are used. Each question is composed of multiple questions to answer one overall question and this is the composition of a construct. The constructs used in this study are:

- Students Like Learning Mathematics
- Students Confident in Mathematics
- Students Value Mathematics.

These establish whether students enjoyed mathematics, were confident at mathematics and valued or found mathematics relevant.

TIMSS as mentioned earlier investigates three underlying constructs. One construct is the 'Students Like Learning Mathematics'. This construct is examined with five questions. Students Like Learning Mathematics is the underlying construct and those who agree in general with all five statements are said to like learning mathematics and those who disagree with all five statements are assumed to not like learning mathematics.

In all scales, agree a lot, agree a little, disagree a lot and disagree a little are used and the following image (figure 11) shows the scales interpretation of the underlying constructs. As the image below shows, the *agree a lot* and *agree a little* are shown to represent that the student values or somewhat values mathematics. The *disagree a lot* and *disagree a little* options represent the students' perception that they do not value mathematics.



How much do you agree with these statements about mathematics?

		Agree a lot	Agree a little	Disagree a little	Disagree a lot
BSBM16J	1) I think learning mathematics will help me in my daily life	○	○	○	○
BSBM16K	2) I need mathematics to learn other school subjects	○	○	○	○
BSBM16L	3) I need to do well in mathematics to get into the university of my choice	○	○	○	○
BSBM16M	4) I need to do well in mathematics to get the job I want	○	○	○	○
BSBM16N	5) I would like a job that involves using mathematics	○	○	○	○
BSBM14F	6) It is important to do well in mathematics	○	○	○	○

FIGURE 11 - STUDENTS VALUE MATHEMATICS

The construct 'students value mathematics' looks at relevance and value. Ultimately, these are being measured in the questionnaire above. These constructs allow for the context to be known and so comparisons of the constructs from a particular classroom with the international average may be examined.

The underlying construct being examined shows the 'Students Like Learning Mathematics Scale' in five different questions. For example, students who agree in general to all five questions from the underlying construct are said to like learning mathematics and students who disagree with these statements are said to like learning mathematics less.

Three constructs are used from TIMSS, 'Students Confident in Mathematics Scale' 'Students Like Learning Mathematics Scale' and 'Students Value Mathematics Scale'. Students Confident in Mathematics Scale uses nine questions while the other two ask five and six respectively.

3.4.2 Expectancy- Value Model

At the most basic level, EVT establishes a relationship between how a person is motivated in terms of his or her view of how important it is to do well at that task and the ability of doing well in that task (Wang, 2012). These should directly influence students' choices after they leave school and influence career aspirations they carry. There are many influences in the classroom environment such as the teacher expectance effect that often affects girls more than boys (Wang, 2012). This is particularly true with children who have adopted a learned helplessness role in the classroom as opposed to those that have mastery-oriented focus. Goals can affect the most basic motivational processes (Grant and Dweck, 2003). Different types of goals are apparent in the classroom environment and they differ in terms of what the student is wishing to accomplish (Eccles and Wigfield, 2002). Goals can be active-learning goals and those that are ability-linked goals. The influences of students' self-perceptions in terms of mathematics can affect their career aspirations (Watt, 2006).

For the purposes of this study, three questions are taken from the EVT and used to establish students' perception of mathematics usefulness and attainment of mathematics. Together these establish students 'importance value' of mathematics and are corroborated with TIMSS questionnaire answers to give an overall view of students' perspectives of mathematics.

3.5 GBL

While play is an important feature of learning and holds many relevant aspects, the rules imposed by GBL do not limit the player. Therefore the player is able to *play* within the game while achieving the task or goal imposed on him/her. The next section outlines the game characteristics in more detail by explaining specifically how the design of the game encapsulates these traits. It is important to note that **GBL** differentiates between play and games with a few characteristics adapted from Prensky 2006:

- Rules
- Goals
- Feedback
- Challenge
- Interaction
- Narrative (Prensky, 2006)

A brief overview of the GBL characteristics is given below and illustrates the complexity of developing a GBT game according to the characteristics as adapted by Prensky above.

3.5.1 Rules

The rules within the game are simple. The player must complete the level by interacting with the game using the Gesture-Based controller, the WiiMote. The player must achieve the first task to complete the next tasks. This means gaining feedback both visually and text feedback by way of a text message appearing on the screen.

3.5.2 Goals

As described earlier, the importance of goals through the game is imperative to its success. Goals are enveloped using the growth mindset, which uses positive language to reemphasise the importance of process over the end result. Growth mindset is the belief that ‘intellectual abilities can be cultivated and developed through application and instruction’ (Dweck, 2008). The literature review describes the straddling of learning goals and game goals within GBL and this is achieved by setting out the learning outcomes that are connected to the curriculum as the intention of the game. This is also a requirement in terms of developing a resource as part of the Project Maths guidelines also mentioned in the literature review.

3.5.3 Feedback

The development of Maths Mission also provides positive and supportive feedback to the participant as they used the game and so a growth mindset was incorporated as a design feature. The game itself requires active participation by the student whilst working in collaborative teams. The game also provided a context for the mathematics concepts and skills being learned.

The feedback given to students includes both visual and text based formative feedback. It is a vital aspect of this research to ensure that the game envelops positive formative feedback. The feedback given ensures that the task is seen as surmountable to students and strategy focused which shows characteristics of mastery-oriented goals. Feedback is also clear and immediate thus promoting flow in the game.

3.5.4 Scaffolding

As mentioned in the literature review, the game needs to be challenging so as to avoid students finding it boring; however, the game also needs to scaffold the activity. The scaffolding ensures that students increase confidence playing the game with knowledge they are presumed to know previously. The students work in teams to ensure that collaboration occurs and that no student is questioned singularly. This team focus avoids the student feeling at risk during the game. The students also have the right to fail during the game without consequences and have the freedom to play throughout thus enveloping aspects of play and GBL together.

3.5.5 Interaction

Interaction is by the use of the Gesture-Based input device. Interaction through GBT allows for the advantages to be encompassed within the mathematics classroom. Students receive feedback in order to interact with the game using the 'growth mindset' language throughout the game (Dweck, 2008). Shaffer, Squire, Halverson and Gee (2005) points at games as a way to offer interaction, unlike books as Plato in the *Phaedrus* famously stated are passive, they argue that games can talk back.

3.5.6 Narrative

As mentioned in the literature review, a short guiding story is imperative for the successful engagement of students (Admiraal *et al.*, 2011). These stories provide a frame in which students can ascribe to a reality and allows for the construction of reality (Bruner, 1963). Narrativity is part of the human experience as humans continuously interact with each other and try to narrate their own life story (Bruner, 1963). Learning through experiences (Vygotsky, 2004) in order to engage with mathematical problems is paramount. The narrative used within Maths Mission hopes to achieve one of the design goals of this game. This design goal seeks to engage students through piquing students' interest in real world mathematics and see the relevance of mathematics in different aspects of life.

The narrative that is given to students represents a virtual world in a destroyed city where students are asked to help out and build the buildings by relaying information to the builder. The students act as engineers to complete these mathematical tasks and the questions asked are representative of what is required by a Quantity Surveyor (QS), although in less detail, to build a building. An interview with a QS informed some of the design of the game and the story of the game. Feedback was given by the QS in the design of the game, for instance, the construction of a building on rough ground versus on ground that already had foundations laid. The QS also verified that the mathematics used in the study were also used in real life.

Drawing on strands of GBL characteristics the design of the game is a culmination of aspects of the literature review and the design and theoretical framework. The design and theoretical framework arose from the literature review as described within this chapter. While investigating the key design elements of Maths Mission and its potential, a need for such a framework was evident from both the literature review and emerging findings from the Irish context. Given the increasing number of journals reporting on GBL in the classroom, these findings are important to education (Hwang and Wu, 2012).

The framework is unique in that it draws upon classroom pedagogical concepts and psychology theories to form the game. This resulted in the development of a framework. The Engagement, Confidence, Collaboration and Game (ECG) model is illustrated below. Motivation is threaded through within the characteristics as described above and therefore brings together engagement, confidence and collaboration into this model. Engagement is adopted through the use of flow theory, enjoyment through the guiding principles of play theory, relevance through real world contexts, confidence through the growth mindset in the feedback and collaboration through the use of teams within the classroom. Overall the framework guides the integral parts of Maths Mission and its key functions resulting in design heuristics that are adhered to within this study.

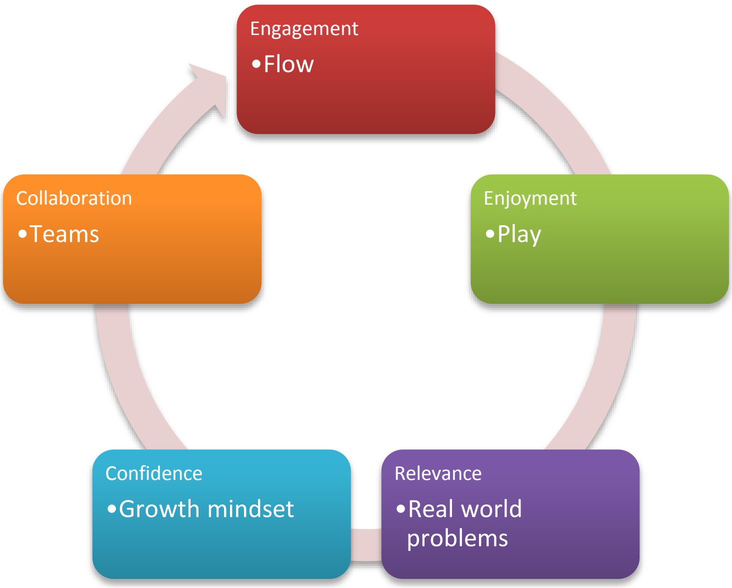


FIGURE 12 - ECG MODEL

The design heuristics are categorised at a high-level into engagement, enjoyment, relevance, confidence and collaboration. Each are listed below with a brief explanation in table 2 of how this is incorporated into Maths Mission.

Research Question	**Design feature**	**Influence of TF on game design**	**Resulting game design analysis**	**Significant lens/tool employed**
1&2	Flow	Ke (2008) states that anything external to the game can interrupt flow. Bai *et al.* (2013) demonstrates this in the game DimensionM whereby separate screens are shown to the player that focus on procedural mathematics.	The questions within the game need to be enveloped within the game itself and not as a separate screen.	Flow theory, EVT, engagement (Abuhamdeh and Csikszentmihalyi, 2012 , Eccles and Wigfield, 2002 , Csikszentmihalyi, 1997)
1&2	Feedback	The importance of immediate feedback is outlined by Miller and Robertson (2011).	Immediate feedback to tell students the answer in a formative way is necessary within the game.	Growth mindset (Dweck, 2008)
1&2	Collaboration	Roschelle and Teasley (1995), Dangwal and Thounaojam (2011), Goos *et al.* (2002)	Students act in teams to achieve the end goal.	Collaboration (Mascolo, 2011)
1&2	Relevance - real world context based	Project Maths - Brosnan (2008, 2013)	Real-life problems are presented in the game by linking them to their career goals. This is done in the second phase of the	Embedded within social context – ZPD and real world context (Rowlands, 2003 , Vygotsky, 2004)

			study.	
1&2	Challenge	Kale and Goh (2012), Miranda and Russell (2012), Abuhamdeh and Csikszentmihalyi (2012), Middleton and Spanias (1999).	Teachers need to keep up with growing advances and students need to be challenged within these technologies. Students must feel challenged prior to engaging with a task in order to be intrinsically motivated.	Flow theory (Abuhamdeh and Csikszentmihalyi, 2012 , Csikszentmihalyi, 1990)
2&3	A short storyline	Annetta *et al.* (2009)	An elaborate storyline can be distracting to students.	Flow theory (Abuhamdeh and Csikszentmihalyi, 2012 , Csikszentmihalyi, 1997)
2&3	Links between the game and the curriculum	Project Maths - Brosnan (2008), Ke (2008)	A deficit in computer design is the lack of connection to the curriculum.	GBL and contexts (Hwang *et al.*, 2015)

TABLE 2 - RESEARCH QUESTIONS, DESIGN FEATURES, INFLUENCE OF THEORETICAL FRAMEWORK ON GAME DESIGN, RESULTING GAME DESIGN ANALYSIS, SIGNIFICANT LENS/TOOLS EMPLOYED

As a result of carrying out a literature review and continually consulting it throughout this doctoral process, the ECG model was developed. The ECG model was then integrated within the development of Maths Mission. The model concentrates on real world problem solving, students' enjoyment, engagement, confidence and collaboration with each other.

3.6 Chapter Summary

This chapter described the three main design and theoretical frameworks used to guide this study. These frameworks focus on motivation while incorporating strands of this topic in the form of engagement, confidence and collaboration. These are then integrated within Maths Mission. The next chapter describes the methodology used within this research.

Chapter 4: Research Methodology

4 Introduction

In order to accomplish answering the research questions using case study and based on key issues that have emerged from the literature review, the methodological requirements are explained. Therefore, this chapter presents and defends the research methodology and methods as appropriate to address the thesis' research questions:

- What are the key design elements of a Gesture-Based game and the key challenges for mathematics classroom implementation?
- What is the potential for a Gesture-Based game to be used as a tool in the mathematics classroom?
- What design features inform the creation of a Gesture-Based game in the mathematics classroom?

This chapter frames the research question prior to explaining the rationale for choosing case study as the most appropriate approach for undertaking this research predicated on a constructivist paradigm. Methods used in data collection, data analysis, subject population and ethical considerations are also discussed.

4.1 Characterising the Problem

The research problem relates to the key design elements of a Gesture-Based game and the challenges for its implementation. Feedback from students and teachers is an integral part in the design process for the creation of Maths Mission and identification of its potential as a teaching and learning tool within the mathematics classroom.

As part of the overall research problem, the challenge is to encompass all the areas of the research problem. In order to accomplish this, a case study methodology was chosen. The rationale for using the case study approach is outlined in the next section.

4.2 Rationale for Choosing Case study

In attempting to address the research problem of developing a new educational technology for the mathematics classroom, constructivist methodological approaches were considered, including action research. Action research is used by practitioners within their own contexts of practice (Zeni, 1998), however, action research does not look at design as an remote activity as is the case here. Regarding a definition, case study

> *"is an empirical inquiry that investigates a contemporary phenomenon (the "case") in depth and within its real world context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 1984, p.13).*

Case study research is therefore adovcated due to the mix of real world context and the phenomenon where the boundaries are permeable (Yin, 2014). Typically case study occurs in a unitary instance, MacDonald and Walker (1997) state that case study is the examination of an instance in action. Case studies are also carried out in their natural context and are designed to carry out an examination of the instance using multiple sources of data collection so as to find plausible reasonings for what is being interpretted in each case. Lincoln and Guba (1985) use the term *'naturalistic inquiry'* for undertaking research within a natural context looking at a phenomenon and drawing traits with constructivism. Yin (2014) describes research as evaluative, descriptive, predictive or exploratory. An evaluative approach is not suitable in this instance given the developments carried out throughout the naturalistic settings. Descriptive and predictive are also inadequate due to the evolving characteristcs of this study. Therefore, this study adopts an exploratory view given the novel undertakings in terms of both the technology and its implementation. There are benefits for undertaking a case study approach. According to the British Educational Research Association (BERA), a case study approach offers a rich account of data (Hamilton, 2011). The main characteristics of case study inquiry include

- *"coping with a technically distinctive situation in which there will be many more vairables of interest than data points, and as one result*

- *relies on mulitple sources of evidence, with data needing to converge in a triangulating fashion, and as another result*
- *benefits from the prior development of theoretical propositions to guide data collection and analysis."(Yin, 2014, p.17)*

Other reasons for undertaking case study as opposed to other research approaches include three considerations – the type of research questions posed, extent of control a research has over behavioural events, the degree of focus on contemporary or historical events (Yin, 2014 ,p.9).

Method	Research question	Requires control over behavioural events?	Focuses on contemporary events?
Experiment	How, why?	Yes	Yes
Survey	Who, what, where, how many, how much?	No	Yes
Archival analysis	Who, what, where, how many, how much?	No	Yes/No
History	How, why?	No	No
Case study	How, why?	No	Yes

TABLE 3 - RELEVANT SITUATIONS FOR VARIOUS RESEARCH METHODS (YIN, 2014)

As the table above shows, case study examines the how, and why in a research question, does not require control over behavioural events and focuses on contemporary events. This is another reason for using case study while answering these research questions. Although the research questions are phrased as what questions, they examine how to create a game and why its implementation brings about challenges.

Therefore, a case study approach is suitable for addressing these research questions. Within this case study research three forms of data collection are used and this allows triangulation of findings. Using interviews, survey questionnaires and observation in this mixed methods research was beneficial as each of these research methods complement each other (Yin, 2014 ,p.9). Interviews were used in phase one along with survey questionnaires; these used questions from the digital competency framework as described in chapter 5. The purpose of carrying out this initial group interview with teachers was to find out the potential of using a GBT game within the mathematics classroom and if it was feasible. A number of research questions for this phase were posed including:

- What level of access, if any, do teachers have to Gesture-Based Computing devices?
- What are teachers' operational skills with computers in general and with Gesture-Based Computing devices?
- What are teachers' personal attitudes toward Gesture-Based Computing in the Mathematics Classroom?

It is important to note that the phrase Gesture-Based computing was used as a generic term to describe all forms that used games available to the general public including the Nintendo Wii, Xbox Kinect and PlayStation Move. Phase two of the study used questions from the TIMSS and EVT framework to form an idea of students' perspectives and career interests as mentioned. This was a nationwide sample and phase two was the springboard for phase three of the study in that the researcher approached the same schools to continue into phase three. Unfortunately no schools from phase two were used in phase three of the study. The aim of phase three was to develop the game and agile software engineering methods were used to develop Maths Mission and pilot the game in two schools. The pilots were a test for feasibility and again potential of Maths Mission within different contexts. Phase four of the study used the same TIMSS and EVT questionnaires as used in phase three and the teachers interview questions were drawn in part from the digital competency framework as used in phase one. Overall these methods used were in line with the design and theoretical framework as described in chapter 3. It can be concluded that the researcher endeavoured to ensure that the research carried out was unbiased and ethical.

4.3 Research Approach - Rationale and Considerations

The research plan adopted in this research not only takes into account the data gathered itself but the process of developing Maths Mission. In doing so, different methods were adopted at each phase of the study. With respect to the data collected after Maths Mission had been developed, a number of elements need to be considered. These elements include that of the inquiry, approaches and design of the data collection (Hwang, Panjaburee, Triampo and Shih, 2013). Fundamental to the research, the research questions dictate the knowledge claims, strategies used and methods employed within the research (Creswell, 2009).

Influences of research can be a researcher's worldview and assumptions regarding the nature of reality (ontology) and knowledge of that reality which can also mean how that knowledge of reality is constructed (epistemology). Each mindset or worldview has repercussions for what view is taken towards the data (Creswell, 2009). The ontology differs across worldviews; however, in a constructivist mindset it is important to note that the knowledge and data can be constructed differently. The meaning denoted from a researcher regarding data may vary depending on their own past. Certain components within the data may appear more important than others based on a researcher's beliefs. Therefore, each researcher approaching the same data may emphasise different points in the same data and construct their own meanings, as shown in figure 13.

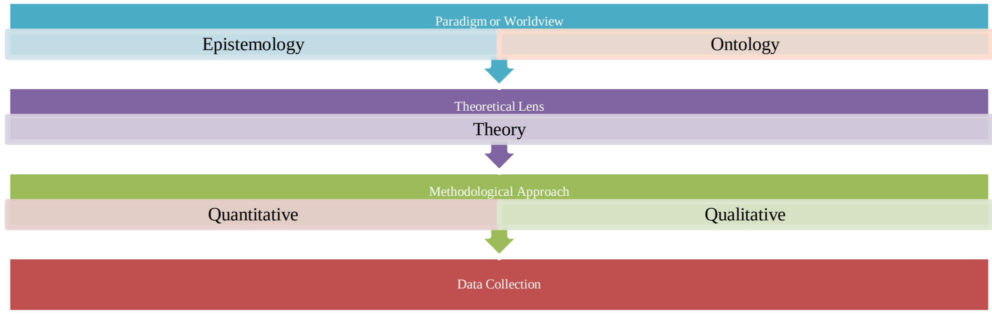


FIGURE 13 - METHODS DESIGN CONSIDERATIONS

As mentioned, adopting particular methods makes reference to a researcher's perspective or worldview. These worldviews are shown in the figure (figure 13) below as research dilemmas. These worldviews adopt different approaches to answering research questions. The column headings denote the main philosophies of the researcher; for instance, a positivist/post positivist stance towards research would be numerical and deductive without consideration of influence on individuals. It also does not account for an individual's past history or interpretation of meanings. Generally, in this research the data can be interpreted through numerical analysis and causalities as well as relationships are explored. A pragmatic philosophy draws from multiple dilemmas balancing against each other where necessary. For instance, a pragmatic paradigm or view of the world would draw upon both quantitative and qualitative data collection tools when necessary (Bazeley, 2013). These may include tools such as observations, survey questionnaires and interviews. In this study, a constructivist paradigm was adopted.

Positivist/ Postpositivist	Interpretivist/ Constructivist	Transformative	Pragmatic
Experimental Quasi-experimental Correlational Reductionism Theory verification Causal comparative Determination Normative	Naturalistic Phenomenological Hermeneutic Interpretivist Ethnographic Multiple participant meanings Social and historical construction Theory generation Symbolic interaction	Critical theory Neo-marxist Feminist Critical Race Theory Freirean Participatory Emancipatory Advocacy Grand Narrative Empowerment issue oriented Change-oriented Interventionist Queer theory Race specific Political	Consequences of actions Problem-centred Pluralistic Real-world practice oriented Mixed models
Adapted from Mertens (2005) and Creswell (2003)			

FIGURE 14 - RESEARCH DILEMMAS (MACKENZIE AND KNIPE, 2006)

Mackenzie and Knipe (2006) state that researchers in instructional technology or other forms of technology should use mixed parallell methods to form convincing bodies of evidence in their work. Ross and Morrison (2004) also state that researchers may benefit from a mixed methods stance as data can be complemented with different methods of inquiry and knowledge claims. It is argued that mixed methods can also contribute strongly to educational effectiveness research (Johnson and Onwuegbuzie, 2004). The main attractiveness of mixing methods is due to its versatility and flexibility. Mixed methods can simultaniously address diverse research questions by integrating both qualitative and quantitative techniques. Therefore, predominantly qualitative data methods were used within this case study; however, quantitative data scales were used to describe the school contexts and overall students' attitudes and perspectives towards mathematics. Using diverse methods can occur at interpretation of the research problem, data analysis, collection and design phase and the procedure of using different methods require a point of interface among both quantitative and qualitative (Tashakkori and Teddlie, 2010). Therefore diverse research methods give a rich account of data and contributes to educational effectiveness research.

4.3.1 **Support of emergent design**

Regarding the development of Maths Mission emergent design was used. This comes from an engineering background and draws on aspects of design experiments once developed by Collins and Brown in 1992 (Creswell and Clark, 2011). The central idea of emergent design is that its focus is on improvement of the educational artefact as it grows throughout the study – in this instance, Maths Mission as it continually grows based on each school visit. The emergent design is a way to use the theory, design and problem as a strategy for developing theories (Dede, 2004). Throughout emergent design a number of advantages are understood. One of the advantages of emergent design is the contribution to theory based on the design research carried out. Types of design theories according to (Edelson, 2002) incorporate the development of domain theories, framework theories and finally a design methodology theory. By improving the educational artefact throughout the investigation of the theory, design and problem is imperative when developing an educational artefact such as the one in this study, Maths Mission. Emergent design draws on evolutionary design instead of fixing a research procedure that is pre-determined prior to research commencement. As emergent design comes from an engineering design background, in this study the design of this mathematical game adopted many software engineering processes. These processes helped to guide the design in terms of iterative feedback when visiting schools. Addressing the emergent design of the software, agile software development practices were employed.

4.3.2 Agile Software Development

Agile software development is a set of practices developed by experienced practitioners (Dyba˚ and Dingsøyr, 2008). Agile software manifesto was developed by these practitioners back in 2001 and state that the practitioners are uncovering improvements to software development *(Development, 2001).*

> *"According to the agile principles enunciated in the agile manifesto, motivated and empowered software developers – relying on technical excellence and simple designs – create business value by delivering working software to users at regular short intervals."* (Dingsøyr, Nerur, Balijepally and Moe, 2012, p.1214).

The principles are guidelines in order to produce high quality software in an efficient manner. Agile software development focuses on the flexibility of creating software. This agility can ensure Rapid Application Development (RAD) and allow for cyclical development cycles. These development cycles can incorporate the user's experience and for this reason is most fitted in the development of Maths Mission. More of agile software development is discussed in chapter 5 when describing phase three of this research. Regarding the collection of data for the development of Maths Mission a questionnaire was sent to schools across the country. These schools are described in the next section.

4.4 School Sampling

A brief description of each of the school contexts for phase four is shown in table 4, after which a brief description is given.

Alias	Gender	Public/Private	Urban/Rural	Progression to University	Established	Environment	Features	Teaching Pedagogy
A	All girls	Public	Urban	34%	1950s	Traditional classroom layout	• Lack of mathematical oriented subjects • Limited resources	Authoritarian
B	All boys	Private	Rural	90%	1930s and extensions built 2010s	Collaborative layout	• Access to a range of mathematical oriented subjects • Wide-ranging resources	Democratic
C	Co-educational	Public	Rural	45%	1990s	Traditional classroom layout	• Access to a range of mathematical oriented subjects • Wide-ranging resources	Authoritarian
D	Co-educational	Private	Urban	47%	1820s and extensions built 1990s	Collaborative layout	• Access to a range of mathematical oriented subjects • Wide-ranging resources	Authoritarian
E	All girls	Public	Urban	75%	1960s and new school opened 1980s with extensions built 2010s	Collaborative layout	• Limited range of mathematical oriented subjects, however, access to technological resources more than others • Mid-wide ranging resources	Empowered

TABLE 4 - SUMMARY OF SCHOOL CONTEXTS

The summary of each school context and therefore, its naturalistic environment is set out in table 4. The summary table illustrates the school in terms of the context. The context is described with the gender of the school, whether it is public or private, urban or rural and university progression percentage. This table also looks at the establishment of the school, physical and classroom environment, key features impacting on student achievement and finally, teaching pedagogy in terms of teacher leadership on the day of the school visit. The context of each school is important in situating where this research is taking place. Chapter 8 describes in detail each school context; however, a brief summary of each school is described to aid the reader's appreciation and understanding of the study.

It is important to bear these contexts in mind when interpreting the results. School A is an all-girls public urban school with a traditional classroom layout. This layout means that each student has their own desk and is separated into rows facing a blackboard. School A's progression to university is 34% and the teaching pedagogy was observed as being predominately authoritarian. School B is an all-boys private rural school with a collaborative classroom layout- seating in groups. The collaborative layout means that the students are sharing a long desk and there is flexibility to move in and around the classroom. The classroom also has a continuous whiteboard on three walls where students can write when conducting collaborative work. School B's progression to university is 90% and the teaching pedagogy observed was democratic. School C is a co-educational public rural school with a traditional classroom layout. School C's progression to university is 45% and the teaching pedagogy observed was again mostly authoritarian. School D is a co-educational private urban school with a collaborative layout. School D's progression to university is 47% and the teaching pedagogy observed was also authoritarian. School E is an all-girls public urban school with a collaborative layout. School E's progression to university is 75% and the teaching pedagogy observed may be described as empowering.

4.5 Research design

There are four phases within this case study research and different phases yield different methods. The table below shows the research questions in relation to the data collection method and description for each phase of the study. These show the research questions and different data collection methods used. As shown in table 5, research question one yielded two data collection methods – group interview and survey questionnaire. Aside from this, attention must be given to the prototype (SIP flight) that was made to allow this data collection to happen. Research question two also had the same data collection procedures along with software development and qualitative modes of inquiry. Research question two also saw the development of Maths Mission based on group interviews carried out in schools to the class. These involved the feedback from students in terms of improvements that could be made to the pilot of the Maths Mission. This was also the time that this game was named Maths Mission. Finally, the last research question, question 3 included survey questionnaire, software development using agile processes, group interview and interview with the teacher. Methods were mixed again to answer research question 3 as these included the TIMSS and EVT framework questions.

Data Collection source 1 and Description **Research Question 1**	Data Collection Source 2 and Description **Research Question 2**	Data Collection Source 3 and Description **Research Question 2**	Data Collection Source 4 and Description **Research Question 3**
Method: Software development, group interview and survey questionnaire Purpose: Find out the potential of GBT games within the mathematics classroomss? Mode of Inquiry: Qualitative Perspective: Teacher	Method: Software development and questionnaire Purpose: Find out students' career aspirations Mode of Inquiry: Quantitative and qualitative Perspective: Student	Method: Software development and group interview Purpose: Gain an insight into students' perspectives of the game Mode of Inquiry: Software development using agile software development techniques Qualitative Perspective: Teacher and student	Method: Survey questionnaire and group interview, software development, individual interview with the teacher. Purpose: Reflect on feedback from students, evaluate effectiveness of Maths Mission. Continually improve features for students' use of Maths Mission. Mode of Inquiry: Quantitative and qualitative Perspective: Teacher and student

TABLE 5 - RESEARCH QUESTIONS, DATA COLLECTION AND DESCRIPTIONS

4.6 Data analysis

Phase one involved survey questionnaires and interviews in two different stages. Surveys were paper-based and transcribed by the researcher. These were then imported into the quantitative data software package known as Statistical Package for the Social Sciences (SPSS) version 20 in order to see the data statistically. The data were then compared and averaged. The purpose of this was to gain an insight into pre-service teachers views of GBT within the classroom. The qualitative data were coded and as the sample size was quite small it was easy to gain an insight into the overall view of the two classes. The interviews were based on two teachers and again were electronically recorded, then transcribed and upon transcription coded. The researcher had undertaken training in NVIVO, however, again the data were quite small and not worth including in the large software programme.

Phase two was to gain an insight into students undertaking Project Maths. Specifically those whom already had a year of experience, the reasoning for this was that the schools were only introduced to Project Maths in 2011 and therefore may not have had all the recommendations from the curriculum in place. The objective was to sample second and fifth year students in Irish second level schools to ascertain their views on mathematics. Schools proportional to size determined the sample. With the help of Dr Jerome Sheahan of the School of Mathematics, Statistics and Applied Sciences at the National University of Ireland Galway, it was decided that schools within any one geographical area would be homogeneous within one area from those in any other geographical area. A frame already exists for schools, cluster sampling with schools as clusters works best for this study. Single-stage cluster sampling was employed, as it was feasible to select all students in second and fifth year in all schools selected. The sampling method included simple random sampling as a way to choose the schools from a list of all second level schools in Ireland. This means that each member of the population has an equal chance of being selected for that particular sample and finally the selection of one member is independent of the selection of any other member of the population (Kiess, 1996). The schools in this population were not placed into homogeneous subgroups like stratified random sampling unlike the TIMSS 2011 Ireland sample (ERC, 2011). The stratified random sample taken by TIMSS 2011 in Ireland is noted in the technical report as drawn up by the Educational Research Centre (ERC). Stratified random sampling was not identified, as the study does not account for homogeneity and removed strata thus opening up the sample to the entire population of second level schools in Ireland. Strata can remove groups such as private schools as omitted by the ERC for the purposes of carrying out the TIMSS assessment in 2011. It was important to this study to allow for entire contexts to be developed and a chance for students of diverse backgrounds to participate. Students were taken into account instead of entire classes or years thus rendering it not feasible in this study, as schools would be required to account for any students not participating in the study.

When selecting the clusters (schools) to be used in the sample, the relative size of each school was taken into account; probability proportions to size works best for this sample selection (so that, for example, this increased the chance of a school that is twice as large as another school being included in the study). The cluster variance is considered in this sample size calculation. Ideally the quantity called the intra-class correlation is known and so a pilot survey was conducted. Note that there will be variation between the opinions of students within each school and between schools. The total variance is the sum of these two variances and the ratio of the between school variance to the total variance is the intra-class correlation. A pilot study is used to determine the participation rate of survey questionnaires; however, as this is limited in scope, the results of this pilot survey to estimate this variance were not used. Instead, the range of responses of some important survey questions was examined and these ranges gave an idea of the variability (this is an approach sometimes used by engineers to estimate standard deviation based on a "six-sigma rule"). It was decided to use over 90 clusters. The generation of the sample was made using the SPSS complex sampling procedure. Therefore, these were distributed across 90 schools across the country proportional to size sampling and after taking into account the time of year that these were distributed an incentive was given to each school. The survey questionnaire was sent out to 100 post-primary schools to allow for a low participation rate. For each survey questionnaire sent out to schools a small donation was given to Our Lady's Children's hospital in Crumlin, Dublin. This is due to the time of year that the survey was being sent out. A second survey questionnaire was sent to 200 primary schools in June 2013 and an increased incentive with the option of completing the survey both on paper or online. The school had the option of completing the survey both online or on paper as both are available.

The time for sending out survey questionnaires can affect the participation and due to the end of the school year in May, schools are generally busy so the donation was increased after the first round of survey questionnaires were sent out. A total of 300 schools were contacted between May and June 2013 and while these were contacted via email, a number of schools were followed up with phone calls and a further email to entice participation with the additional incentive of increased donation to the hospital. The response rate remained low with 175 respondents in primary and 118 in post-primary.

Phase three was in relation to the usability and human computer interaction of Maths Mission. For successful implementation it was important to ensure the game was 'user friendly' – students were able to play the game without any issues occurring. This led to two pilot schools where open-ended questions were asked to the class in relation to any improvements that could have been made to the game. The pilot resulted in the naming of Maths Mission as at that stage it was not named.

Phase four data were gathered from survey questionnaires and qualitative interviews as well as researcher field observations. The quantitative survey data were gathered and recoded within SPSS and a number of statistical methods for interpretation including descriptive statistics were used as well as Cronbach's alpha and factor analysis. The qualitative data were analysed using Microsoft Excel, as the researcher is proficient in Excel to use pivot tables, tables and charts while coding, categorising and re-coding. A number of questions were asked while coding the data and these were closely related to the approach to the field observation notes:

- What are people doing? What are they trying to accomplish?
- How, exactly, do these do this? What specific means and/or strategies do they use?
- How do members talk about, characterise, and understand what is going on?
- What assumptions are they making?
- What do I see going on here? What did I learn from these notes?
- Why did I include them? (Savenye and Robinson, 2001)

Coding the data led to the development of themes resulting from individual schools. Each school represents a particular situation of implementation and the final school, school E, represents a more in-depth situation than the other schools as three classes were part of the study. The researcher looked at ways of recruiting schools for this study to ensure that each type of school could be represented according to the different types. For instance, in the school descriptions section it describes schools in terms of urban and rural settings as well as single-sex and co-educational schools to represent a broad range of schools.

Phase four also focused on the emergent design of Maths Mission through classroom use and in so doing data collected through observation, survey questionnaires and interviews in each school. The survey questionnaires were the same from phase two and the researcher attended a summer school given by Dr Laura Dwyer from Boston College in relation to statistical methods that were used in TIMSS. The data were again transcribed and SPSS was used to produce findings in relation to the classroom context.

In-field observation and analysis of game-playing was the focus of qualitative observational data. Direct observation of the participants was used at each school visit during game-play. Concurrently, participants were asked to think-aloud to reveal what they were doing while playing the game. The researcher observed participants' behaviours, peers and environment when they were in the classroom. Analysis of game-playing consisted of asking students to state what improvements could be made to the game. Details of the classroom environment were noted regarding access to subjects, classroom layout, equipment available and subject availability to students. Moreover, these observations were categorised under the headings of collaboration, problem solving, discussion and engagement. These categories were described within the classroom and as per the description of each classroom visited – these were also noted in relation to physical environment, features and teacher pedagogy. These observations were gathered and supported by the schools information on their website or from the department of education to gain an insight into the context of the school. During school visits students also filled in the survey questionnaire regarding their perspectives and career interests. Upon analysis of the data, a scoring method was used to condense the data. The scoring method is explained in more detail in chapter 6. Chapter 6 shows the scoring as this brief overview showed the classroom context regarding TIMSS and EVT perspectives more clearly than in-depth statistical methods. The data were also analysed for correlations and these are presented in the appendices. The correlations are useful as they show the relationships between each question within the constructs as described in chapter 6.

With regard to design features to improve the usability and human computer interaction within the game, the students were asked the same question regarding improvement and this feedback was then iteratively implemented into the game after each school visit. Information was recorded by the researcher and input into the game after each school visit.

Interviews within phase four were recorded and transcribed. These data were then coded. Common themes among schools arose and these are shown to be the main findings in the thesis discussed in chapter 9. These data from each phase remain under the auspices of the National University of Ireland Galway in keeping with ethical procedures to store data in a locked cabinet five years after the doctoral study has completed. Upon submission of the thesis to the university library, the researcher endeavours to protect the software and therefore the thesis will go under embargo.

In order to ensure that the ethical considerations are met throughout the research process, the researcher was granted ethical approval by the National University of Ireland Galway to undertake this research. The protection of children in this thesis includes the addition of pseudonyms where necessary and the blurring of children's faces. The researcher is also approved to work with children by being Garda vetted. The children, heretofore known as students, individuals or players, participating in this study received guardian or parental permission prior to engaging in this research study. Students that participated and schools names are all under pseudonyms for their protection.

Finally, students were given information regarding the study, and as with all participants in this study, they were informed that participation is voluntary and they had the right to withdraw at any stage of the research. The teachers participating in this study could withdraw at any stage and review their transcripts from the interviews at any time. A teacher throughout the school visits also supervised students. Data protection protocols were followed and are in line with the British Educational Research Association (BERA).

4.7 Validity and Reliability

Every aspect of this case study research including the questionnaire development needs to provide a valid and rigorous foundation. The following sections describe validity and reliability in terms of this research

4.7.1 **Validity**

Validity regarding the case study research design can be tested by investigating four areas; construct validity, internal validity, external validity and reliability (Yin, 2014). Case study as per the characteristics described above usually uses multiple sources of evidence, establishes a chain of evidence and have key informants review draft case study report (Yin, 2014). According to Johnson and Onwuegbuzie (2004) the questionnaire is valid when it measures what it set out to measure. In terms of the validity of the questionnaire, in order to avoid questions becoming open for interpretation by students, a pre-test questionnaire was sent out to schools in phase two of the study. Initially the pre-tested questionnaires tested the accuracy of the questionnaire to ensure what was asked was actually the intended questions. Many iterations of pilot questionnaires ensured that there was no confusion surrounding the questions. The rest of the questions in the questionnaire were validated questions as per TIMSS and EVT.

There is also a question of naturalistic environment when research is conducted in varying schools. The contexts of each school matters in terms of resource allocation, teaching methodologies, cultural context and while these are useful in terms of understanding the environment, these vary among all schools. However, even though these are contexts that vary among schools, these contexts illustrate the differences in naturalistic environments and gain an insight into the overall picture of Irish schools in different contexts. It is important to distinguish the naturalistic environment among schools in order to gain deeper knowledge into issues that arise during implementation. As well as observation within schools and the naturalistic environment, the demographic profile of the participants within the study varied through the phases and this impacted on the environment of implementation within each of the phases.

4.7.2 Reliability

Reliability can be referred to as consistency in results (Leedy and Ormrod, 2005). Demonstrating reliability means being able to measure the internal consistency and test re-test correlation (Leedy and Ormrod, 2005). Reliability refers to the extent to which the data collection techniques or analysis procedures will yield consistent findings (Creswell, 2009). Consistent findings can mean if another researcher were to use the same instruments on a different sample population there should be a high degree of correlation. Within this research various forms of methods were used for triangulation purposes and to confirm findings from initial reports. The three main methods that are used in the data collection are; survey questionnaire, observation and interview. Each of these needed to be checked for reliability. A number of questions are usually asked with respect to reliability and these include the following:

- Will the measures yield the same result on other occasions?
- Will similar observations be reached by other observers?
- Is there transparency in how sense was made from the raw data? (Saunders, Lewis and Thornhill, 2007).

In the case of the methods in this study, each of these questions yield 'yes' and demonstrate similar answers. The measures taken include frameworks to guide the researcher and can therefore be used again in different settings at different points in time. Observations were guided and field notes taken, therefore, if another researcher were to look at the same school setting similar data would be gathered. However, if a different researcher were to carry out the observations the guidance notes would also contribute to their data gathering and similarities should be drawn. If the same study were to be carried out again then this study would yield the similar outcomes regarding results. The data analysed used qualitative and quantitative methods described in each phase, for instance, chapter 5 describes how the data was gathered and analysed within phase one. The design process and observations are grounded within the guidelines and are consistent throughout and there is transparency of raw data obtained. Causality is not investigated in this study and therefore, the causes as to why the students answered specific questions was not investigated (Mark Saunders, 2007).

In terms of threats to reliability, as stated in (Saunders *et al.*, 2007), Robson states four types of threats to reliability:

- Subject or participant error
- Subject or participant bias
- Observer error
- Observer bias

Participant error can occur if the student is not aware of the meaning of a particular survey questionnaire question, although this is reduced with the pilot survey questionnaires sent in February 2013 that checked for this error. As these survey questions are deduced from international research and students complete the survey questionnaire prior to meeting the researcher there is little to no participant bias.

Observer error and bias are reduced with the observation guidelines per school and these are outlined in the data analysis chapter with regard to school contexts. Observations are guided with different prompts via field notes to instruct the researcher on different considerations when visiting the school. These prompts guide the researcher and do not inhibit any other observations that can take place. Observation bias can occur due to seeking specific things within a context and not observing the overall picture. This is accounted for in terms of prompts of the researcher only (Saunders *et al.* (2007).

4.8 Summary

The main research questions addresses the key elements of the creation of a GBT game as well as understand its potential as a tool for the classroom. The research questions are answered in the pragmatic sense looking at the case study approach and mixed methods research.

The methods of inquiry, approaches undertaken and design of data collection were all described. The researcher uses a mixed-methods case study approach with emergent design to develop and implement Maths Mission within the mathematics classroom. This ultimately addresses the following research questions:

1. What are the key design elements of a Gesture-Based game and the key challenges for mathematics classroom implementation?
2. What is the potential for a Gesture-Based game to be used as a tool in the mathematics classroom?
3. What design features inform the creation of a Gesture-Based game in the mathematics classroom?

Data are presented in a way that reflects a mixed-methods approach. The reliability of the survey questionnaire, observations and teacher interviews were examined and justified through a review of identified threats. A summary of each school context outlined the population and natural environment of each of the five schools in the final phase of the study. Overall this chapter described the study, characterised the problem and research questions as well as outlined the rationale and considerations of using case study as the approach for answering the research questions. Methods were then discussed as well as the sample school population and ethical considerations when carrying out this research. The following chapter, chapter 5 now outlines phase one of the study.

Chapter 5: Case Study: Phase One

5 Introduction

This chapter will report on phase one of this case study research that focuses on the design and implementation of a Gesture-Based Technology (GBT) prototype in the mathematics classroom. In Ireland and within the realm of mathematics, GBT is in its infancy. The study of GBT within the discipline of mathematics is a relatively new phenomenon. For this reason, phase one carried out a preliminary study exploring the possibility of the design of a low-cost GBT prototype and its feasibility in the mathematics classroom. Therefore, the purpose of phase one is to identify any key technical challenges in developing a low-cost GBT prototype and to explore the feasibility of this technology within the mathematics classroom.

Phase one of this study was split into design and feasibility stages. There were three stages in phase one. Stage one explored the best-fit technology for the classroom context and ultimately developed a prototype known as SIP flight[13]. Figure 15 shows the final version of SIP flight. This prototype was then used to progress into the feasibility stages, stage two and three.

FIGURE 15 - FINAL VERSION OF SIP FLIGHT

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[13] SIP flight refers to a digital dart and dartboard developed using the WiiMote. SIP stands for Statistics, Integers and Probability as these are enveloped in the playing of darts using the WiiMote as illustrated below. *It is a customisable digital dartboard that uses the WiiMote, to throw darts at a projection of a dartboard.*

Upon completion of stage one, there was a realisation that the technical development of the game occurred within a vacuum. It was realised that there was little or no evidential knowledge about teachers’ attitudes to SIP flight. Therefore, stage two focused on gathering pre-service teachers’ attitudes to GBT and the prototype - SIP flight as a possible teaching and learning tool in the classroom. This questionnaire was carried out in October 2012 and acted as a baseline for moving forward into stage three whose purpose was to establish in-service teachers’ attitudes and particularly their perceptions of the feasibility of the technology within the mathematics classroom by conducting a group interview in November 2012. Having briefly described the stages of the study, the following section gives an overview of the details of phase one.

5.1 Overview of phase one

Figure 16 shows an overview of phase one, stage one focused on the technical design stage of the prototype while stage two and three centred more on the feasibility of GBT for the mathematics classroom. The design stage was composed of a cost-benefit analysis of GBT technology and following on from this, the best-fit technology from the cost-benefit analysis was then used to develop a digital dart and dartboard known as SIP flight. Overall, stage one describes the cost-benefit analysis and the design challenges that happened as a result of developing a prototype that is low-cost and for the mathematics classroom. The design stage was completed in May 2012.

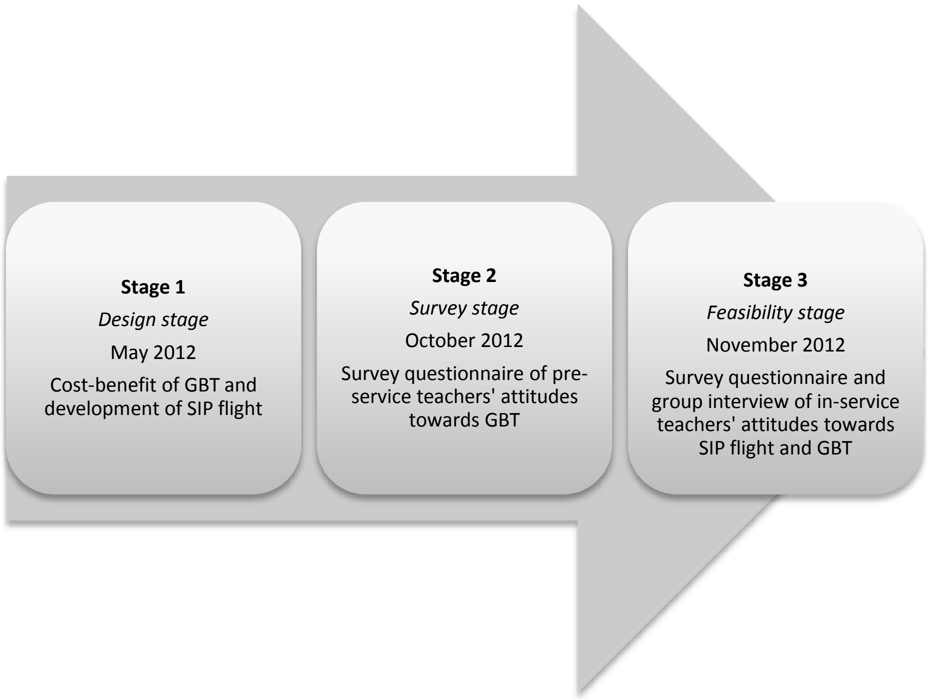

FIGURE 16 - PHASE ONE STAGES

More specifically, the main purpose of these stages were to address the issues related to feasibility and look at the initial potential prior to developing more detailed game:

- What level of access, if any, do teachers have to Gesture-Based Computing devices?
- What are teachers' operational skills with computers in general and with Gesture-Based Computing devices?
- What are teachers' personal attitudes toward Gesture-Based Computing in the Mathematics Classroom?

5.2 Stage One

Overall, this phase was exploratory in nature and aimed to ensure the feasibility of subsequent research by the researcher by identifying and addressing possible research implementation challenges. Stage one involved an initial assessment of GBTs by the researcher. This assessment explores the cost-benefit of GBT and the practical implications of employing GBT in schools before moving forward. Based on this assessment, SIP flight is then developed with the most viable GBT for the classroom context.

5.3 Stage One Outcomes

The purpose of stage one is to assess the best GBT in terms of its educational practicality within the mathematics classrooms in Ireland. A key factor in the determination of practicality is the available school budget. Cost is a major consideration when assessing equipment for a school. Cost is also a major factor found as part of the report on digital competences in the digital agenda across the Europe (European Council, 2012). This report found that equipment and access costs are key influences when accessing the Internet. Even though this factor relates to the Internet, this finding is also the case with new technologies and reducing the 'barrier to entry'. This evaluation of different affordable GBTs determined the most accessible platform in terms of availability to teachers in classrooms in Ireland. The benefits and drawbacks of each GBT considered are illustrated table 6 below.

Gesture-Based device	**Benefits**	**Drawbacks**
WiiMote 	• The controller is portable and students may be handed the controller • The WiiMote carries a signal of more than a 30 foot range • The WiiMote uses Bluetooth technology that allows up to four remotes • Existing research conducted by Dr Johnny Chung Lee[14] allows the possibility of making an interactive whiteboard out of a Wii controller using an infra-red light source and a Bluetooth dongle • The WiiMote also uses batteries that can be replaced easily	• The graphics on the Wii console are not a high standard • The WiiMote sensor is not as accurate as the PS3 Move • The WiiMote comes with lots of accessories, sensor bar, Nunchuck and WiiMote

[14] Johnny Chung Lee operates a project that connects the Wii controller to infra-red light source and a Bluetooth dongle. Accessible at: http://johnnylee.net/projects/wii/ Date accessed: 15th December 2013

PS3 Move 	• The PlayStation console allows for Blu-ray DVD playback • The graphics on the PlayStation console are better than the Wii console • The PlayStation Move sensor is very accurate	• The PlayStation and Move are sold separately and are expensive • The PlayStation console is needed in order to connect the PlayStation Move via the computer. Therefore, all equipment is necessary • Not as much research is conducted using PS3 Move in education compared to the Wii • The PlayStation Move was released September 2010 and not many games exist in the market that are educationally based • The PlayStation Move need to be connected to PlayStation console to charge them

TABLE 6 - BENEFITS AND DRAWBACKS OF THE WIIMOTE AND PS MOVE

Based on the assessment of benefits and drawbacks of each console, the data in table 6 shows that the Nintendo Wii remote (WiiMote) has far greater benefits than the PlayStation Move (PS Move). Benefits particular to a mathematics classroom include a range of use of up to 30 feet and allowing students to remain seated and participate fully. This allows for greater accessibility within the mathematics classroom as students, no matter what their posture, are facilitated in participating fully. Also, four WiiMotes can be used at the one time, therefore more participants can engage with the technology at once. The Nintendo Wii console has relatively low standards in terms of graphics. However, poor graphics on the Nintendo Wii console are easily overcome by connecting the WiiMote to a developed piece of software independent of the Nintendo Wii console thus allowing for better graphics. In terms of cost the Nintendo Wii is more affordable for schools that have a low budget to spend on resources and therefore more accessible. Bluetooth technology enables the communication between the Nintendo Wii Remote (WiiMote) and a computer directly without the need for the Nintendo Wii console itself. Thus the WiiMote is the most viable option in terms of cost. The PS Move is inseparable from the PlayStation console and thus renders this option expensive. The school needs to purchase a PlayStation and also a PS Move controller in order to adopt GBT within the classroom.

Both the PS Move and WiiMote, as illustrated in the benefits and drawbacks table, show that the PS Move has a highlighted ball at the top that changes colour depending on how many players there are connected to the PlayStation console. The Nintendo WiiMote is rectangular and the PS Move is more rounded. Both include a wristband to wear while using these. This is to ensure users do not throw the controller out of their hands while using either of them. Thus the only benefit that PS Move has above the Nintendo WiiMote is that each student connecting to the PlayStation console is a different colour ball on the PS Move. For these reasons, the Nintendo WiiMote is preferred as this is the lowest in terms of cost. There is, however, a difference in terms of how each device communicates with a computer.

The WiiMote uses infrared sensors to communicate with a sensor bar, accelerometers are used to detect whether the person moves the controller up, down, left or right. The buttons can be used more easily on the WiiMote as opposed to the PS Move and replacing a battery is not an issue on the Nintendo WiiMote. The PS Move can only be charged when attached with a cable to the PlayStation console and therefore is not as flexible. Therefore, owning both a console and Move device is a requirement in order to charge the PlayStation Move, as it is not battery operated.

Summaries of the results from the cost-benefit analysis from stage one are that the WiiMote is the most viable cost. Both are similar in terms of being handheld, the PlayStation Move is colour coded; however the PlayStation Move requires a console to charge, while the Nintendo WiiMote uses batteries. It is for these reasons that the WiiMote was decided to be the best option in this phase.

At the time this phase was being carried out, the Xbox Kinect did not feature as a contender as the Kinect in 2011 acknowledged challenges when smaller individuals stood beside taller individuals. The Kinect screen showed children as kneeling adults. In terms of the possibility of development, this is the most expensive option of the three and is limited in terms of accessibility if a student is seated. The Xbox console and Kinect are sold separately and the cost-benefit analysis shows that the cost is far greater than the cost of a single WiiMote.

Following the cost-benefit analysis of the technology, the process of the design stage focuses on the development of SIP flight using the most suitable option, the Nintendo WiiMote. The development of SIP flight is described in the following sections.

5.3.1 SIP flight

As mentioned, the WiiMote was established as being the most viable option for developing a prototype in stage one. SIP flight is a prototype that was developed by the researcher in order to provide a GBT teaching and learning tool that allows students to practice Statistics, Integers and Probability (SIP). It allows students to use SIP flight as a way of practicing simple integer manipulations. Also SIP flight provides a customisable platform to practice forms of statistics as well as probability. This feature facilitates a way in which students engage in calculations using both positive and negative numbers. The image below shows the intended use of SIP flight.

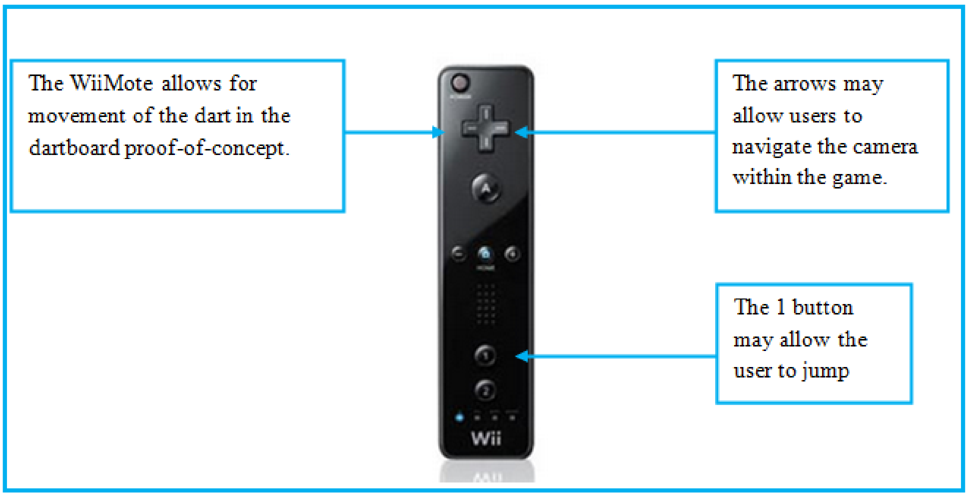

FIGURE 17 - NINTENDO WIIMOTE CAPABILITIES IN SIP FLIGHT

As mentioned in the introduction, SIP flight is a dart throwing exercise and utilises the dartboard as a target. The dartboard requires a dart to be thrown and this is where the WiiMote is used in this phase; it allows for the movement of the dart in SIP flight. As illustrated in the figure above (figure 17) the capabilities of the Nintendo WiiMote allows the user to change the camera and jump. These are not necessarily part of SIP flight; however, the possibilities allow for SIP flight to be developed in different ways as shown in the figure above.

SIP flight used XNA Game Studio 4.0 (XNA) to write the software with the programming language C#. This is the first time the researcher has programmed in C# and used XNA. This marks a significant milestone in terms of developing a low-cost GBT for the mathematics classroom. She acknowledged the challenges encountered in learning a new programming language and took several iterations before developing SIP flight in May 2012.

Following on from this, a key challenge in using the WiiMote directly with a Microsoft Windows 7 (WIN7) computer is that of connectivity. The establishment of the connectivity between the WiiMote and a laptop is a significant milestone for this research. Many iterations of SIP flight eventually allowed for the connection and communication between the computer and the WiiMote via Bluetooth. As a result of researching this milestone, the doctoral project could proceed. Further details with regard to the development of SIP flight are discussed below.

5.3.2 XNA Game Studio 4.0

During the initial stage of developing SIP flight, the decision was made to develop it using a *game engine*. The development of SIP flight used XNA. XNA is a game engine that allows for programmable graphical games development. The game engine allows for game creation on windows, windows phone and Xbox 360. XNA includes the XNA Framework which has libraries based on the Microsoft .NET[15] Framework. XNA was

[15] .NET pronounced dotnet. ".NET 2015 is the umbrella that represents the key pieces of the .NET platform delivered from Microsoft, including

published by Microsoft in 2010 and was up-to-date at the time of development in 2011-2012. As of 2013, CodePlex has taken over support for XNA and Microsoft has removed their support. Microsoft has fully retired XNA as of April 2014. While game developers can continue to use this framework, it has received its last update and will not continue to improve and grow features.

5.3.3 C# Programming Language

Development in XNA requires programming in C# or JavaScript. C# programming language is an object-oriented language developed by Microsoft. It builds on similar concepts to that of the Java programming language. This programming language is a modern, general-purpose programming language. Similar to Java, it is object-oriented and incorporates a structured language. It is built on part of the .NET framework. C# is the main programming language used in XNA and this programming language is generally accepted as an industry standard for game developers. It is used to build games as it allows for Boolean conditions, events management and conditional compilation. The syntax of the language is similar to most modern object-oriented languages such as semicolons at the end of statements, double equals to denote two statements equalling each other, assignments through one equal sign and square brackets denoting arrays.

5.3.4 Connectivity

Both the C# programming language and XNA were employed as part of developing SIP flight. The main requirement of SIP flight was to establish connectivity between the WiiMote and the WIN7 computer via Bluetooth. Due to this, many iterations of development occurred including the purchasing of several Universal Serial Bus (USB) adapters. Each USB adapter used different WIN7 drivers to use Bluetooth within the WIN7 operating system. Standards vary between the hardware of the computer, the

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the .NET Framework, the recently announced .NET Core, and a shared common layer of packages, compilers and runtime."MICROSOFT. 2015. *.Net* [Online]. Available: http://www.microsoft.com/net [Accessed 15th September 2015].

hardware of the USB and the Bluetooth software. Within Windows, there still exist challenges with a single standard of Bluetooth communication. There is still no singular Bluetooth standard in Windows. Ultimately, to achieve connectivity this is an exercise of trial and error between the different hardware components and the various standards of Bluetooth windows drivers and the WIN7 operating system. In parallel with the development of SIP flight, continual reference was made to the curricular strands. There follows a description of those strands for the reader in the subsequent sections.

5.3.5 Learning Design of SIP flight

As described previously, SIP flight stands for Statistics, Integers and Probability, and flight refers to the dart flying to the dartboard. Throughout the initial stages of development, a pre-service mathematics teacher was consulted throughout the learning design of SIP flight.

The consulting pre-service teacher had originally used a magnetic dartboard to demonstrate these statistical, integer and probability concepts; however, the magnetic dartboard lost its magnetism due to overuse. SIP flight provided an alternative solution that could be customised and at the same time seemed to be more flexible when teaching mathematical concepts.

SIP flight can be used for statistics and probability by using the dartboard to provide statistical data whilst at the same time the probability of different integer outcomes may be determined. For example, teachers may use SIP flight for integers by using both positive and negative numbers and probability by working out the probability of getting -17 or +19 in each round.

It is important to note that a number of in-service mathematics teachers outside of this doctoral research currently use SIP flight in the mathematics classroom. However, in this phase, SIP flight is only used as a demonstration of the capabilities of GBT in the classroom. As the curriculum was continually consulted throughout the design, the intention of SIP flight is for it to be used to support learning statistics, integers and probability; however, there might be alternative ways in which SIP flight could be implemented by in-service teachers. Thus, the learning design only suggests areas that SIP flight could be used to teach in the mathematics classroom.

The strands and strand units of the existing Project Maths curriculum were identified in consultation with the pre-service teacher involved and align with the NCCA (2011b) document on syllabuses and assessment. These are as follows:

5.3.6 Strand 1 – Statistics and Probability Strand

Statistical reasoning with an aim to becoming a statistically aware consumer strand unit

Students can engage with statistics by representing the dart as data input and collating information with respect to each student throwing the dart in SIP flight. Students can then discuss the purpose of using these statistics and why these can be important. Students can also look at the misuse of statistics and see the purpose of useful statistics. Statistics that are used in sport and games can be discussed as SIP flight opens up the world of sport in terms of darts themselves and how analysis can occur. The statistics can then be represented on a graph.

Finding, collecting and organising data strand unit

Students also find, collect and organise their own data and can present these data to their classmates based on their participation with SIP flight. Students can formulate questions with regard to each team's answers. It is also important that the teacher guides the students through the problems at hand in order to clarify problems.

Students are encouraged to clarify the problem during their presentations, formulate questions to other teams and explore alternative methods of data collection through SIP flight. Upon collating the data, statistics can be generated per group and within the class a sample can be taken to represent the class statistics. These can be used to communicate among other classes using SIP flight. Students then have the opportunity to plan and collect different data and represent comparative data in the form of a spreadsheet.

5.3.7 Strand 3 – Number Strand

Number systems strand unit

The number systems strand is not covered extensively; however, estimation and probability calculation is a meaningful task within computational learning. The chances of scoring particular points after each of the students' teams have had their turn throwing the dart is a possible computational task. Learning strategies here include: calculating percentages, generalising, articulating observations and conclusions as well as students practicing the calculation of positive and negative numbers.

Students who learn about either/or options as designated as 0 and 1 have the opportunity to transfer understanding of binary systems to the probability of events as likely to occur or are not likely to occur (0 or 1). Thus allowing for cross-curricular connection. Other connections are possible when students are encouraged to represent their data in different forms such as percentages and establish a way to describe their entire class based on these percentages as part of SIP flight. Students may also estimate their answers and teachers may discuss learning factors, multiples and prime numbers in N. Depending on the teacher customising the dartboard, the teacher may set-up the dartboard with multiples, prime numbers or allow for working through a result backwards.

Concepts of Probability strand unit

The language used while using SIP flight as a teaching and learning tool facilitates students' discussing probability using the correct terms guided by the teacher. Drawing from the primary curriculum, words like chance can be used to introduce probability concepts. By using SIP flight, teachers can introduce the term 'what are the chances' whereby students identify where this term is used in real life, therefore, introducing concepts of probability while making connections with real life.

Overall, this completes the design stage and conducting the feasibility stages. If teachers were to implement SIP flight, teachers were not supported with worksheets or other teaching aids. As described, SIP flight was only used as a demonstration of a GBT to illustrate its uses in the mathematics classroom in order to collect teachers' reactions. This preliminary study acted as an exploratory phase through iteratively designing the 'best fit' technology to support implementation through experimentation. Following on from this stages two and three look at the feasibility of GBT and the prototype – SIP flight.

5.4 Stage two and three

Stage two used a survey questionnaire to assess this feasibility for teachers. Stage three used an amended version of the same survey questionnaire used in stage two as well as a group interview for in-service teachers. A description of the participants is listed below:

- Stage two: Forty-eight pre-service mathematics teachers in their first and second year of initial teacher education.

- Stage three: Two in-service mathematics teachers, one primary teacher with nine years experience and a post-primary teacher with nineteen years experience.

The group interview in stage three was semi-structured and designed to elicit information with respect to the school's Information and Communication Technology (ICT) infrastructure, teachers' experience with technology and possible uses of SIP flight. The group interview acted as a way to gain feedback from teachers regarding SIP flight and GBT potential in the mathematics classroom. As both stage two and three use a similar survey questionnaire, a description of this is given below.

It is important to note that the amendments made to the survey consisted of changes to group members' backgrounds. The survey questionnaire used in this preliminary study is presented in appendix three. The pre-service teachers were asked an additional question relating to their familiarity with Project Maths and whether they were in school during the time of the introduction of Project Maths into the curriculum. The answer to this question may impact on their familiarity with software recommended for use as part of Project Maths, including spreadsheets like Microsoft Excel. The survey examined six distinct areas as illustrated in the table below.

Section	General Aim
1. Background	**Section one is designed to elicit an understanding of pre-service teachers' background of Project Maths.**
2. Teachers' competencies	**Section two is designed to gain an understanding of teachers' competencies in the use of computers.**
3. Teachers' knowledge of Word	**Section three is designed to gain an insight into teachers' knowledge of Word processing software.**
4. Teachers' knowledge of Excel	**Section four is designed to explore teachers' comfort levels with Excel or spreadsheet software.**
5. Teachers' knowledge of GeoGebra	**Section five is designed to find out if teachers have used or are comfortable with using the mathematical software GeoGebra.**
6. Teachers' knowledge of Gesture-Based devices	**Finally, section six is designed to find out if teachers have previously used Gesture-Based computing devices such as the PlayStation Move, Nintendo Wii or the Xbox Kinect and any possible uses for these devices in the mathematics classroom.**

TABLE 7 - SECTIONS OF THE PRELIMINARY SURVEY QUESTIONNAIRE

The survey questionnaire was divided into six sections. The first two sections establish the teachers' background and their perceived level of ability when using technologies. The following three sections focus on Word, Excel and GeoGebra. These technologies are all recommended by the

Project Maths curriculum for teachers to use as teaching and learning tools in mathematics. The final section was designed to find out pre and in-service teachers' use of GBT. A question regarding teachers' use and frequency of use was asked with respect to existing GBT available to teachers. Examples of these GBT available to teachers include the Nintendo Wii, Xbox Kinect and PlayStation Move. The main intention of this survey is to elicit information with respect to teachers' operational skills, access to various technologies and personal attitudes towards different technologies. The questionnaire mostly contained Likert scale type questions together with qualitative questions that were designed to determine teachers' beliefs and ideas about GBT (Mc Namara and Paolucci, 2014). In order to accomplish this, a theoretical framework was adopted to guide the questions asked in the survey questionnaire.

5.4.1 Guiding framework

A framework by the European Council in 2012 was developed to illustrate the characteristics of a person that is digitally competent (Mc Namara and Paolucci, 2014). This theoretical framework was applied in the feasibility stages of this phase and is based on the *Digital Competences Framework (DCF).* The questions used as part of the survey questionnaire given to teachers in stages two and three were guided by this framework.

Digital skills and competence are key contributors to a knowledge-based society as set out in chapter 3, *Digital Competences in the Digital Agenda* in the *Digital Agenda for Europe Scoreboard 2012* report (EuropeanCouncil, 2012). As mentioned on page 96 of the report, digital skills are enveloped within digital competence and the report describes the need for '*confident and critical use of Information Society Technology (IST) for work, leisure, learning and communication' (European Council, 2012).* Digital competence encompasses the ability to select information and analyse it creatively, critically, constructively, confidently and responsibly (European Council, 2012).

The research framework that was used to guide stages two and three was taken from the digital skills scoreboard, which is part of the digital competencies report by the European Council and addresses three key factors:

- Environmental factors
- Individual competence
- Personal attitudes (European Council, 2012).

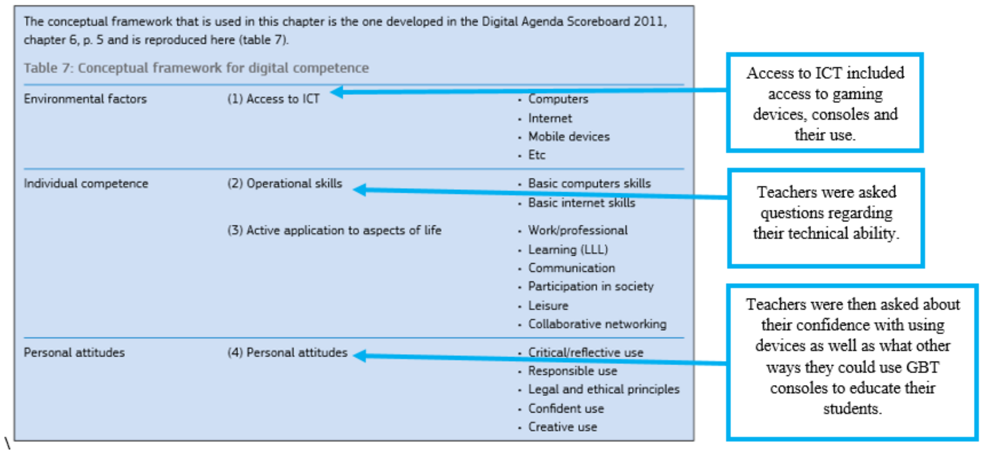
The conceptual framework that is used in this chapter is the one developed in the Digital Agenda Scoreboard 2011, chapter 6, p. 5 and is reproduced here (table 7).

Table 7: Conceptual framework for digital competence

Environmental factors	(1) Access to ICT	• Computers • Internet • Mobile devices • Etc
Individual competence	(2) Operational skills	• Basic computers skills • Basic internet skills
	(3) Active application to aspects of life	• Work/professional • Learning (LLL) • Communication • Participation in society • Leisure • Collaborative networking
Personal attitudes	(4) Personal attitudes	• Critical/reflective use • Responsible use • Legal and ethical principles • Confident use • Creative use

FIGURE 18 - A CONCEPTUAL FRAMEWORK FOR DIGITAL COMPETENCE (EUROPEAN COUNCIL, 2012)

As outlined in the figure (figure 18) the access to technology, operational skills and personal attitudes are key elements of the theoretical framework that guides the survey used in stages two and three. Active application to aspects of life in the framework is omitted from the survey questionnaire as individual competence factor concentrates on societal factors as opposed to the integration of certain technologies and experience of these technologies within the classroom context.

Stages two and three focus on the feasibility prototype by gaining insights into teachers' reactions to GBT and SIP flight. DCF – Digital Competencies Framework – acts as a guide in order to carry out this phase and concentrates on three main areas. These are:

- Teachers' access to technology,
- Teachers' operational skills and
- Teachers' personal attitudes toward technology in the classroom.

The participants from both stages two and three of this phase are composed of forty-eight pre-service mathematics teachers in their first and second year of initial teacher education and two in-service teachers with nine and nineteen years of experience teaching mathematics.

5.5 Stage Two and Three Outcomes

This phase of the study determined that there is a potential for GBT in the mathematics classroom (Mc Namara and Paolucci, 2014). This phase was published in a peer-reviewed publication as a chapter named Gesture-Based computing in the Mathematics Classroom within the book GBL Opportunities and Challenges in 2014. As illustrated in the chapter, results corroborate with existing literature in terms of teachers' perceptions of technology (Mc Namara and Paolucci, 2014). These perceptions show that the more exposure to certain forms of technology, the more uses teachers will find for those particular technologies. There follows a summary of the outcomes from stages two and three.

5.5.1 Pre-service survey questionnaire results – stage two

Stage two of this phase focused on a survey questionnaire given to pre-service mathematics teachers in their first and second year of initial teacher education. The bar chart below shows pre-service teachers' responses to a question regarding their perception of being 'good at computers' and their experience with Excel or spreadsheet software. Eighteen per cent of pre-service teachers have no experience of using spreadsheet software. This is surprising as this is one of the recommended technologies in Project Maths. However, just under half of pre-service teachers believed that they were 'good at computers' and 'good at Excel'.

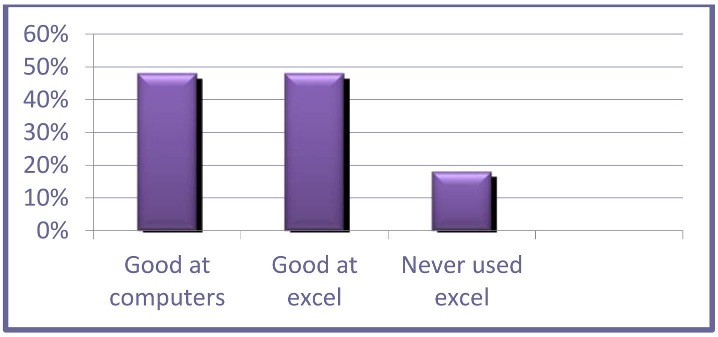

FIGURE 19 - BAR CHART PRE-SERVICE TEACHERS EXPERIENCE WITH SPREADSHEETS (MC NAMARA AND PAOLUCCI, 2014)

The researcher believes that practical experience might be a confounding factor and limit pre-service teachers' ability to focus on new ways of integrating the technology for the purposes of learning (Mc Namara and Paolucci, 2014). The survey reported that pre-service teachers found only traditional forms of usage for these devices such as exercise and games.

Two out of the forty-eight pre-service teachers' cohort commented on the capability of the GBT being used in other ways to teach mathematics. The first pre-service teacher stated that GBT could be used to develop psychomotor skills and to explore triangles in trigonometry. The pre-service teacher went onto describe students' ability to 'feel' for objects and visualise problems. The quotation below from pre-service teacher A illustrates the pre-service teachers' perceptions of how GBT could be used in the mathematics classroom.

"To develop psychomotor [sic] skills, to explore triangles for a more in-depth knowledge of trig [sic]. Where the student can move the objects round and get a "feel" for them. With visualisation of problems where they can manipulate questions for a more visual experience of maths problems" Pre-Service Teacher A.

The second pre-service teacher suggested, as shown in the quotation below from pre-service teacher B, that GBT could be used as a way to play mathematics games that have the ability of making mathematics fun while engaging students in a physical activity. As shown in the quotation below, GBT is suggested as a way to get students to play mathematical games.

"Getting students to play maths games. The physical activity will get the students more involved and will make maths seem more fun" Pre-Service Teacher B

Only two pre-service teachers commented on more than traditional forms of use, this finding corroborates with Bourgonjon, Valcke, Soetaert and Schellens (2010) in the sense that students' personal experience with the Nintendo Wii relates to the ways that students found the tool to be useful in a mathematics classroom. Exposure also helps make explicit connections to the usefulness of different teaching and learning tools. Ease of use and learning opportunities may have impacted pre-service teachers' perception of what other forms of learning could occur using a tool such as the Nintendo Wii. The following section presents a summary of the second feasibility stage, stage three of this phase.

5.5.2 **In-service survey and group interview results – stage three**

Practicing teachers were invited to participate in this group interview. At the start of the group interview, these in-service teachers were asked to fill out a similar survey questionnaire that was given to pre-service teachers. This established the teachers' context in terms of experience and exposure to certain technologies that are recommended by Project Maths as well as GBT. Results are now discussed within these contexts.

The primary teacher was first asked about the Information and Communications Technology (ICT) infrastructure in their school. The teacher elaborated by stating that there was an interactive whiteboard in the classroom as well as an Internet enabled teachers' computer on their desk. Laptops are also provided to staff within the school. The primary teacher had experience with interactive whiteboards, computers and laptops. As per the survey questionnaire the primary teachers stated that they were comfortable completing advanced tasks on the computer.

The post-primary teacher, on the other hand, comes from a school that is not as ICT enabled compared with the primary teacher. The teacher had a Windows computer that is Internet enabled in all classrooms throughout the school. The teacher also stated that there were no interactive whiteboards in the school and upon filling out the survey questionnaire stated that they were not comfortable completing advanced tasks on the computer.

After a brief demonstration of SIP flight during the group interview, both teachers were asked to suggest ways that this technology could be used in the mathematics classroom. The primary teacher suggested that SIP flight could be used in different ways in mathematics such as

> *"Balancing stacks-averages, throwing dice/darts (probability), cutting pizzas/other items into fractions segments, filling containers with liquids/capacity" (Mc Namara and Paolucci, 2014).*

The post-primary teacher only suggested using GBT for other uses such as teaching volume. Overall, the primary teacher suggested four ways that SIP flight could be used, while the post-primary teacher only suggested one way that it could be used. This corroborates with research conducted by Miranda and Russell (2012) suggesting that teachers' experience and confidence correlate with teachers' ability to see perceived uses of different technologies.

Both teachers were interested in learning about GBT devices and integrating them in meaningful ways. Meaningful ways of adoption may include a 'hook' at the start of a lesson that allows for greater engagement and enthusiasm with a topic or anything that is beneficial to the students as they learn concepts and mathematical skills. The post-primary teacher mentioned that any change in approach that allows for visual interaction with mathematical concepts and skills helps students to engage with the subject more deeply. The post-primary teacher commented that:

> *"...Any sort of change in approach and it's visual and it's away from talk and chalk well it's marker and talk now." (Mc Namara and Paolucci, 2014)*

The primary teacher also indicated that:

> *"Well I think I suppose I'd be coming from the fifth and sixth class primary school and definitely anything like that anything interactive at all they love it and they'd learn probably more from something like that…"(Mc Namara and Paolucci, 2014)*

Both teachers recognise a need to incorporate an interactive element into the classroom to engage students actively. The results dictate that there is potential for such a device at both primary and post-primary levels and the school environmental factors are key influencers as to whether these get adopted or not. Results showed that teachers are generally comfortable with using technology. The school factors including the ICT infrastructure may pre-dispose teachers to using different forms of technology over other schools. For instance, in this cohort, one teacher had full access to an interactive whiteboard, Internet and a laptop while the other stated that the school did not have any interactive whiteboards and teachers did not have their own laptops. The supportive nature of the school's ICT infrastructure mirrors that of the research done in (Niemi, Kynäslahti and Vahtivuori-Hänninen, 2012) in that the school's environment dictated how much technology was used in the classrooms in Finland.

Both teachers suggested that SIP flight is a great example of something that could be used in the mathematics classroom. Both teachers mentioned that the level of complexity might impact on the game itself and that the levels of the game need to appeal to diverse learners within a mathematics classroom. Finally, having discussed the results raised from all three stages of phase one, the final section of this chapter draws conclusions and recommendations from this phase.

5.6 Conclusions and recommendations from phase one

The conclusions from all three stages of phase one are presented below. The design stage focused on the technical challenges encountered by undertaking exploratory development of a small mathematical GBT game known as SIP flight. The feasibility stages used the prototype as a way to explore teachers' perspectives on its implementation in the mathematics classroom.

Prior to development, stage one of the study focused on finding out the most viable option of GBT for schools. It was decided that the WiiMote is the most viable option in terms of both cost and benefits. Following on from this, the technical challenges explain the establishment of connectivity between a WIN7 computer and WiiMote via Bluetooth. As discussed, there are many standards within Bluetooth on windows. The conclusion is that the Targus Bluetooth USB adapter and WIDCOMM driver were successful in communicating with the WiiMote. Following on from stage one, the feasibility stages sought to explore the reactions of teachers with respect to GBT and SIP flight.

The feasibility stages included the survey and group interview of both pre and in-service teachers. The pre-service group seemed less comfortable with technologies and this could be due to the level of exposure to these technologies and lack of experience utilising these in the classroom (Miranda and Russell, 2012). The pre-service teachers results also allude to the fact that practical experience of technology may determine if pre-service teachers see technology capabilities explicitly.

The in-service teachers in phase one of the study were optimistic and supportive of such technologies provided it engaged different levels of learners, and movement from a predominately didactic approach to an active approach to students' learning. The feedback from in-service teachers in the group interview indicate that more experience teachers have with technology, the more uses teachers will find to use certain technologies as teaching and learning tools (Miranda and Russell, 2012). Providing supportive documents and experience with the technology may enhance teachers' perceptions of the capabilities of GBT in the mathematics classroom.

Another conclusion from the group interview is that the available ICT infrastructure within schools directly impacts on teachers' pre-dispositions to different forms of technology. As Niemi *et al.* (2012) states, the school environment dictates how much the technology is used in the classroom. Although both stages two and three were carried out on a small scale and therefore, not generalizable, these stages give an insight into the diverse teaching environments and complexity of ICT mediated environments in the mathematics classroom.

The recommendations for further development of a Gesture-Based mathematical game based on the conclusions and technological advances are:

During early 2013, the support from Microsoft[16] to ensure the game engine was kept up-to-date was withdrawn. As a result of this, the recommendation for further development is to investigate a new game engine.

In order to save time establishing connectivity between a WIN7 computer and WiiMote using Bluetooth, the Targus USB adapter and WIDCOMM windows driver components should be used.

All teachers want technology that is easy to apply, flexible and adaptable to diverse learning needs of the students. The purpose of further development of a mathematical game should aim to incorporate these characteristics as well as enveloping a way to promote students' active learning.

Teachers' perceived comfort and use with technologies could be helped with more exposure to the technology being used in different ways as well as

[16] As technology tools are usually evolving due to customer feedback and improvements, withdrawing support can result in a stagnant platform and programmers can also withdraw from using the platform if there are no updates to that platform.

presenting teachers with supportive documentation containing explanations and sample lesson plans.

As a frame of reference for moving into further phases of the case study and before development of a relevant and focused game for the mathematics classroom, the researcher determines a need to explore the perception of students. This is done with the use of a survey questionnaire which is developed as part of phase two. Phase two, therefore, explores students' existing perspectives towards mathematics and career aspirations as a way to determine student motivations and goals. This is an important design feature for developing Maths Mission and is indicated as part of the theoretical framework where Watt *et al.* (2012) states the relationship between students' career aspirations and future choices for pursuing mathematics has a strong link. The next chapter discusses the survey questionnaire used in this thesis and results that determine the focus of Maths Mission.

Chapter 6: Case Study: Phase Two

6 Introduction

Phase one concluded that it was worthwhile to proceed with developing a GBT game for the mathematics classroom. The researcher aimed to develop a game that aided learners with active engagement and help alleviate specific learner issues such as engagement in the mathematics classroom. In order to identify specific learner issues, a survey was developed to gather data on these learner issues from students across Ireland.

This chapter discusses phase two of this study. This phase focuses on the development of a student survey questionnaire. This chapter discusses the survey questionnaires, results, conclusions and recommendations elicited from this phase.

6.1 Overview of phase two

The purpose of phase two was to gain an insight into students' attitudes, motivations and perspectives towards mathematics across Ireland. Based on the theoretical framework discussed in chapter 3, students can be intrinsically or extrinsically motivated. In the creation of the survey-Trends in International Mathematics and Science Study (TIMSS) and Expectancy-Value Theory (EVT) are used to gain useful data in determining students' engagement with mathematics. According to EVT, there is opportunity in extrinsic motivations such as career aspirations as a way to encourage students' engagement in mathematics. Career aspirations can directly influence students' goals. A students' achievement is impacted when a student places effort into a task and expects to succeed in that task. It also states that career aspiration directly influences students' expectations to succeed and the value placed on tasks to achieve these occupations (Wang, 2012). For this reason, it is important to gain an insight into students' attitudes, motivations and perspectives towards mathematics and their career aspirations. This data will then confirm if engineering type tasks and activities should be used in the game.

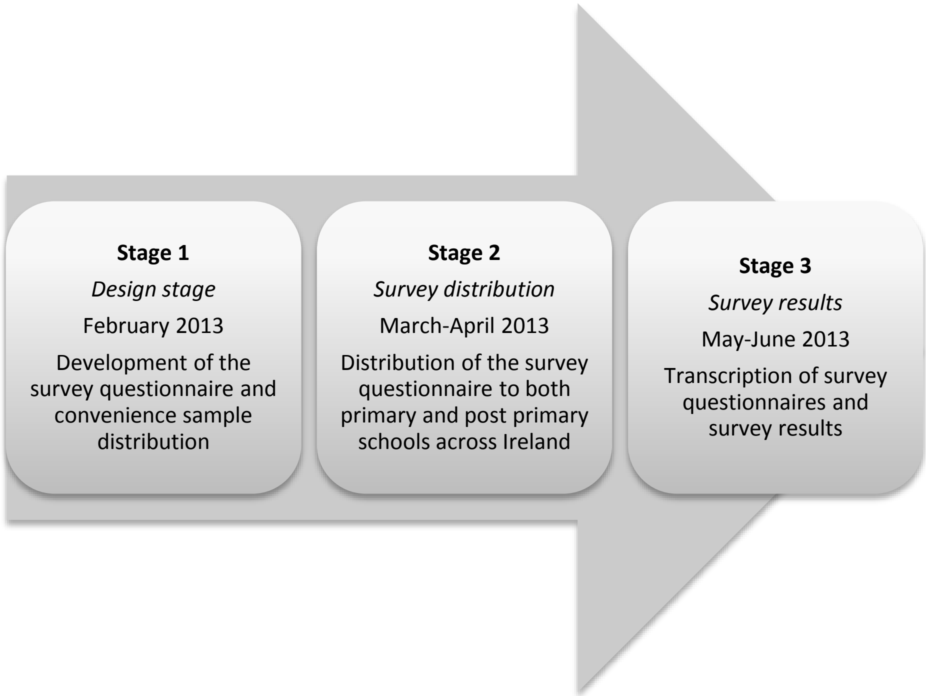

FIGURE 20 - PHASE TWO STAGES

While developing this survey questionnaire, the researcher examined several motivational theories prior to establishing the most appropriate for answering the research problem. As illustrated in the figure above (figure 20) phase two is divided into three stages. The design stage focused on finalising the survey and was completed in February 2013. This stage also gathered data from a convenience sample to pilot test the survey questionnaire items for their validity. In this instance, the validity refers to the accuracy of the questions in terms of whether the questionnaire achieves what it had set out to ask. Continuing on from that, stage two focused on the distribution of the survey across primary and post-primary schools in Ireland. Finally, in stage three the results were collated and the data were analysed throughout May and June 2013. There follows a description of the theoretical framework used to guide the survey in phase two.

Phase two adopted a survey questionnaire driven by the overarching theoretical frameworks, TIMSS and EVT as discussed in the chapter 4. TIMSS was used to guide the questionnaire to elicit information regarding students' enjoyment of mathematics, confidence and engagement of mathematics and value placed on mathematics while also gathering data regarding students' perceived usefulness of mathematics. The theoretical framework indicates that students' career goals impact upon their motivations in school and these are therefore, asked as part of the survey questionnaire.

The main data collected from this phase was designed to find out students' career aspirations and topics students have most preference for in mathematics. The survey was sent to students at primary and post-primary school as described below.

The survey participants are:

- One hundred primary schools – targeting students in their fifth and sixth class at school.
- Two hundred post-primary schools – targeting students in their second and fifth year at school.

State examinations occur in third and sixth year in post-primary. For this reason, it is important to note that the survey questionnaire was sent to second and fifth years in post-primary schools only. First year students in post-primary were omitted from the study as it was decided that students in this year would not have enough experience with the Project Maths curriculum and therefore may skew results. There follows a description of the survey questionnaire.

The survey was split into six sections. Students were then asked to list their career aspirations before finally using elements of the TIMSS and EVT survey to elicit information regarding students' attitudes. Appendix three shows the TIMSS and EVT section, which was also used in phase four of this study to describe school contexts.

Section	General Aim
1. Background	**Section one is designed to find out the year students are currently in as well as if they are taking higher**

	or ordinary level mathematics.
2. Students' subject choices	**Section two is designed to gain an understanding of students' subject choices.**
3. Students' least and favourite subjects and mathematics topics	**Section three is designed to gain an insight into students' least and favourite subjects and least and favourite mathematics topics taken in school.**
4. Students' career aspirations	**Section five is designed to find out what students' career choices are and what they would like to do after completing their education.**
5. Students' attitudes	**Finally, section six is designed to find out students levels of enjoyment of mathematics, confidence in mathematics, perceived usefulness of mathematics and expectations of doing well in mathematics.**

TABLE 8 - SECTIONS OF THE SURVEY QUESTIONNAIRE

The first two sections of the survey are designed to gather information with regard to students' own backgrounds and their level of mathematics. The second section gathers information regarding any subject choices. The third section is one of the most important as it asks students to point out what is their least and favourite mathematics topics. The fourth section focuses on their career aspirations, which is again another major aspect of this survey. This is asked as an open-ended question. Finally, the fifth section looks at students' levels of enjoyment of mathematics, confidence in mathematics, perceived usefulness of mathematics and expectations of doing well in mathematics.

The students asked to complete this study are taken from the fifth and sixth class at primary level and second and fifth year at post-primary level. For this reason, two separate survey questionnaires were designed to cater for each level of school. The survey was amended to adjust for reading level and topics covered in mathematics. For instance, students at post-primary level were offered the strands from Project Maths: Statistics, Probability, Geometry, Trigonometry, Number, Algebra and Functions. Students at primary level were offered their equivalent, Data, Shape and Space, Number, Algebra and Measures. More details with respect to the development of the survey are in the following section.

6.2 Development of the survey questionnaire – stage one

Stage one focused on the development of the survey questionnaire based on the EVT theoretical framework. The purpose of development of the survey questionnaire was to gain an insight into students' career aspirations with respect to engineering type careers and mathematics topics preference.

As the EVT is the main theoretical framework that guided the survey questionnaires, questions that are needed focus on students' career goals as well as their current subjects, favourite topics and least favourite topics in mathematics. Once the survey questions had been finalised, it was time to distribute the survey to a convenience sample to test the clarity of each of the questions.

As a precursor to sending the survey across Ireland, the survey questionnaire was initially sent to the convenience sample to ensure there were no confounding factors when students filled in their answers. As a result of this exercise, the researcher amended one question in the survey. An amendment with respect to the wording 'university' was changed to 'course' as students did not always intend to go to university; however, many intend to go onto complete a course at third level.

6.3 Distribution of the survey questionnaire – stage two

After the initial collection of data from the convenience sample, the researcher undertook sampling design calculations for a sample population proportional to size with the help of Dr Jerome Sheehan of the School of Mathematics, Statistics and Applied Mathematics at the National University of Ireland, Galway.

Upon request, a list of schools in primary and post-primary level was provided by the Department of Education and Skills. Using this list, the sampling strategy undertaken was a clustered stratified sampling design (Mc Namara, 2013b). The relative size of the school was taken into account and resulted in a sample proportional to size, therefore, schools that are larger in population than other schools had a higher chance of being selected in the sampling calculation.

After the sampling design was determined, the survey was then sent across Ireland to two hundred primary and one hundred post-primary schools. The survey questionnaire was offered to these schools in paper and electronic formats. Schools were contacted by telephone after an electronic mail (email) was sent with the survey. Schools were contacted again a week after the initial email was sent. Post-primary schools were contacted first as the shorter school year would prohibit the researcher from contacting the school any later than May. Primary schools were then emailed and followed up with by phone calls. After the initial cohort of participants sent in their answers to the survey, it was then decided to offer an incentive to participate to increase the response rate. An amount of twenty cent per survey completed was initially offered and donated to Our Lady’s Children’s Hospital in Crumlin. After a poor response rate ensued, the researcher increased the incentive to thirty cent per survey completed. For the schools that did participate in the survey, these schools were contacted and invited to participate in the next phase of the study.

The results were analysed throughout data collection and finally thoroughly analysed afterwards. The results from the convenience sample were presented as a poster presentation in March 2013 at the Educational Studies of Ireland conference and are henceforth referred to as Mc Namara (2013a). The results from the sampling design were presented and published as conference proceedings in September 2013 at the Fifth National Conference on Research in Mathematics Education in Ireland: MEI5. This is referred to as Mc Namara (2013b). Below is a summary of the results from this survey questionnaire.

6.4 Results of the survey questionnaire – stage three

The results are presented from the lowest to highest school years. Thus the results start with primary school participants' answers to the survey. Table 9 shows primary students' favourite mathematics topic in primary school. Students reported that their favourite subject is physical education. Fifth class reported that their favourite topic is shape and space. Sixth class reported their favourite topic as number. Overall, 83 and 92 primary school fifth class and sixth class students participated in the study, a total of 165 responses.

Favourite mathematics topic in primary school		
Topics	Fifth class	Sixth class
Algebra	5	21
Data	13	13
Measure	10	7
Number	21	39
Shape and Space	34	12
Grand Total	**83**	**92**

TABLE 9 - FAVOURITE TOPIC PRIMARY SCHOOL

Shape and space was the most favoured topic in mathematics in fifth class and there was a shift, as it becomes the second least favoured topic in mathematics in sixth class. The favourite in sixth class is numbers and this is followed by algebra.

Table 9 shows the sixth class results of the career aspirations when they finish their education. Engineering type careers and teaching were the top two career aspirations, arts was too broad and categorised loosely based on their answers for acting as well as singing. Teaching focused on many different areas including early childhood, primary, post-primary and lecturing. Engineering type careers centred on building, civil engineering and construction overall, thus confirming the types of careers to integrate into the game. Seven students left blank data in the paper based surveys. A disadvantage of undertaking a survey in paper is that there are no required fields when filling in paper; however, in the electronic format students cannot progress without answering all required fields in the survey.

What jobs am I interested in for the future are?	
Working with animals	7
The arts – musician, filmmaker, actor	20
Engineer – civil, construction	14
Finance – accountant, banker	8
Law – solicitor, barrister	4
Medicine – nurse, doctor	5
Sport – all types	13
Teaching – mainly working with children is specified	14
Blank	7
Grand Total	**92**

TABLE 10 - SIXTH CLASS CAREER ASPIRATIONS

Moving on to the post-primary results, the response rate was low across all one hundred post-primary schools and a total of one hundred and eighteen students participated in the study. Although not generalizable, this phase gives an insight into students' perceptions of mathematics. As shown in table 11, students' least favourite topic in mathematics was geometry and trigonometry and this is reflected in the following table – table 11. The strands were encapsulated as the Project Maths curriculum combines these and thus they are combined for the purposes of this study.

Count of My least favourite topic in mathematics is?	
My least favourite topic in mathematics is?	Total
Strand 1: Statistics and Probability	19
Strand 2: Geometry and Trigonometry	48
Strand 3: Number	4
Strand 4: Algebra	33
Strand 5: Functions	14
Grand Total	**118**

TABLE 11 - POST-PRIMARY LEAST FAVOURITE TOPIC IN MATHEMATICS

Surprisingly out of this cohort, only fifty per cent expected to do well at the end of year examinations (Mc Namara, 2013b). As shown in the table 12, engineering was the top career aspiration chosen at post-primary school including civil and construction. This is similar to the result at primary school. Teaching was also one of the top career aspirations; however, most participants specified that they wanted to work as a Montessori teacher or work with children in general. It should also be noted that the post-primary participants are exactly half females and half males in this cohort. Again, as teaching was generalised into many different types, it is for this reason that engineering type careers were taken as the career aspiration from these data. It is unclear if students referred to different types of teaching and working with children as one and the same thing. This is one of the limitations of survey questionnaires, as the participants were not followed up with after sending in their surveys. This was also an anonymous survey; therefore, only the researcher could identify the schools that participated and not the particular participants.

What jobs am I interested in for the future?	
Science – no specification in answers	4
Sport – all types	8
Shop work	2
Finance – bank, accountant, finance	9
Arts – English, history, law	9
Beauty therapy	6
Medicine – Doctor, Nurse	11
Guard	3
Teaching – Montessori, working with kids	27
Engineering – civil, construction	14
Working with animals – Veterinarian, farmer	10
The arts – film, musician, actor	6
Blank	9
Total	**118**

TABLE 12 - POST-PRIMARY CAREER ASPIRATIONS

The following section outlines the conclusions from this phase and offers recommendations for the subsequent phases in this doctoral research.

6.5 Conclusion and Recommendations from phase two

The design stage focused on designing the survey and gaining an insight into the survey participants' answers. By undertaking a survey of a convenience sample, the participants highlighted that there was a confounding factor in one question and that was re-adjusted to mirror the correct wording for future surveys. Course and university are terms that are interchangeable in Ireland and students often refer to course to mean attending university.

The second stage focused on the distributing of the survey across a sample population proportional to size across Ireland. The survey needed to be in both paper and electronic format with an incentive to gain any participants for the study. Incentives were also given to increase the response rate of surveys and some schools participated for this reason.

The third stage focused on the analysis of the data from the survey. It can be concluded that the results presented the decrease in students' attitudes towards geometry and trigonometry from fifth class to post-primary school. For this reason, it was decided to use these as the topics to be covered in the development of the game. It was also concluded that a significant career aspiration of the students is engineering and engineering principles will be integrated into the game in phase three. It was also noted that only half of students expected to do well in their end of year examinations. The EVT presents an opportunity to act as a way to extrinsically motivate students by focusing on their career aspirations and linking their least favourite topics to those careers. Also, for the schools that did participate in this phase, the same schools will be partaking in the following phase and consequently, the study will be addressing the same cohort of students.

Chapter 7: Case Study: Phase Three

7 Introduction

This phase focuses on the development of the Gesture-Based game that addressed the key findings from phase one and two – Maths Mission – through design, learning, pilot and WiiMote stages. The recommendations from phase one stated that the game should focus on geometry and trigonometry and should integrate civil engineering and construction concepts in a way that mimics approaches inherent in related types of careers.

Continuing on the development of the technology for the game some decisions need to be made at this time. These decisions related to the development of the software environment and how to include the WiiMote as a gestural control. Specific conclusions from the first phase – for instance, Targus Bluetooth USB adapter, WIN7 and WIDCOMM driver needed to be included as well as taking into consideration teachers' per-disposition of technology and the complexity of the ICT mediated classrooms – all teachers want technology that is easy to apply, flexible and adaptable to diverse learning needs of students. At this time there was a need also to explore the development of new software as Microsoft withdrew support for XNA game engine and as a result a new game engine was needed.

7.1 Overview of phase three

In order to develop this game, phase three was divided into four stages, design, learning, pilot and WiiMote stages.

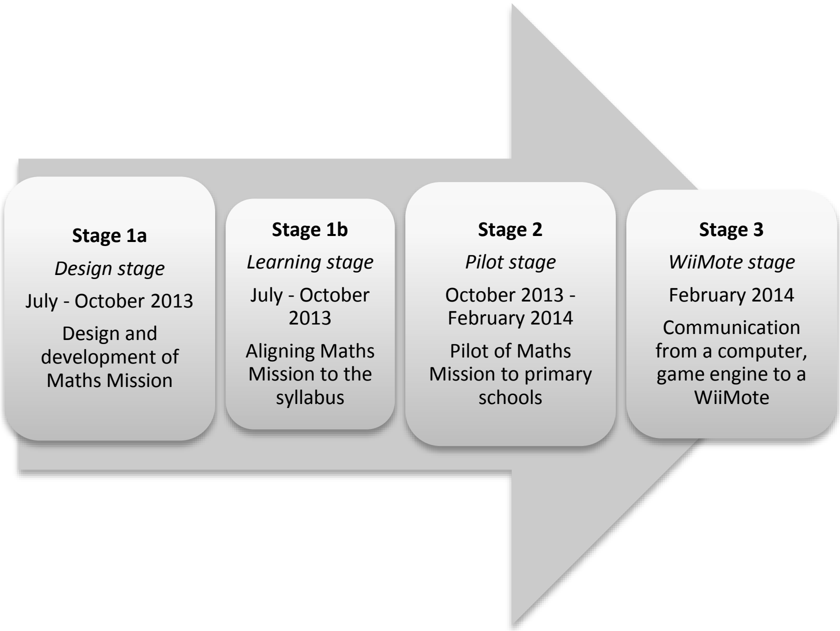

FIGURE 21 - PHASE THREE STAGES

As illustrated in the figure above (figure 21) the design stage was conducted from July 2013 until October 2013. Simultaneously, part b, the learning stage was conducted alongside the design stage. The design stage focused on the design and development of Maths Mission. The learning stage focused on the relevant learning outcomes that were aligned to the game. The pilot stage centred on students' feedback about the initial version of Maths Mission in the mathematics classroom. Finally, the WiiMote stage sought to overcome technical difficulties when communicating between the WiiMote and a computer.

Stage one part a, the design stage centred on the design and development by investigating the most appropriate game engine to develop Maths Mission. The design stage also took into account the GBL literature and targeted students' engagement towards mathematics. The GBL literature recommended particular strategies to be used in order to target specific student perspectives, an example of which is the growth mindset strategy. For instance, process praise instead of person praise can alter a students' perception of their ability (Kamins and Dweck, 1999). Students can benefit from a different mindset and value that everyone is capable of hard work to increase their potential. In the game, associating the feedback with the process instead of the person can target student engagement.

In **stage one part a,** the design stage made an assessment regarding the best game engine to use to develop Maths Mission. The game engine needed to be available to the researcher at a low-cost. The game engine also needed to be platform independent meaning that a game developed in this game engine can be published on Windows or Macintosh computers. The design and development of Maths Mission needed to envelop the characteristics from the literature that target students' engagement towards mathematics. As recommended from phase one, Maths Mission needed to appeal to diverse learning needs, be easy to apply and promote students' active learning.
Stage one part b, the learning stage focused on continual consultation of the syllabus. In The learning design needed to be encapsulated in documentation for teachers to support adoption in the mathematics classroom and also align with the Project Maths curriculum.

Stage two, the pilot stage gathered feedback from primary and post-primary students. The schools involved in this stage were part of a convenience sample. The participant population consists of:

- fifth and sixth class students from a co-educational primary school and
- second year students from a co-educational post-primary school.

Stage two allowed for continual development and the integration of enhanced features. This was done by observation of students playing Maths Mission and asking for feedback of how it could be improved. An example of agile software development is shown in the figure (figure 22) below and works towards the conceptualising, designing, coding and play testing of Maths Mission in a form of cyclical development.

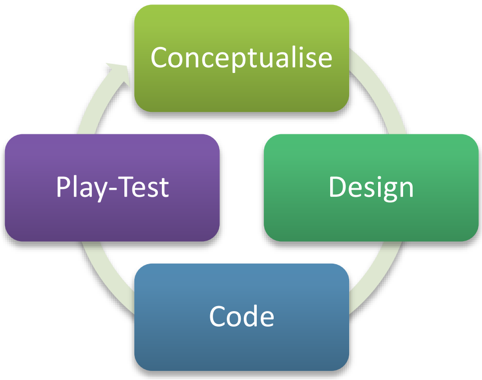

FIGURE 22 - AGILE SOFTWARE DEVELOPMENT (MC NAMARA AND PAOLUCCI, 2015)

Stage three then focused on the communication from the WiiMote to a computer. Stage three needed to get the WiiMote to connect to a computer and this was done through continuous testing and development of Maths Mission throughout this phase. This was done through trial and error of different pieces of software to enable the communication and is discussed in more detail towards the end of this chapter.

7.2 Game Design – Stage one part a

Stage one of phase three focused on the design and development of Maths Mission. The initial steps were to explore the different game engines suitable for developing Maths Mission. The following section outlines the process involved in exploring the most suitable game engine.

Typically the first decision of the game development process may involve investigating what platform to develop on. The decision regarding platform has already been decided from phase one, Microsoft Windows 7. The second decision was to find the correct game engine to develop the game. Unfortunately, Microsoft's support for XNA game studio 4.0 was withdrawn thus retiring the game engine. Retiring a game engine means that it would not be kept up-to-date thus becoming legacy software and also no longer used in industry.

As the first decision has already been made as a result of phase one, this phase needed to make a decision regarding a game engine. As mentioned in phase one, a game engine is a tool that can be used to create games. Game engines usually consist of already made pieces of code that can be utilised for the purposes of building the game. Game engines can encapsulate the programming process by allowing the user to add in graphical features that include three-dimensional (3D) rendering of objects on-screen and in real-time (Shiratuddin and Thabet, 2011). Game engines also allow the manipulation of these objects by attaching a script to this object. Game engines can be two-dimensional or three-dimensional and usually take the form of a *scene* that can be built by using different objects.

The game engine is composed of different engines such as a rendering engine and physics engine which enable particular features for developing games. Objects are rendered using the rendering engine, the sound can be attached and a physics engine enables the objects to have gravity. The physics engine, as the name suggests, also enables objects to collide into each other on-screen. The collision detection helps the user interact with objects in the world created by the game engine. The collision detection is used for the player to interact with the multiple choices when faced with a question within the game. In short, the next main decision was surrounding the game engine. The following sections go through the main features and why one was chosen over the others before proceeding with this research.

Blender is a game engine although it uses the programming language C++ instead of C# (Blender, 2012). Many other game engines were investigated and did not facilitate the needs of this game development. As the researcher had already learned to code in C#, it was then decided that this programming language would also be needed in the new game engine. For this reason, Blender was not suitable.

Captivate, GameMaker and Construct2 are all two-dimensional (2D) game engines and did not have the features desired for 3D development. After much investigation, it was then decided that Unity3D was the most suitable game engine for the following reasons.

Unity3D is not tailored to any specific platform and could be published for Windows and Macintosh Operating System (OS) even if it is developed on a

Windows machine. There is support for publishing the game on a Nintendo Wii, PlayStation 3 and Xbox 360 as well as Adobe Flash.

The primary language that scripts can be written in is C# and Unity3D has the physics engine of Nvidia's PhysX which at the time of development were both industry standards for game development. Unity3D is available as a free download and at a discounted price for students with all the commercial features available (Studica, 2013). Unity3D also has the capability of allowing AutoDesk 3DS Max files to be imported into the game engine (GameSutra, 2014). The 3D rendering of objects was imperative in the game development of Maths Mission. For these reasons, Unity3D seemed to be the optimum solution when considering game development. The following section details some of the decisions as to why Maths Mission was developed as a 3D game instead of a 2D game.

In many different subjects, a 3D GBL environment has proven to significantly increase students' motivation (Tüzün, Yılmaz-Soylu, Karakus, Inal and Kızılkaya, 2009). A 3D environment lends the possibility of exploring a virtual world as a model of the real world and the game can provide a platform to develop a means of understanding real world activities.

Another valuable reason for the inclusion of a 3D environment was to allow students see voluminous blocks such as the sides of a building. Working on these could form an understanding of how to construct a building from the ground upwards and potentially draw attention to how the world is made around them. As well as a virtual world being 3D, communication to the player is another consideration when designing any game.

7.3 Game Development – Stage one part a

The use of the PlayStation Move was required initially to ensure school visits could commence. In phase one, it outlined the benefits of using the Nintendo WiiMote over the PlayStation Move. Phase one also recommended that the WiiMote should be used in future phases of the study. However, due to technical challenges the PlayStation was used to collect preliminary data. The technical challenges that occurred were that the communication between Unity3D and the WiiMote was not possible without the addition of an external programme integrated in Unity3D known as a plugin[17]. For this to occur, Unity3D professional edition needs to be used. Due to time constraints in finding the correct plugin available to be integrated, the PlayStation Move was used until the WiiMote communication could be established. Thus, the school visits form part of gaining feedback from students about Maths Mission itself and no feedback was collected regarding practicalities such as the expense of the PlayStation Move or feasibility of Maths Mission from an educator's point of view.

The temporary solution of using the PlayStation to collect students' feedback regarding Maths Mission involved the re-development of Maths Mission using the PlayStation Move Software Development Kit (SDK) until a new solution could be found to establish this communication between the WiiMote and Unity3D. The re-development of Maths Mission allowed the communication between the PlayStation and the Windows 7 computer only. It should be noted that once communication to Windows was established, the next step was to enable communication to Unity3D within Windows. In order to accomplish this communication, the PlayStation network was used. The Move.Me SDK includes access via the PlayStation Network to develop software-using Windows that enables a developer to interact with the PlayStation console.

Below shows the networking protocol to communicate between the PlayStation console, PlayStation Move and computer. This included the input of the Internet Protocol (IP) address from the school network. Therefore, a PlayStation console, PlayStation Move, eye camera (to detect the PlayStation Move) and small television were all required in order to play Maths Mission in the classroom.

[17] A plugin is a software component that is usually written as an extension to another programme and allows for further features to be incorporated into that application.

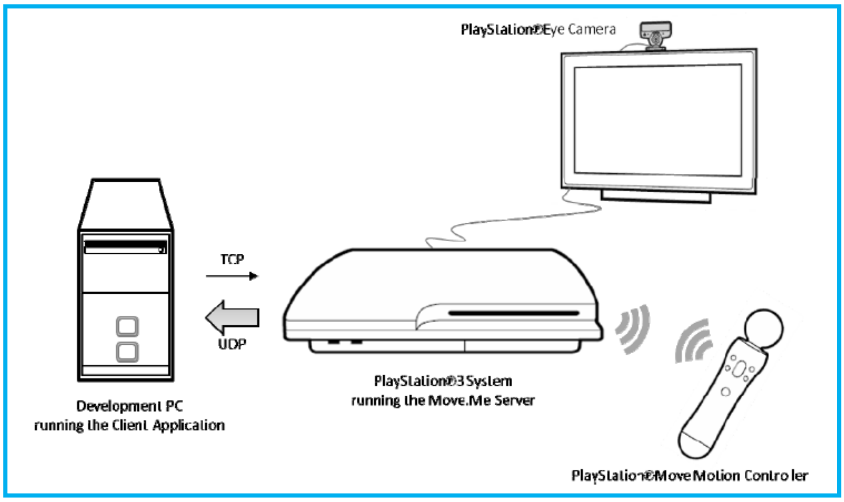

FIGURE 23 - PLAYSTATION NETWORK PROTOCOL TO COMMUNICATE BETWEEN DEVICES

Move.Me only establishes the communication to Windows and not to Unity3D. Therefore, different plugins were used to communicate to Unity3D after the networking protocol was established.

The PearlTree illustration below exhibits the different options available including independent plugins for Windows such as moveonpc[18]. Moveonpc connects directly to Windows without the Bluetooth services. As the Bluetooth services are required, moveonpc did not function correctly and another plugin needed to be tested. MotionJoy was also tested and was unsuccessful. Images of the tests of different plugins such as PS Move Sharp that were carried out appear in appendix one – Game Design Document. UniMove was then tested and established communication. It was then decided that UniMove would be used as the plugin.

[18] MoveOnPC is an application used to connect the PlayStation Move to Windows.

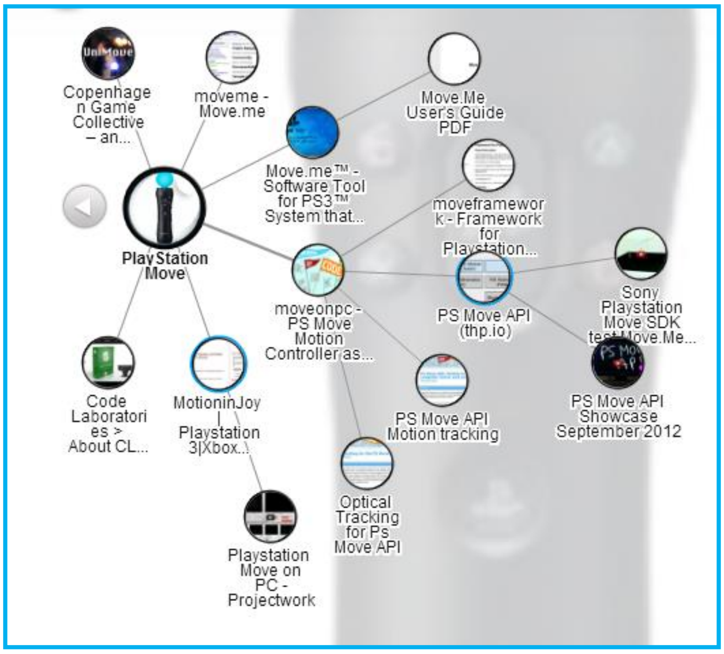

FIGURE 24 - PLAYSTATION MOVE ON PEARLTREE

The following section examines the initial designs of Maths Mission and improvements that were made as a result of the school visit with the PlayStation.

Initial designs

The initial design of Maths Mission included an opening scene to start the game. This scene contained the game narrative and instructions of how to play the game. The instructions are limited and the focus is on instructing the player of the first task they are to carry out. The initial opening scene appeared on-screen for a limited period of time and could not be skipped by the player.

FIGURE 25 - INITIAL OPENING SCENE

The narrative is described as, ‘you are an engineer in a destroyed city’, the scene then explains the first task by stating that previous engineers laid down boxes to collect and these boxes allow the player to measure the perimeter. Following on from this, the scene tells the player to use the PlayStation Move controller to navigate through the 3D world in order to measure the perimeter of two buildings.

Once the initial opening scene disappeared, Maths Mission needed to allow for communication to the PlayStation Move. As mentioned, Maths Mission used the PlayStation Network to interact with the PlayStation console. This required the IP address and Port from the network to communicate with the computer. The school network needed to be accessed in order to facilitate this communication. Text boxes appeared on-screen to allow manual input of the IP address and port numbers. The figure below (figure 26) shows the text boxes that appeared on-screen.

FIGURE 26 - PLAYSTATION STARTING POSITION

Aside from the communication being established via IP address and port in the school network, the starting position of the player within Maths Mission needed to be established. The starting position is an important aspect of any game as this seeks to allow the player to view how to begin the game. Therefore, transparent boxes on the top left of the scene showed the time lapsed and perimeter. Other boxes floating in the scene showed the layout of the scene in the form of Pythagoras' theorem.

An interim scene was part of the design of Maths Mission and showed the stages leading up to construction that took place in an engineer's office. Some of these interim scenes are shown in appendix one – Game Design Document. In conjunction with stage one part a, stage one part b consulted the syllabus prior to piloting Maths Mission in schools. There follows a section that discusses the environment and game structure.

Communication to the Player

Communication to the player in Maths Mission is by way of a text message that appears on-screen. This interaction with the player using text messages that appear on-screen is similar to that of a game that is currently in the market known as 'Grand Theft Auto' (GTA, 2009). These interaction techniques are used in games to communicate with the player and allow the player to progress onto the next task. Text messages on-screen can show questions and prompts, these can act as an effective component in allowing for scaffolding through the learning environment (Sawyer, 2006). In earlier games such as SuperMario on the Nintendo, Mario would find out that the princess was not in the castle by way of text appearing on the screen. This is useful for Mario in finding out whether she is in another world and thus trying to complete his mission of finding the princess by exploring other worlds.

Character in the Game

In Maths Mission, there is no specific character in the game. The student, now referred to as the player, is a capsule that represents the WiiMote on-screen. The console is what interacts with the game itself when selecting and moving items. The next section highlights the multiple-choice questions as a learning experience and interaction style for players within a 3D game.

Multiple-Choice Questions

As mentioned earlier, a text message on-screen forms the basis of communication with the player in Maths Mission. In this case a Multiple Choice Question (MCQ) can be shown by text message on-screen. An image on three different boxes then displays three options to the player. Using the physics engine component of Unity3D, players select their answers by colliding with one of these options. This results in part of the building being constructed in the background. The students need to differentiate among a number of choices once the student is given a question to answer. MCQs are great learning experiences for students especially if they are uncomfortable with direct answers. The MCQs appear as boxes on-screen and are close in range to each other; for instance, the first option might be the number 5 and the next two options are 6 and 7.

Below is an image of one of the MCQs in the game. The objects happen to be boxes that appear in front of the player wherever they are in the scene. These objects drop in front of the player on-screen. The objects appear due to the player interacting with the game, for instance, when the player answers a question correctly or incorrectly then new options appear with a new text message. The figure below (figure 27) shows the text message at the beginning of the game and the options are given to the player. The text message changes depending on the question and the options disappear from the screen once the question is answered. The options that appear on the image shown below are 5, 6 and 7 and these are to answer the question that appears as a text message ‘Choose the length of one side of the blue SQUARE building?’

As well as specific game contexts, the classroom context plays an important role in the feasibility of using Maths Mission. The subsequent section discusses the classroom environments and which are most conducive to Maths Mission.

FIGURE 27 - MULTIPLE CHOICE QUESTION

Classroom Learning Environment

The classroom-learning environment is set-up in a way that makes it more conducive to collaborative learning. These collaborative learning environments allow for more classroom discussion and emphasise teamwork among students. An example of this type of learning environment is described as follows: if there are desks in the room they are spread out so students can stand. The class is split into two teams. As mentioned earlier, teachers are given access to https://mathsmission.wordpress.com/ and this shows a sample lesson plan that is given to teachers prior to visiting the classroom.

Classroom Implementation

The way in which Maths Mission is implemented in the classroom can vary. Teachers have two options when implementing Maths Mission: teams or class wide instruction. Teams using Maths Mission can form groups that allow for more mathematical discussion as per the recommendations of Project Maths. The teams are told to nominate two people; one person is the team leader who communicates the next steps to be taken by the player and the other person is the player who will hold the controller to interact with the system. The rest of the team navigate through the game and communicate to the player with the WiiMote the possible options to choose as well as working out particular problems. Feedback to the students is an important aspect of this game development as this feedback allows students to form opinions of what is correct and incorrect.

Feedback to the player

There are two forms of feedback, summative and formative. Summative gives students particular marks for their work. While this is not really characterised in Maths Mission, it does, however, have scores players can achieve based on correct answers. Formative feedback, on the other hand, provides a way to qualitatively guide students (Kiili, 2005). The formative feedback in Maths Mission acts as both visual and text-based feedback. For example, players receive both a text message on-screen guiding them and also a visual display of the building being constructed based on their answer. For instance, if the player selects the correct perimeter of a building, the outline of the building appears on-screen and so on.

The feedback is encouraging and adopts a growth mindset (Dweck, 2008). This growth mindset is enveloped in Maths Mission by allowing the player to make mistakes and learn from these mistakes through visual and text message feedback. The feedback is also positive and supportive as per the literature on GBL (Iverson, 2005). The feedback focuses on the task at hand regardless of the student playing the game. The feedback endeavours to guide the players onto each task seamlessly without the need to interrupt the game.

Game Narrative

The game narrative or story for the game is presented to students prior to the game starting. In the game, the student is located in a destroyed city where they complete mathematical questions that enable the construction of buildings in the city. As mentioned in chapter 3, the game integrates the ECG theoretical framework and is described under each of the main characteristics below. An illustration of the ECG framework is shown in figure 28.

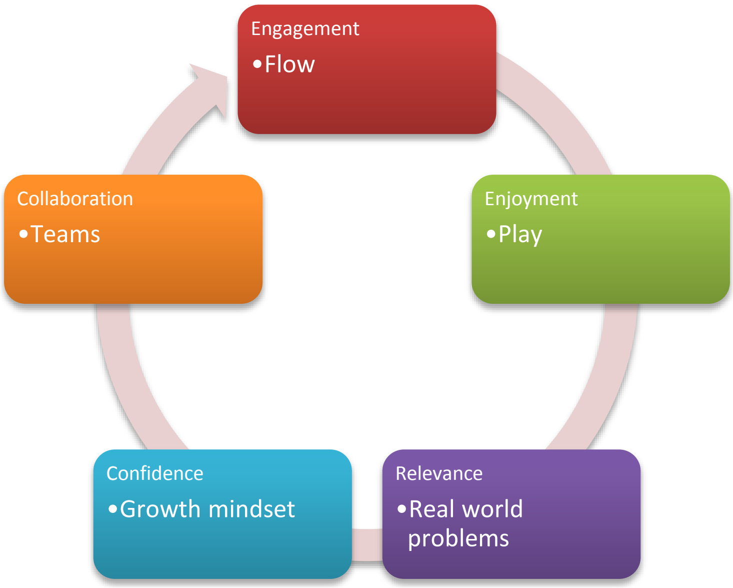

FIGURE 28 - ECG FRAMEWORK

Real world problem solving is a result of aligning to the syllabus in order to apply mathematics to real life. The Project Maths curriculum emphasises the real world situations being enveloped while teaching mathematics (Brosnan, 2008). Thus, the game problem to be solved surrounds the game storyline. The story told to students prior to playing Maths Mission is that they are engineers in a destroyed city and they need to solve mathematical tasks to help rebuild this city. A quantity surveyor was consulted in this process to ensure that the measurements in the destroyed city mirrored that of real world situations such as the wall heights, brick sizes and cost of a painter.

Enjoyment of the game is integrated through the element of play in the classroom. Huizinga's representation of play in the classroom shows that students have the freedom to fail. This is represented within Maths Mission by focusing on the process and allowing students to continue through the game with the freedom of getting an incorrect answer and continuing to play.

Engagement with the game is enveloped in Maths Mission by the adopting of the characteristics of flow. The students are prompted about mathematics problems throughout the game. Problems are presented within Maths Mission through text messages and MCQs that are within the game scene. The game scene is therefore not interrupted by another screen appearing in front of the player unlike Bai *et al.* (2013), thus the creation of a flow experience (Admiraal *et al.*, 2011). The game also needs to be 3D as studies have shown the improved engagement of students as a result of 3D games (Bai *et al*, 2013).

Confidence in doing mathematics is part of showing Maths Mission as an accomplishable task. Students from diverse backgrounds can play Maths Mission and positive constructive feedback is given upon completing each task. This can build a students' perception of their ability by focusing on the process over the person (Kamins and Dweck, 1999). This is described in the feedback section below.

Collaboration while playing Maths Mission is necessary when either playing the game via teams or class wide discussions; students need to work as a team to complete the game within the class times. The promotion of discussion allows students to talk about mathematical problems in Maths Mission. Movement is also necessary when using the WiiMote; the students can opt to crowd around a particular computer together. Another option is if the teacher wants to use Maths Mission as a class wide tool the teacher can give a WiiMote to a single student up to 30 feet away from the activity.

7.4 Learning design – Stage one part b

Maths Mission addresses the growing gap between primary and post-primary curricula in Ireland by reinforcing key concepts in mathematics through Digital GBL. The main intention of Maths Mission was to draw from both primary and post-primary curricula and skills development. It is important to illustrate what part of the curriculum Maths Mission is targeting and show how it can be targeted. The learning outcomes taken from the curriculum are aligned with Maths Mission. The following sections discuss the primary and post-primary syllabus respectively.

Primary syllabus

As indicated by the NCCA, these curricula detail the strands and strand units for mathematics at primary level. The strands are simplified across Number, Algebra, Shape and Space, Measures and Data.

Number strand

Maths Mission offers a way to connect to a virtual world and construct a building by answering mathematical questions. The calculation of the area requires students to be familiar with the perimeter and that it has four equal sides, therefore the length of one side is 5 and multiplying the length by breath gives the area of 25.

Shape and space strand

The primary shape and space strand focuses mainly on two-dimensional (2D) and three-dimensional (3D) objects. Shape and space is the most inherent part of Maths Mission, as students need to interact with objects within the three-dimensional (3D) virtual world. Students look at both 2D and 3D shapes throughout Maths Mission.

Measures strand

Maths Mission has a number of strand units from the measures strand throughout the game. Length is one of the initial questions asking students to find the length of one side of the square building. This is to reinforce the concept that the building is square and also to guide students from ‘length’ to ‘perimeter’ to ‘area’. The area of the building is asked after the length. Time and money are asked throughout the latter parts of the game when asked the quantities of tiles required, bricks needed and cost of a painter to paint the square building.

Data strand

The primary data strand figure shows only two strand units, representing and interpreting data and chance. The data strand is the least represented in Maths Mission, as it does not deal with chance or statistics.

Post-Primary Syllabus

Before discussing the post-primary syllabus, it is important to note the transition from primary to post-primary schooling in Ireland. Students are usually required to move school and there is a greater emphasis on examinations at post-primary level. Teachers are offered a bridging framework to integrate and make the transition from primary school mathematics to post-primary school mathematics easier.

The bridging framework as set out by the NCCA reveals how primary mathematical language differs from that in post-primary. For example, chance is used to describe probability in primary. The bridging framework acts as a guide for both primary and post-primary teachers and in order for teachers to become aware of the mathematical language being used at both levels of the educational process (NCCA, 2011a). In essence, it is the connection of both curricula to each other. The bridging framework also supplies a mathematical glossary for both primary and post-primary teachers. As illustrated in the table, the curriculum is matched from both primary to post-primary. As shown in the diagram, all five strands are covered briefly at primary level and are dealt with in more depth at post-primary level. This acts as a way to show the progression and acts as a stepping-stone for students from primary to post-primary.

5th/6th Class, Primary – Junior Cycle, Post-Primary

	Primary		Post-Primary	Page #
Strand(s):	Number, Measure	⇨	Number (Strand 3)	2-5
Strand:	Shape and Space	⇨	Geometry and Trigonometry (Strand 2)	6
Strand:	Data	⇨	Statistics and Probability (Strand 1)	7
Strand(s):	Algebra	⇨	Algebra, Functions (Strand 4, Strand 5)	8

FIGURE 29 - BRIDGING FRAMEWORK

As shown in an image of the bridging framework (NCCA, 2011a), number and measure strand at primary level is the number (strand 3) at post-primary level and so on.

Maths Mission is aligned with strand 2 and 3 of the post-primary curriculum and as pointed out earlier it is aligned with shape and space in the primary curriculum. The post-primary curriculum allows students to explore different topics in strand 2 with different learning outcomes. The learning outcomes to 'explore patterns and formulate conjectures' and 'explain findings' are catered for in Maths Mission as students use it as a way to express their ideas and problem solve. Students demonstrate justification of conclusions by explaining findings to each other before progressing in Maths Mission.

Students are required to apply units of measure interpreting the tiles of 45cm^2 in an area of m^2. Identifying the necessary information, students tend to work out the problems on paper before choosing the correct or incorrect answer. Selecting and using suitable strategies for finding the length of a perimeter and area appears throughout the first stage of playing.

Strand	Topic	Description	Learning outcome
2	2.1 Synthetic Geometry	Theorem 14:	Apply the results of theorem to solve problems Prove the specified theorem
	2.3 Co-ordinate Geometry	Property of the line	Explore the property of the line
	2.4 Trigonometry	Right-Angled Triangles	Apply the theorem of Pythagoras to solve right-angled triangle problems of a simple nature involving heights and distances. Solve problems using right-angled triangles
	2.5	Synthesis and Problem-Solving	Explore patterns and formulate conjectures Explain findings Justify conclusions Apply their knowledge and skills to solve problems in familiar and unfamiliar contexts
3	3.4 Applied Measure	Measure and Time Problems involving perimeter	Interpret and apply units of measure and time Solve problems that involve calculating speed, distance and time Identify necessary information to solve a problem Select and use suitable strategies to find length of a perimeter and the area of the following plane: the square.

FIGURE 30 - POST-PRIMARY CURRICULUM

The post-primary curriculum is condensed into the figure above (figure 30) and incorporates aspects of both strand 2 and 3, geometry and trigonometry and number respectively. The learning outcomes although shown here are explained in the subsequent section.

Strand two shows in the figure above (figure 30) cover various topics within the strand. The strand unit Synthetic Geometry includes *'Theorem 14'* also known as Pythagoras' Theorem. This theorem states that 'In a right-angled triangle the square of the hypotenuse is the sum of the squares of the other two sides'. The initial two buildings in Maths Mission are both square, they are laid adjacent to each other forming two sides of a triangle. The final square building is hidden and forms the hypotenuse of the triangle. An example of the layout of the buildings is in the figure below (figure 30).

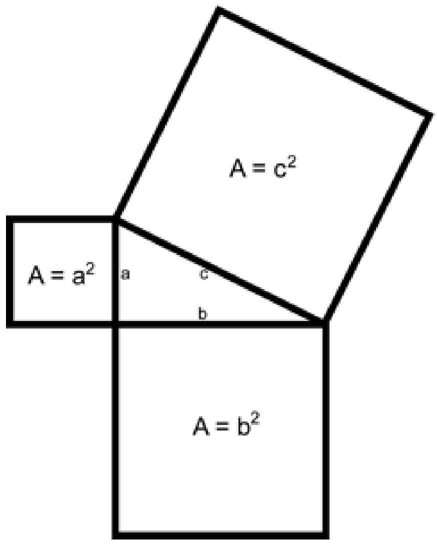

FIGURE 31 - THEOREM 14

Students are also exposed to elements of trigonometry by solving heights and distances of the buildings. Throughout the mathematical tasks in Maths Mission, students can explore patterns, justify conclusions and reinforce knowledge from topics covered at primary school. The following section outlines the learning outcomes in Maths Mission.

Learning Outcomes

The primary and post-primary learning outcomes for the student are outlined in the figure below (figure 32) and are taken from the NCCA and Project Maths curricula.

Student learning outcomes are determined by the curriculum covered at primary and post-primary. Therefore, the table below outlines the learning outcomes for Maths Mission.

Characterise basic operations	• How to convert • Understand about estimation
Identify patterns	• Generalise and explain patterns and relationships
Recognise the basic concepts of geometry	• The plane • Lines • Identify different types of angles

Learn to solve problems that involve finding	• Percentages • Selling price • Quantities (including specified amounts)
Demonstrate measure and time	• Calculate, interpret and apply units of measure by interpreting cm2 and m2
Categorise area and volume	• Find the area and perimeter of two-dimensional (2D) shapes • Solve problems including the area • Investigate the surface area of a square building • Understanding both 2D and 3D
Evaluate trigonometry	• Right-angled triangles • The theorem of Pythagoras

FIGURE 32 - MATHS MISSION STUDENT LEARNING OUTCOMES

In the figure above (figure 32), it shows the collective learning outcomes from both primary and post-primary. The learning outcomes are what the students take away from Maths Mission and what is intentionally outlined in certain parts of both curricula. In order to get a sense of what questions are asked in Maths Mission, there is a list provided below. This is not an extensive list; however, it gives the reader a sense of how the game starts and progresses. As mentioned above, the questions are asked as MCQs and options appear in the game for the player to 'collect' the correct answer. Upon collection, the building in the virtual world is created. Some of the MCQs are presented in a list below:

- What is the length of one side of the square building?
- What is the perimeter of the blue SQUARE building?
- What is the area of the blue SQUARE building?

- Great, I have all the area to lay down the floor tiles. How many tiles will I need?
- Keep up the good work! Now I need to find out how many bricks I need per wall. The bricks are 20cm * 50cm. That is 20cm width and 50cm height. How many tiles are needed for the floor of this building?
- How much does it cost for the painter to paint the walls?

After the design and development of Maths Mission, pilot studies whose main purpose is to find out the different learning environments and experiences that each school has to offer when implementing Maths Mission were done. The following sections describe the pilot studies that took place through two schools visits.

7.5 School visit 1: October 2013 – Stage two

A preliminary school visit to a primary school took place in October 2013. This school visit was conducted with the PlayStation and not with the WiiMote due to technical challenges. The primary purpose of this school visit was to find whether any improvements needed to be made to Maths Mission. In the game, the player, operated by a student, was included in the game in the form of a construction worker. The starting position was behind trees and obstructed by objects such as a measuring tape and map in the form of Pythagoras' theorem. The image below represents the opening scene and starting position of the player.

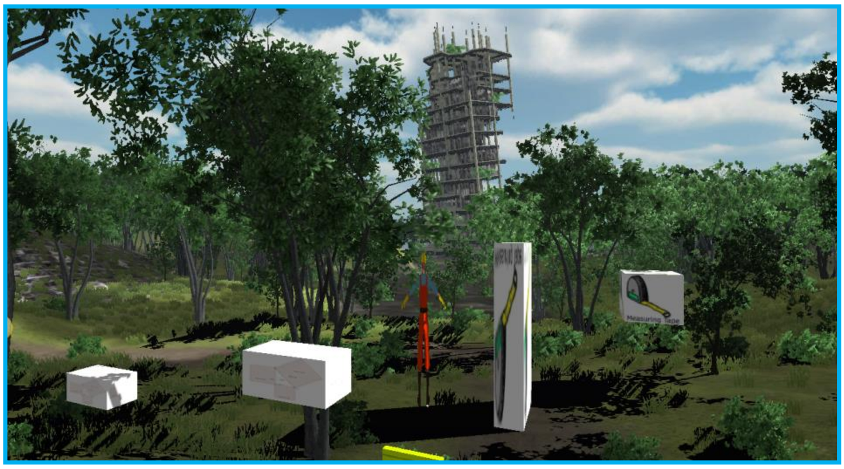

FIGURE 33 - PLAYER AS A CONSTRUCTION WORKER

Feedback from students resulted in the game being called Maths Mission. Students in this school requested a miniature map as some of them got lost while playing the game or they ran out of time after trying to find their way to start the game. The image below shows the miniature map of Maths Mission as a result of this school visit.

FIGURE 34 - MINIATURE MAP OF MATHS MISSION

The miniature map focused on an overview of the full screen. This is also a static map and shows the entire landscape of the game. The boxes outline the buildings and the building lying on its side represents a building obstructing the third and final building.

The interim scenes were also included in this version of the game and students spent an extended period of time trying to digest the information on-screen. It is for this reason that the interim scenes were omitted after this school visit (see appendix one – Game Design Document).

The version demonstrated in this school in October 2013 included manual input from students. Students needed to insert their calculations of area and perimeter onto the screen. Feedback from these students resulted in the manual input from students being omitted and the calculations of area and perimeter done automatically. The image below shows the buttons students needed to press upon collecting each box to calculate the perimeter. Students also needed to reset the perimeter to calculate separate buildings.

The area and perimeter score would then appear on-screen as a result of collecting each box and then pressing the button to add the perimeter.

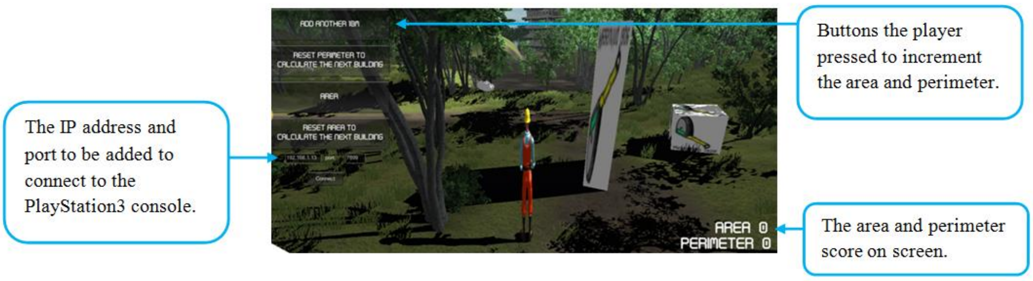

FIGURE 35 - PRE-AUTOMATED CALCULATION OF PERIMETER

Due to the manual input from students when calculating the area and perimeter, a lot of time was allocated to the area and perimeter when the aim of the game is to construct a building by answering mathematical questions. Students also had access to a help button that defines perimeter and area in Maths Mission.

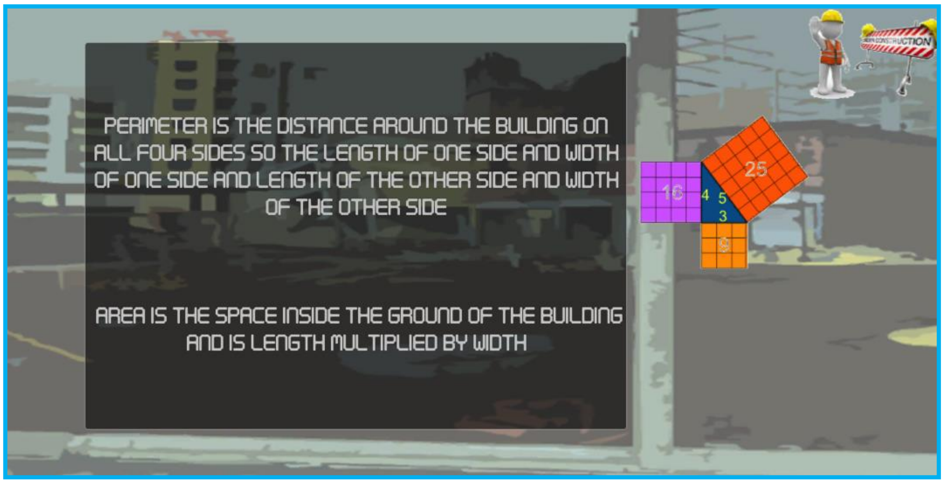

FIGURE 36 - HELP BUTTON

The help button hindered collaboration and communication among students and was therefore omitted after the pilot in October 2013. Figure 36 above illustrates what appeared upon clicking the help button – a definition of perimeter and area in order to aid the player.

The following were the changes after this school visit:

- The opening scene was shortened.

- The starting position was changed.
- The construction worker was omitted.
- Interim scenes were omitted.
- Manual calculation of area and perimeter were made automatic.
- The miniature static map was added to the scene on the top right corner.
- The game was called Maths Mission.
- The help button was omitted.

7.6 School visit 2: February 2014 – Stage two

The visit that took place in February 2014 asked students in second year in post-primary school for any improvements that could be made to Maths Mission. In this school visit, Maths Mission was also demonstrated using the PlayStation Move. Students in this school played the game and asked questions regarding game development. The opening scene was shortened; however, students got impatient with the timing of this scene. This reaction was because students had moved from another classroom and wanted to start immediately when they found out it was a game. To ensure all students knew what the game was about, the researcher had to re-iterate the goal of the game to the students. Initially it was observed that the females in the class were shying away from the game while the males were immediately enthusiastic about playing a game in mathematics class. After the game was set-up, students played the game together in teams and the females in the group stated that a lighter background would benefit being able to see the objects on-screen more easily. The researcher also noticed that it was difficult to set-up the PlayStation to the school network without school administrator's access. This is an important part of development, as it means school networks are not easily connected to and Maths Mission would need to be standalone. Aside from that, the game was ready to go into the next phase of the study.

Upon completion of the school visit, it was then decided to concentrate solely on re-developing the game to enable the communication to the WiiMote. In order to do this, the researcher would need a different plugin for Unity3D. The following section discusses this as part of the process of stage three.

7.7 Communication to the WiiMote – Stage three

In order to establish communication from the WiiMote to Unity3D many plugins were tested. The researcher's computer needed a re-installation of Windows and unfortunately after testing the alternative plugins, the Bluetooth and USB ports were damaged.

The researcher investigated an alternative method to use the WiiMote in the mathematics classroom. The alternative would be to develop a game directly for the Nintendo Wii console. After some investigation and contact with Nintendo in 2011, it was recognised that the development of a game directly on the Nintendo Wii console can only be developed with licensed developers. If one is not a licensed developer, which the researcher is not, then stipulations from Nintendo state that a licensed developer needs to be present for the development. A payment of a fee of over ten thousand euro needs to be paid for this licence and the nearest Nintendo licenced developer to supervise the activity was based in the United Kingdom. Also, the game would not be publishable on the Nintendo Wii console until going through tests with Nintendo headquarters. It is for this reason that more alternatives were investigated.

As illustrated in the PearlTree diagram above, alternative plugins were tested before finding the correct version. A plugin developed by ByDesignGames was then used to establish the communication. As the WiiMote needed to communicate to Unity3D via Windows and the researcher knew that Apple has a single standard of Bluetooth from the research conducted in phase one, an Apple MacBook Air was then tested. This proved successful and an Apple MacBook Pro was borrowed from the School of Education in NUI Galway to conduct the rest of the school visits. This simple set-up includes the Nintendo WiiMote and the Apple MacBook

Pro Bluetooth services turned on. Therefore, a Nintendo WiiMote along with an Apple MacBook Pro was used to play Maths Mission.

The gesture-input is illustrated below. The input the player makes is calculated using the accelerometer in the WiiMote device. For instance, when a player points and moves the WiiMote left, the player on-screen moves left. This is calculated by the x-axis, when x is increased to above 100, the player moves left on-screen.

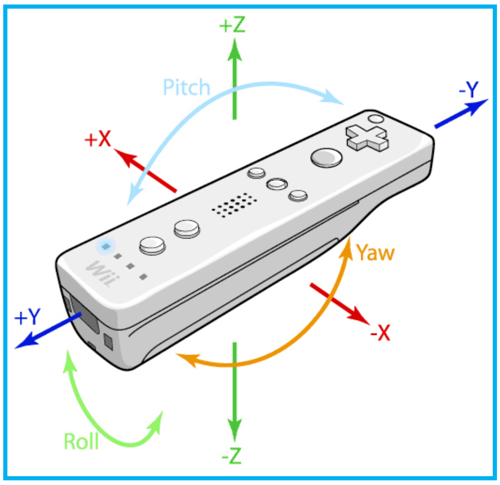

FIGURE 37 - WIIMOTE GESTURE-INPUT

After re-developing Maths Mission to use the WiiMote gesture-input, as shown in figure 37, behaviours of objects within the game needed to be controlled by the WiiMote. These were done through the scripts or code integrated within Unity3D. For instance, there are scripts that render objects in front of the player, text messages on-screen, a script to allow the WiiMote as a controller, camera movement, player movement and most importantly scripts to build buildings. As mentioned earlier, these scripts are attached to objects in a scene and determine the behaviour of these objects. The following section describes how the scripts were set-up in Maths Mission.

Scripts

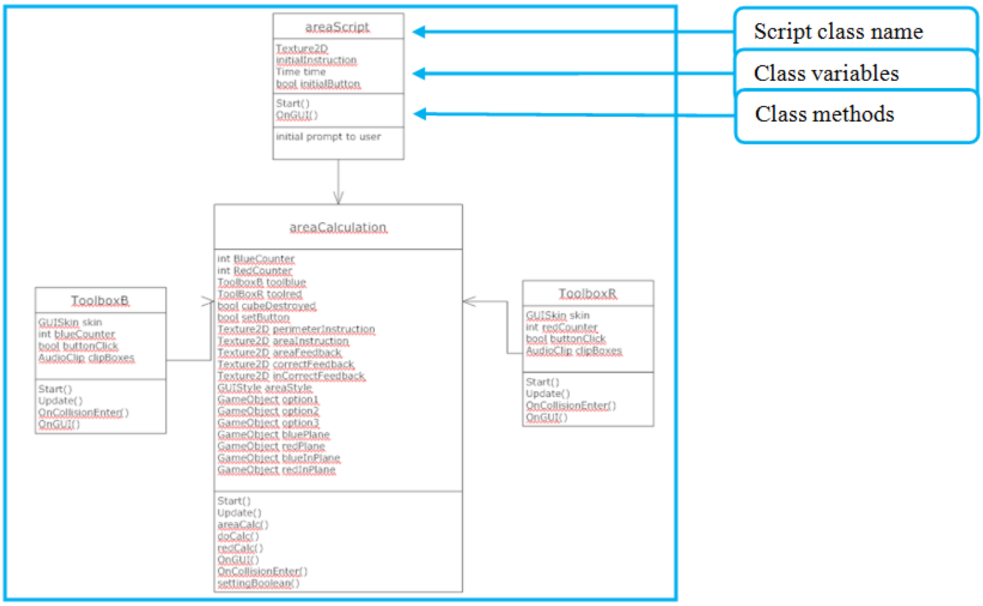

FIGURE 38 - SCRIPTS IN MATHS MISSION

Initially, Maths Mission had a single large script that was rigid and a very large file for the computer to process. As shown in the figure 38, the scripts that are 'called' within Unity3D communicate with each other. Each class shown in the diagram above shows the name of the script, variables declared and methods used in that class.

The scripts are developed in an *add-on* software that integrates with Unity3D known as Monodevelop. Monodevelop is a cross-platform, Integrated Development Environment (IDE), meaning that it can be used on Microsoft Windows as well as Macintosh, and allows for scripts to be written and imported into Unity3D. Each script is then attached to a particular object or capsule within the 3D world. These scripts then change or update the behaviour of the objects and/or player within the game. For example, the script that permits the player to move is integrated with the script called UniWii that allows the WiiMote to act as a way for the player to move instead of the buttons on a laptop or a computer keyboard. The plugin that was integrated into Unity3D allowed for these capabilities and the researcher updated that script to adjust for the particular buttons and movements that are integrated within Maths Mission.

Finally, Maths Mission was developed using the Nintendo WiiMote and connects by pairing the device to an Apple MacBook Pro. The blue building and red building perimeters remain on-screen. The trees were omitted from the final cut and the player is no longer a construction worker. The player appears as a white capsule on the miniature map. The image below shows the blue and red boxes to represent the perimeter being accrued upon the WiiMote collecting the perimeter. The following image shows Maths Mission as the version that was brought into the subsequent phases.

FIGURE 39 - PHASE FOUR MATHS MISSION DEVELOPED

7.8 Limitations

As with all games developed there are limitations. Limitations include the features involved that are technologically not possible, due to time constraints or limitations due to the scope of the game. The game currently does not include:

- Player login system

The player cannot login to a system and save their details as separate players. It does not hold a database behind the game.

- Intelligent tutoring systems

This game is not an intelligent system and does not entail an evolving nature throughout. The questions asked in the game are the same every time that the game is played.

- Artificial intelligence for its answers (they are the same multiple choice answers every time the game is used and the same scenario). However, students navigate through the game using navigation mesh, which is a path-finding algorithm.

The answers are hardcoded (they cannot change automatically) into the game. This is due to the size of the game itself and time spent learning new programming languages such as C# as well as game engines like the one used for this study, Unity3D.

Upon completion of the design and learning, piloting and WiiMote stages, it is important to gain an insight into the conclusions from this phase and recommendations for future phases. There follows a description of the conclusions and recommendations from phase three.

7.9 Conclusions and recommendations from phase three

The development of Maths Mission was an arduous process due to the technical constraints experienced when using Microsoft Windows 7 and Bluetooth. These technical challenges included the need to use the PlayStation temporarily until these challenges could be overcome and the WiiMote could take its place. These challenges are referring to the lack of communication between Unity3D and a WiiMote without a plugin. Therefore, the PlayStation had to be used initially to allow for school visits to commence. Unfortunately, these issues required amendments to allow for the WiiMote to communicate to a computer.

The game engine used to develop Maths Mission is Unity3D. The development decisions from this phase included a 3D environment, feedback is both visual and formative, the character is seen as a white capsule, interaction with the player is via text message and the main limitations relate to the fact that there is very little artificial intelligence within the game, no player login and no intelligent tutoring system.

In addition, there is no character in the game, as it appears as a white capsule that represents the WiiMote. The interaction with the player is through text messages. MCQs are used to ask the player questions and the options appear in front of the player. The classroom environment can be more conducive to learning when allowing discussion to continue as per the recommendations of Project Maths. The classroom implementation may be in the form of teams or classroom wide play. Feedback is encouraging and adopts the growth mindset through the language used. The game narrative envelops real world problem solving, enjoyment, engagement, confidence and collaboration through the game's characteristics. Conclusions with regard to the design of Maths Mission are intertwined with the recommendations for the next phase. Therefore, the following is a list of the recommendations that can be made from this phase.

The recommendations for the next phase are:

- The game needs to remain within a 3D environment.
- The camera view overlooking the player from an orthographical viewpoint acts as a map for the virtual world.
- The opening scene can be amended based on school visits.
- Interim scenes should not be included.
- Automatic calculation of the area and perimeter is an important characteristic and should be kept.
- No help buttons should be included.
- School networks should be avoided at all costs, due to the time and network unknowns when setting up the computer.
- Finally, the Nintendo WiiMote will now be implemented using the Apple MacBook Pro from the School of Education at NUI Galway to visit more schools.

Following on from the completion of the development of Maths Mission, it is important to test Maths Mission in different contexts. Taking the recommendations from phase one, two and this phase – phase three – Maths Mission is then implemented in schools across the country in order to discover what the key design elements of a Gesture-Based game are and its classroom implementation challenges. As seen in the pilot studies in phase three, there were challenges regarding implementation and with the diverse cultural and environmental aspects of schools it is important to discover multiple contexts when implementing Maths Mission. Therefore, based on the research questions[19], the researcher then decided to bring the game into a number of schools to collect data from both teachers and students to fully explore its potential and any further design features that would enhance use within the Mathematics classroom. The next chapter outlines phase four – implementation of Maths Mission.

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[19] What are the key design elements of a Gesture-Based game and the key challenges for mathematics classroom implementation?
What is the potential for a Gesture-Based game to be used as a tool in the mathematics classroom?
What design features inform the creation of a Gesture-Based game in the mathematics classroom?

Chapter 8: Case Study: Phase Four

8 Introduction

Following on from the first three phases of this study – phase one: preliminary studies on the game features, phase two: survey questionnaire development on student learner needs and motivations and phase three: game development – phase four reports on the implementation of the game in five schools across Ireland. This chapter outlines the following: school background contexts including classroom environment, teacher background and styles, student profiles, the implementations of the game within each school and design amendment changes of Maths Mission. Small changes were made to the game while implementing it in schools as a response to the feedback from the users. Overall this phase explores the key challenges of implementation and the potential of the Gesture Based game as a tool in the mathematics classroom. As a reminder the research questions are presented below:

1. What are the key design elements of a Gesture-Based game and the key challenges for mathematics classroom implementation?
2. What is the potential for a Gesture-Based game to be used as a tool in the mathematics classroom?
3. What design features inform the creation of a Gesture-Based game in the mathematics classroom?

The following section gives a brief overview of phase four.

8.1 Overview of phase four

All schools within this case study were visited from March 2014 – October 2014. After each school visit small changes were made to Maths Mission and this was then used to gain an insight into how effective the different design elements were in Maths Mission and identify the key challenges of implementation and potential of the game as a tool within the mathematics classroom.

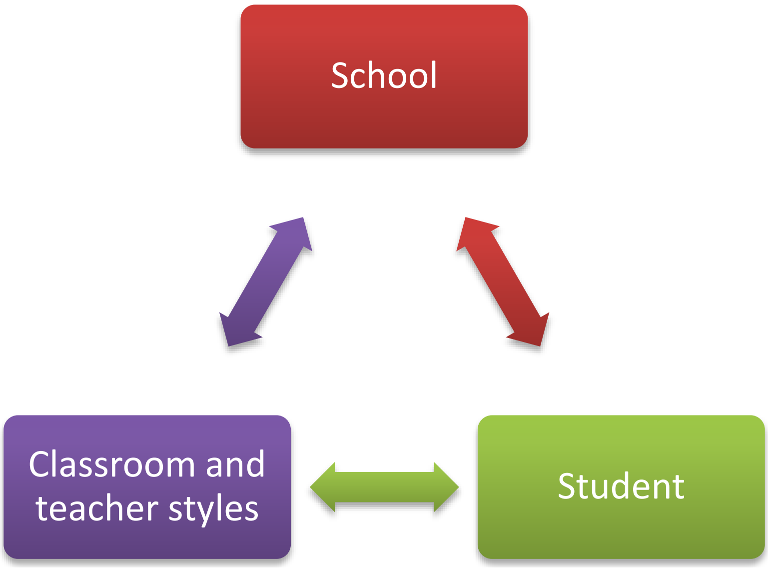

FIGURE 40 - BACKGROUND CONTEXT CONSTITUENTS

Figure 40 shows the background context layout. Firstly, the school - this presents the school demographics and information gathered from public records as well as from the websites of the schools involved in this study. Secondly, data regarding the classroom environment and teacher context illustrate the diverse range of classrooms involved and differing teacher experience. Thirdly, the student profile data are presented and show students' attitudes, motivations and perspectives towards mathematics.

8.2 School Background Context Descriptions

As a way to develop an idea of each school visited, a school demographics table – table 13 – formed from the school's public information is also presented. The history of the school, specifically information relating to the schools' establishment and ethos was gleaned from the school's own website. Although not meant to be representative of all schools nationwide, they do present a representative profile.

Alias	Gender	Public/Private	Urban/Rural	Progression to University[20]	Established

[20]University refers to the seven Universities in the Republic of Ireland namely National University of Ireland (Galway, Maynooth, Cork and Dublin), Dublin City

A	All girls	Public	Urban	34%	1950s
B	All boys	Private	Rural	90%	1930s and extensions built 2010s
C	Co-educational	Public	Rural	45%	1990s
D	Co-educational	Private	Urban	47%	1820s and extensions built 1990s
E	All girls	Public	Urban	75%	1960s and new school opened 1980s with extensions built 2010s

TABLE 13 - SCHOOL DEMOGRAPHICS

The sample was made up of two all-girls schools, one all boys school and two co-educational schools. As shown in the diagram above, three of these schools were urban and two rural with a mix of times when they were established from the 1800s through to the 1990s.

In order to differentiate between each school in terms of attainment, a set of league tables is published annually in a national newspaper and gives an account of students' attainment of third level places. The league tables can be used as a performance indicator (Borooah, Dineen and Lynch, 2010) in terms of students' ability to attain their top choices of third level colleges.

University, Trinity College Dublin and University of Limerick. These figures include their affiliations including Mary Immaculate College, St Angela's College Sligo and St Patrick's Dromcondra. The figures stated are based on 2013 School Days statistics and include any repeat Leaving Certificate students. http://www.schooldays.ie/ Date Accessed: 29th October 2014.

It is important to note that the GaelCholáistí (Irish-medium schools) were not represented as Maths Mission was not translated to Irish and so GaelCholáiste were not visited in this study.

In terms of an international context, it is important to note that the majority of schools in Ireland are non-fee paying. This is as a result of the abolishment of fees from second-level (post-primary) education under the *Free Education Scheme* of 1967 (Central Applications Office, 2000). Therefore, fee-paying schools in Ireland are currently very much a minority with an estimate of fifty-six in Ireland[21]. For the sake of examining different school contexts, two fee-paying schools were part of the convenience sample of this study. The following section now presents the data with respect to classroom environment and teacher style.

8.3 Classroom Environment and Teaching

Following on from school demographics, the schools are now described in terms of school environment both of the school and classroom, key features impacting on student achievement and teaching pedagogy. This section is similar to that of the TIMSS classroom context; however, this is through researcher observations instead of survey questionnaires to the school. As indicated in the TIMSS context framework, a school and classroom environment can affect the *ease and effectiveness of reaching curricular goals* (TIMSS, 2011). TIMSS school and classroom context focuses on certain well-researched school quality indicators. These include: the school location; student socioeconomic background, instruction affected by mathematics and science resource shortages, teacher availability and retention, principal leadership, school emphasis on academic success, and safe, orderly, and disciplined school. Although these are not examined throughout this study by a survey questionnaire, certain qualities were observed throughout each school visit. Classroom contexts were also shown

[21] This figure is approximate and taken from the http://www.schooldays.ie/secondary-schools-in-ireland/Independent-Secondary website, accessed: 6th March 2015.

with respect to classroom instructional resources, technologies and engagement as well as the teaching approaches to adopt these.

Classroom environment was one of the causes for the decline in students' positive attitudes towards mathematics (Middleton and Spainias, 1999). Researcher observations were gleaned from the school visit as well as parts of the teacher interviews. These data show the physical environment of the school and classroom layout, subject choice availability, teaching pedagogy and teacher background. The following bullet points show what each of these headings mean in the case of this research.

- The *physical environment* shows the nature of the school itself and the layout of the classroom. *Physical environment* is split into school and classroom and shows the overall school background in terms of establishment and resources available within the classroom respectively. The *physical environment – classroom* refers to the resources available in each classroom visited as well as whether the school has specific designated mathematics classrooms. Some of the mathematics teachers had their own designated mathematics classroom just as a science teacher has physics, chemistry or biology laboratories designated to them. A description is also given to the reader in terms of the layout of the classroom for the reader to form an understanding of the classrooms visited.

- Subject availability can impact on whether students wish to pursue STEM careers, students decide during the latter years of school and can be predicted based on their levels of enjoyment of mathematics and science rather than achievement (Maltese and Tai, 2011). Therefore, *key features that impact on student achievement* show the facilities and subject choices available to students in each school in this case study. Subject choices include the availability of mathematical-oriented subjects such as physics, engineering and construction.

- *Teaching pedagogy* is sometimes understood to discuss the role of the teacher in terms of distribution of authority and expertise (Mascolo, 2009). The *teaching pedagogy* describes what pedagogy is used in terms of student/teacher relationship and teacher leadership as observed during the school visits. As the teaching pedagogy was observed in terms of distribution of authority and expertise, the following are types of styles that were observed, authoritarian, democratic and empowered. Authoritarian refers to the traditional teaching style of a strict teacher where the decision-making lies with the teacher and knowledge is relayed in a lecture style communication. Democratic refers to a more open style of teaching, students participate in the decision making processes within the class; however, knowledge may still be relayed from teacher to student in a teacher-centred approach to teaching mathematics. Empowered teaching style in the classroom can be characterised as students being encouraged to take an independent role in constructing their own knowledge. This may be referred to as student-centred as students are empowered to facilitate their own classroom discussions in an encouraging environment.

- *Teacher background* refers to how long the teachers have been teaching mathematics, teacher education and their relationship with technology. Teacher background can sometimes interfere with successful implementation of the intended curriculum (TIMSS, 2011); therefore, it is an important context to bear in mind when interpreting the results. The information pertaining to the teacher background was gained from a semi-structured interview. A version of the interview schedule is available in appendix four.

8.3.1 School A

School A - Physical environment - school

School A's physical environment was one that would not have been out of place in the early 1950s. The school was established by a religious congregation in the early 1950s and has had very little structural investment and improvement since its foundation. The school was classified by the

Department of Education and Skills as a disadvantaged public school under the Delivering Equality of Opportunity in Schools (DEIS) action plan and was in a city in the southwest of the Ireland with approximately three hundred students.

School A - Physical environment - classroom

The classroom observed by this researcher did not have a lot of resources in the school. The classroom comprised of a chalkboard, teacher's desk and chair. All students were separated into rows. There was a large amount of space between each student's desk and the next student's desk. School A did not have a designated classroom and therefore required teachers to carry any materials with them around the school from classroom to classroom between each forty-minute class.

School A - Key features impacting on student achievement

The school had a music room; a science laboratory and students participate in physical education in a hall within the school. Subjects such as physics, engineering and construction were not available within the curriculum, thus possibly limiting the choices of students as they transfer to University. Therefore, this limits the courses students can take at University or third level if physics is a subject entrance requirement. From the school demographics table provided above, there were a low number of students going onto University at 34% in previous years. The DEIS status of the school suggests that priorities outside of technology take precedence and is evident from the school visit and basic resources available within this school.

School A - Teaching pedagogy

From the observations, the teacher seemed to have a traditional pedagogy where the main knowledge provider was the teacher and can be considered as teacher-centred. In this school the authority and knowledge lay with the teacher and students seem to be taught in an autocratic style of teaching; therefore, the environment can be restricted in terms of collaboration among students.

School A - Teacher background

From the initial section of the semi-structured interview, information was gained with respect to the teachers' own background. School A's teacher had been working within the school for over thirty-three years and initially qualified as a business studies teacher. The teacher completed a three-year degree in commerce and went on to complete the one-year higher diploma in teaching. Even though mathematics was not his degree subject, the teacher had been teaching the subject since he started in the school. The teacher had two classes for mathematics and was acting vice principal until the school closes. In terms of technology use, the teacher had access to a computer and used it daily to prepare for classes. There was a computer in the mathematics classroom and students did not have access to their own computers. The correlations are now presented that show the student context within the school. In terms of the relationships within each construct, correlations are presented under each construct heading.

8.3.2 School B

School B - Physical environment - school

School B was established in the 1930s and had been extensively refurbished with extensions added onto the older stone exterior walls. The school was surrounded by both old and new alike and had a tremendous amount of facilities for a school of its size. The student population was under two hundred boys; however, small class sizes and the extensive amount of facilities make this school look like it is much larger. The school was also a boarding school and fees were compulsory whether the student was a day pupil or boarder.

School B - Physical environment - classroom

In terms of the classroom, School B had a designated mathematics classroom that had a plentiful supply of resources and an Apple Macintosh desktop for the teacher to use throughout the class. The teacher had all of the books available from the curricula at his or her disposal and the students had been allocated one book. The books acted as a resource that could be consulted by the teacher or students during the school year. The desks were together in rows and a collaborative friendly atmosphere was observed throughout. The entire wall of the mathematics classroom was a whiteboard. Posters hang around the classroom and showed different areas of mathematics. This classroom environment allowed for permanent fixtures as the teacher did not have to move to another classroom to teach mathematics. The classroom included such resources as mathematics posters, challenges and tips that acted as a constant reminder of mathematics in real life. The teacher mentioned that Project Maths supplied some of these posters. The National Centre for Excellence in Mathematics Teaching based at the University of Limerick supplied other posters.

School B - Key features impacting on student achievement

Students had access to resources such as a library, technology suite and mathematically oriented subjects such as engineering and physics. Fee-paying schools were unusual as the Project Maths curriculum was standard across fee and non-fee paying schools; however, as a fee paying school it may impact on the amount of resources accessible to students in terms of accessing a range of textbooks, a library and a large range of subject choice.

The school has a history of students' level of attainment being particularly high. 90% of students attain their first choice in university as shown in the demographics table above – table 13. Also, according to the Department of Education and Skills, the inspector's report[22] for another subject stated that this school had made 'exciting progress in relation to ICT integration to support student learning and teaching' and there were efforts being made to integrate different forms of technology such as the iPad into the classroom in various subjects.

School B - Teaching pedagogy

It was observed that in terms of classroom management and the researcher observed on the day that the teacher also operated a task-oriented style whereby there was little focus on the relationship with the student and more on the task at hand.

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[22] The inspector's report for this school accessed via the Department of Education and Skills was consulted and specific reports are not cited to preserve the anonymity of the school.

School B - Teacher background

The teacher was not qualified to teach mathematics and had been teaching in the school for more than 19 years. At the time of this research he was pursuing a post-graduate degree in mathematics teaching offered jointly by the University of Limerick and the National University of Ireland Galway. The teacher did not mention his original degree.

The teacher in School B had access to the Internet and the students had an iPad in the non-state examinations years such as first and second year of second level and transition year. In their third year and sixth year students sat the Junior Certificate and Leaving Certificate respectively and therefore students did not have access to the iPads during this school year.

The teacher was also a Geography teacher and used the Internet mainly to access slides available on Google Drive that would have been prepared previously. The slides were mapped from the syllabus and YouTube clips were used frequently for subjects like geography. Students used the iPad as a way to create through education, as the teacher called it *"to EduCreate"*. Even though the examination years did not have access to the iPad, the students were taken to a computer room once a week where they looked at the teacher's slides that were available to download on Google drive.

8.3.3 School C

School C - Physical environment - school

This school held many community events that served the locality. In terms of facilities, the school offered swimming and catered for most science subjects at leaving certificate level with a designated laboratory for each of them. School C would be considered an average school with 45% of students progressing to university level. The school was relatively new and was purpose built to house the amalgamation of a number of other schools in the area in the 1990s.

School C - Physical environment - classroom

The classrooms were not designated for subjects like mathematics and the teacher moved between rooms on a class-by-class basis. The school environment did not allow for permanent fixtures in the school classroom.

There was a computer within the classroom but no interactive whiteboard. The computer room where the class was held had a number of computers along the outskirts of the room and the computers were approximately ten years old. These were all Dell desktop computers and there was a low level of support for technology in the school. The support was basic and if a computer breaks, the computer remains broken for the entire year until a support agent can be brought out to the school to fix the machine. A single teacher took on the role of updating the computers. There were no replacement machines available and for a school of over seven hundred students, there were a little over twenty computers in the computer room. This room also acted as a classroom for other subjects. The desks were along the outskirts of the room and form a rectangle in the room. The classroom set-up in the computer room was different from other rooms as the other classrooms had desks separated from each other. The teacher had arranged for the desks to be re-arranged for this school visit and the desks were pushed together in rows of four desks in the centre of the room. The teacher's desk was elevated by a step and there was an overhead projector available for teacher's use.

School C - Key features impacting on student achievement

School C had access to a wide range of subjects including mathematically oriented subjects such as engineering, physics and construction. The intention of most students was to go onto third level and the percentage of students going onto university is reflected in the school demographics table above – table 13 – as just below half of the students sitting their leaving certificate[23]. There were a lot of facilities and students can participate in a range of activities within the school. Two computer rooms, gymnasium, laboratories and home economics suites were all at hand in this relatively new school. In an earlier inspector's report from 2007, the school was stated

[23] When referring to leaving certificate this means the leaving certificate established and is not referring to the leaving certificate applied or alternative programmes that are offered in this school.

as having a ‘good level’ of ICT facilities and should seek to develop these further.

School C - Teaching pedagogy

The teacher adopted a traditional style of teaching pedagogy and a mix of authoritarian and democratic styles but the style remained predominantly authoritarian throughout the school visit. As observed by the researcher, the teacher focused on the student and relayed information to the student as an entity willing to absorb new knowledge.

School C - Teacher background

The teacher decided to answer all questions by electronic mail instead of undertaking a formal interview. The teacher had been teaching mathematics and music for the past seven years in the same school. The teacher used the computer for roll call, displaying textbooks, preparation of tests and Microsoft PowerPoint presentations. The teacher regularly visited textbooks online and YouTube clips to demonstrate mathematics and applied mathematics. Every classroom was equipped with a computer - either a laptop or desktop, Internet access and a data projector within the school.

During the school visit, it is worth noting that the teacher mentioned collaborative learning. The teacher discussed the school participating in a field trip and suggested that this is where students collaborate; however, he did not relate collaboration to within the classroom itself. Collaboration and communication within this mathematics classroom was somewhat limited, as it was not practiced within the classroom on a regular basis.

8.3.4 School D

School D - Physical environment - school

The school had a diverse population of students as compared with the other schools in this study. School D participated in a large amount of extra-curricular activities and had the facilities within the school to do these. In terms of progression to university, the school had just under half of students sitting their leaving certificate going to university. The school had been renovated a number of times since its foundation.

School D - Physical environment – classroom

School D had small classrooms and desks were grouped together in rows. The school had iPads available under the control of the Principal and were locked in a safe in the Principal's office. Across all classes observed, School D had large groups in each classroom observed and in this particular visit approximately 40 students were in attendance on that day. The teachers did not have their own designated classrooms and were required to move among classrooms along with students.

School D - Key features impacting on student achievement

There were a diverse range of facilities within the school with a lecture hall, music room and computer room available for students. Students were offered a range of subjects that were not offered in other schools such as technology, metalwork and woodwork. This could be a choice on the part of the school as a fee-paying school that offers a range of subjects available to students who attend the school. Individual tuition was also provided and there were also private night classes available for many of its students. A single teacher ran a design and technology blog and students could volunteer to participate in different competitions in relation to the subject of design and technology as part of an extra-curricular activity within the school. There did seem to be support for technology; however, support was for technology in general and support was not for subject-specific integration of technology.

School D - Teaching pedagogy

As observed by the researcher, the teaching pedagogy revolved around the teacher and was very much teacher-centred. The teacher exhibited an authoritarian style throughout this school visit.

School D - Teacher background

The teacher had been teaching for less than five years in total and all within this school. The teacher had iPads available on the day of arrival; however, when told that the files could not be transferred onto the iPad, the teacher was puzzled. The teacher was also uncertain how to switch them on. The teacher was supplied a laptop by the school and was unsure of the difference between Apple and Windows machines.

8.3.5 School E

School E - Physical environment - school

School E had roughly twenty-four girls per class group. The school was a public non-fee paying school and had voluntary family contributions towards activities and fundraisers. A high percentage of students intended to go onto university as reflected in the school descriptions table above – table 13. The school had two computer rooms and other facilities to engage in science subjects and home economics. Three classes were visited in this school; therefore, three teachers were interviewed and the school's description refers to all three classes.

School E - Physical environment – classroom

The classroom set-up allowed students to sit one per computer as well as in pairs. The school atmosphere overall was relaxed and emphasised whole-child development. Posters and framed photos were hung on the walls of the corridors and classrooms and represented a large amount of religions and awareness that was encouraged for the students to adopt.

There was no Wi-Fi. There was an overhead projector in the classroom but no interactive whiteboard. The whiteboards could be turned into interactive whiteboards. Students were not allowed to use their own devices. Computers in the classes obtained viruses and were then removed. Classrooms did not permit permanent fixtures, as there was no designated classroom for mathematics teaching and learning.

School E - Key features impacting on student achievement

The school was renovated and had plenty of resources for students including two computer rooms that facilitate classes including introduction to computer programming using Scratch[24]. Apart from two computer rooms,

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[24] Scratch was developed by Massachusetts Institute of Technology (MIT) in an effort to teach programming concepts to younger students from primary school upwards. These programming concepts allow students to engage with basic concepts such as x and y axis, types of variables and decision making to allow sprites or avatars to move on screen. Scratch is available from the MIT website: http://scratch.mit.edu/. Date accessed: 28th October 2014.

there were also large halls, religion rooms, chaplaincy office, home economics kitchens, sewing rooms and resource classrooms for one-to-one tuition. There were smaller class sizes than other schools ranging between twenty and twenty-four students per class.

The school environment was relaxed and students had already been in the computer room to develop their own resources using Scratch. The resources in the school seemed plentiful allowing more than enough equipment with two large computer rooms and resources focused on the academic side rather than sports or extracurricular activities. The school was located near sports centres. In terms of technology support, the teachers seemed proficient in different levels of support including programming and technology. The teachers did not seem to be knowledgeable in terms of windows or apple computers or the difference between the two types. However, the teachers were resourceful in terms of attaining technical knowledge. For instance, teachers attended continuous professional development technology courses for better integration of technology in their classrooms. These were done autonomously from the school and the teachers seemed enthusiastic to learn about diverse ways to adopt technologies for the teaching and learning of mathematics.

School E - Teaching pedagogy

In all three classes within this school, the teaching pedagogy suggested a strong relationship with what could be described as a social constructivist in nature. The teachers acted as facilitators during the classes that took place in the computer room. Teachers and students actively participated in the classroom activities and mathematical discussion was encouraged throughout all three classes. All three teachers participated in an effective (Schmuck and Schmuck, 1988) and democratic style throughout this school visit encouraging the students to participate and letting students take the lead in doing the activity. The researcher observed that all three teachers engaged in empowering teaching styles.

School E - Teacher background

All three teachers had been teaching mathematics between two and six years. Each teacher had classes across all levels of the school. Depending on the topic the teacher would use overhead projectors, GeoGebra or bring the students to the computer room to work on the topics. There was no Internet across the school and teachers needed to provide their own devices if they wished to use a computer within the class. One teacher mentioned that there was Internet available previously; however, broken cables and machines led to the disconnection of the local area network cables.

8.4 Student Profiles

Moving on from the classroom environment and teaching, this section now presents the methodology for collecting data with respect to the student profile. As mentioned previously, the scales used as part of this doctoral research gain an insight into students' attitudes, motivations and perspectives by using different scales (also known as constructs) from the TIMSS and EVT frameworks. The constructs are part of the TIMSS international context survey questionnaires and provide details of students' background contexts. As discussed in chapter 4, the theoretical framework chapter, TIMSS provides an insight into *effective educational strategies* for development and improvement (TIMSS, 2011).

While TIMSS looks at five broad areas including community and home contexts, this study focuses on school context, classroom context and students' attitudes towards learning mathematics. These context questionnaires are an important part in forming the overall picture of each school and are an essential aspect of data collection (TIMSS, 2011). National and community context as well as home contexts were outside the scope of this doctoral research. Surveys were only collected from the student and not the principal or parent. These were again outside the scope of this doctoral research.

While national and community contexts were not supported explicitly by survey questionnaire, the previous section of this chapter elicited information with regard to demographics, geographic characteristics, student flow in terms of ability grouping, also known as tracking, curriculum and teacher background (TIMSS, 2011).

Student profiles provide an insight into students' readiness to learn. Their attitudes, motivations and perspectives are essential to academic success (TIMSS, 2011). In order to gain an insight into the students' profile, a description of the survey questionnaire is described below.

Section	General Aim
1. Background	**Section one is designed to find out the year students are currently in as well as if they are taking higher or ordinary level mathematics.**
2. Students Like Learning Mathematics Scale	**Section two is designed to find out students' perspectives with respect to whether they enjoy mathematics, like mathematics and find mathematics interesting.**
3. Students Confident in Mathematics Scale	**Section three is designed to find out whether students do well in mathematics, find it confusing, can learn mathematics quickly and whether the teacher tells the student that they are good at mathematics.**
4. Students Value Mathematics Scale	**Section four is designed to find out whether students value mathematics in their daily life, whether they need it for a course or job and whether they find it important to do well in mathematics.**
5. Expectancy-Value Theory	**Section five is designed to find out whether students expect to do well**

	in their end-of-year examinations, activities or work and whether they find the information learned useful.

TABLE 14 - STUDENT SURVEY CONTEXT QUESTIONNAIRE

There follows a brief description of each scale and more detail can be found in the theoretical framework chapter, chapter 3. As mentioned above, there were four constructs used in the survey questionnaire. This elicited information with respect to students' enjoyment of mathematics, whether students are confident in mathematics, students' relevance of mathematics and finally, students' expectancy to succeed in mathematics. Each construct was made up of multiple questions to inform the single main question; for instance, the students like learning mathematics scale is made up of five individual questions or statements that students agreed or disagreed with. Each statement was collated to form an aggregated scale to facilitate quantitative analysis.

For instance, using the students like learning mathematics scale as an example, statements such as 'I like learning mathematics', 'I enjoy learning mathematics' or 'mathematics is boring' are grouped and analysed together. Students would then be expected to answer similarly to the first two statements shown and answer the reverse in the statement 'mathematics is boring'. Their responses then showed whether they like, not like or somewhat like learning mathematics based on the one construct. The following section looks at each construct and the results from the students that participated in this study. The section outlines each of the students' responses reliability analysis per construct.

8.4.1 Student context reliability analysis

Prior to describing the reliability analysis results from each construct, it is important to note that each of the constructs used the TIMSS international context questionnaires four-point scale with no middle answer as explained in chapter 4. The * indicates that this is a reverse coded question. Initially, it is important to find out whether students responses to these statements are reliable.

The reliability analysis shows how the students in each school answered questions and whether these answers were consistent across each construct or inconsistent. A description of the statements used in each construct is also given while highlighting the different figures of consistency.

8.4.1.1 Students Like Learning Mathematics Scale

The students like learning mathematics scale examined students' perspectives with respect to if they enjoy mathematics, like mathematics and find mathematics interesting. The statements posed in this scale or construct were as follows:

- I enjoy learning mathematics
- I wish I did not have to study mathematics*
- Mathematics is boring*
- I learn many interesting things in mathematics
- I like mathematics

As mentioned, students were asked to agree or disagree with those five statements. The following section describes the reliability analysis conducted on their responses.

In order to gauge each student's reliability when answering this construct, a Cronbach's alpha reliability analysis was performed on each construct. A table – table 15 – is presented below showing each of the school's reliability in terms of the students like learning mathematics scale. As shown, school A was the most internally consistent, meaning that when students answer one question 'I like learning mathematics', students are more likely to answer 'I enjoy mathematics' similarly to that of their counterparts. The data were placed alongside data from the United States to give an international context to the data. This is due to inaccessibility with international averages across these data.

	School A	School B	School C	School D	School E	Cronbach's alpha reliability coefficient United States
Like Learning Mathematics	.928	.783	.792	.752	.891	.89
Confident	.924	.914	.884	.782	.852	.89
Value	.895	.663	.666	.786	.852	0.79
Expectancy Value Theory	.741	.602	.572	.451	.799	

TABLE 15 - CRONBACH'S ALPHA

The Cronbach's alpha was very high in School A and most correlated among the subgroup of this construct. The .928 exceeded the minimum acceptable level of (0.70) according to Nunnally and Bernstein, 1994 as cited in Pridmore, Bradley and Byrd, 2006 and was therefore reliable. While determining Cronbach's alpha to be greater than .7 to proceed, the schools are shown on a case-by-case basis. As shown in Cronbach's alpha, all schools reached above .7 and were therefore reliable in this construct.

8.4.1.2 Students Confident in Mathematics Scale

The students confident in mathematics scale is designed to find out if students usually do well in mathematics and their confidence levels for working on mathematics. The following scale, students confident in mathematics scale, examines eight different questionnaire items. The questionnaire item 'my teacher thinks I can do well in mathematics <programs/classes/lessons> with difficult materials' was adjusted and omitted programs and lessons from the questionnaire item.

This scale asked students if they usually do well in mathematics, find it confusing, learn things quickly and whether or not their teacher tells them that they are good at mathematics. A list of the statements that were used in this construct is provided below:

- I usually do well in mathematics

- Mathematics is more difficult for me than for many of my classmates*
- I learn things quickly in mathematics
- Mathematics makes me confused and nervous*
- I am good at working out difficult mathematics problems
- My teacher thinks I can do well in mathematics class with difficult material
- My teacher tells me I am good at mathematics
- Mathematics is harder for me than any other subject*

The statements above from TIMSS provide an insight into students' confidence in mathematics. As with the other constructs examined, Cronbach's alpha examined the reliability of this construct when asked at each school.

8.4.1.3 Students Value Mathematics Scale

Students were asked six questionnaire items within the Students Value Mathematics Scale construct. These questions related to whether students find mathematics valuable in daily life, learn other school subjects, need it to get into the course of their choice, need to do well in the job they wish to pursue, would like a job involving mathematics and finally consider if it is important to do well in mathematics. There were no reverse coded questions in this construct and it was examined in the same way as the previous constructs, first looking at Cronbach's alpha before conducting a correlation analysis. The questionnaire item 'I need to do well in mathematics to get into the university of my choice' was adjusted to 'I need to do well in mathematics to get into the course of my choice', this is due to the small number of universities in Ireland and many students referring to third level as a course as well as participating in third level institutions. University may also not be an option for students in disadvantaged schools; however, course refers to both college and university. The school demographics section above showed the University progression, while these data show the course and college progression. This gives an overview of the school as a whole. The list of statements asked as part of this construct is below:

- I think learning mathematics will help me in my daily life
- I need mathematics to learn other school subjects
- I need to do well in mathematics to get into the university of my choice
- I need to do well in mathematics to get the job I want
- I would like a job that involves using mathematics
- It is important to do well in mathematics

Similarly, for this construct, the reliability analysis was conducted. As illustrated in the table – table 15 – Cronbach's alpha reliability coefficient was relatively low in all four schools compared with the other underlying constructs examined in the survey questionnaire.

Cronbach's alpha for School A showed the reliability coefficient for School A for the Students Value Mathematics Scale as being .895 and in the United States is .79. Therefore, the reliability of the construct was highly internally consistent. School B's Cronbach's alpha for this underlying construct was .663 and below the level of reliability. Cronbach's alpha for School C was one of the weakest across other schools with .666 and below that of a good reliable resource. The internal consistency was lower than that of other schools thus rendering these survey questionnaire items not reliable for this school. Although School B and C were rendered not reliable, the findings are still reported for these schools. School A, D and E were the only schools that were considered reliably internally consistent. School D was above the Cronbach's alpha reliability cut-off of .786. This means that students answered questions with greater variation in Schools B and C than the other schools. School E also answered consistently across this construct than the other schools. School B and C's data could mean that students were unsure of the value of mathematics more than School A, D and E. School D looked more like the United States data in that it was closer to the internally consistent score of .79 than any of the others.

8.4.1.4 Expectancy-Value Theory

Now turning to the final construct examined in the survey questionnaire, which is not part of the TIMSS but is a motivational framework in its own right. The three items investigated were perceived usefulness, attainment toward examinations and doing well during activities in class. These data investigate the importance students place on doing well. These three items relate to the utility value and attainment value. Both of these values together are known as the importance value.

Theorists argue that students' beliefs can be explained by their choice, persistence and value placed on a particular task (Eccles and Wigfield, 2002). For this purpose, the three items that were used explain the attainment value and utility value as outlined in chapter 3, theoretical framework for game design chapter. The following shows the statistical analysis of the student background context questionnaire that was carried out in all five schools.

Correlations

Another statistical analysis was performed on these data to give the relationships within each construct. The correlations show the strongest and weakest relationships between statements. The correlations illustrate each school in terms of the significant relationships among the students and their attitudes towards learning mathematics. These data are described under each school (case) within this study. Correlations are available in the appendix of this thesis – appendix five.

8.4.2 Overall scoring of student context

Scoring – Like Learning Mathematics Scale

As a way to illustrate an overview of each school, a scoring method shows an overall picture of students' attitudes towards mathematics with the 'Students Like Learning Mathematics Scale'. Prior to discussing the scoring in detail, the way in which these were calculated is discussed. The scoring was calculated by choosing each question and averaging the answer across the four point scale- 0 being disagree a lot to 3 agree a lot. This illustrates a way of viewing the schools in terms of participants within each classroom. Students were scored in terms of their agreement with these five statements

	School A	School B	School C	School D	School E
Enjoy Learning	1.16	1.90	1.55	1.42	2.08
Did not have to study	1.83	0.90	1.31	1.79	0.80
Boring	2.08	1.54	2.10	2.02	1.24
Interesting	1.33	2.09	1.39	1.46	1.76
Like	1.20	2.09	1.48	1.29	2.06
Important to do well	2.25	2.72	2.62	2.53	2.30

TABLE 16 - STUDENTS LIKE MATHEMATICS SCALE SCORING

As shown in the table above – table 16 – School B and E had the highest score in terms of enjoying learning, finding mathematics interesting and liking mathematics overall. School B and E also had the lowest in terms of not having to do study and finding mathematics boring which are two negatively posited questions. Students disagreed a lot with finding mathematics boring and wishing they did not have to study mathematics. In stark contrast, School A, C and D reflected similar scores compared to B and E. School A had the lowest score in terms of enjoying learning mathematics, and the highest in terms of not wanting to study mathematics. Similar scores were reflected in the boring category. Students in School C found it more boring than A and D. This scale gives an overview of the scores attained during the mathematics context questionnaires. Now the next scale in the survey, the students' confidence in mathematics will be discussed.

Scoring – Confident in Mathematics Scale

	School A	School B	School C	School D	School E
Usually do well	1.37	1.36	2	1.61	1.72

Mathematics is more difficult for me than my classmates	1.41	1.27	1.51	1.40	1.27
Learn things quickly	1.20	1.45	1.31	1.13	1.69
Makes me confused and nervous	1.62	1.2	1.55	1.55	1.29
I am good at working out difficult problems	1	1.54	1.27	1.08	1.53
My teacher thinks I can do well in mathematics	1.62	2.36	2.17	1.92	1.93
My teacher tells me I am good at mathematics	1.45	1.63	2.03	1.61	1.67
Mathematics is harder for me than any other subject	2	1.45	1.55	1.87	1.19

TABLE 17 - STUDENTS CONFIDENT IN MATHEMATICS SCORING

Scoring illustrates the context in the school in terms of the classroom average scores. For instance, all school's perception of usually doing well is in and around similar figures on average. School B and E did not find mathematics as difficult as D, A and C in that order. The same was true for learning things quickly. School B and E both had a higher average for learning things quickly and the lowest was School D followed by A and C. School C and D were very similar in this case followed closely by A in terms of mathematics making students feel confused and nervous. Again, School B and E were similar in terms of working out difficult problems and School A was the lowest. Interestingly, School D and E were close with the teacher thinks students can do well in mathematics. School B and C were similar with this as well and School A perceived that their teacher does not think they will do well in mathematics. School C scored the highest for teachers telling students that they are good at mathematics. Schools B, D and E teachers tell them they are good at mathematics but less than School A.

Scoring – Value Mathematics Scale

	School A	School B	School C	School D	School E
Help me in daily life	1.52	2	2.06	1.89	1.78
Need mathematics to learn other school subjects	1.75	2.18	1.82	2	1.76
Need to do well in mathematics to get into the course of my choice	1.56	2.54	1.86	2.07	1.88
Need to do well in mathematics to get the job I want	1.47	2.2	2.03	1.97	1.76
Would like a job that involves using mathematics	0.75	1.72	1.24	0.97	1.09
It is important to do well in mathematics	2.25	2.72	2.62	2.53	2.30

TABLE 18 - STUDENTS VALUE MATHEMATICS SCORING

Reading from the table – table 18 – School B and C were similar with respect to mathematics helping in daily life. School B and D were highest regarding students tending to agree with needing mathematics to learn other school subjects. School B and D were similar again when it came to needing mathematics to get into the course of their choice. School B, C and D were quite high and tended to agree a lot with needing to do well in mathematics to get the job they want.

In an effort to understand students' expectation, three items were used from the Expectancy-Motivation Achievement Value Theory (EVT).

Scoring - EVT

	School A	**School B**	**School C**	**School D**	**School E**
expect to do well end-of-year	1.66	1.72	1.89	1.66	1.94
expect to do well on activities and work	1.79	2	1.88	1.76	2.09
useful information	1.58	2.45	2	1.91	2.14

TABLE 19 - EXPECTANCY VALUE THEORY SCORING

The scoring for this construct showed in the table above – table 19 – that School A was similar to School D when it came to expecting to do well at the end of the year examinations. School B, C and E were similar with agreeing more that they expect that they will do well at the end of the year examinations. School B and E were similar with respect to doing well on activities and work. School A and D were similar with this question. School A offered the lowest score when finding mathematics useful and all other schools had a higher result. School B and E again topping this.

8.5 Implementation of the game into the schools

Teachers were given an opportunity to express their opinion of Maths Mission. As per the ethics guidelines for this study, the teacher could leave this study at any time, without notice or reason. The following is a narrative of the interviews that took place after each school visit and relates to the potential of Maths Mission in the post-primary level classroom. School A - E data are from the teacher interviews, observations and student feedback regarding the usability of Maths Mission.

8.5.1 School A

School A's teacher thought that there was potential for Maths Mission as long as it is low-cost or able to be borrowed by the school and was available across multiple topics. The teacher's outlook was positive in terms of technology supporting the teacher. Framing the results within context, the school was established in the 1950s and has had little in the form of renovations since then, the students within this school scored below average in terms of university progression, found that mathematics was not useful and were generally not as confident in mathematics as other schools. The classroom had little in terms of facilities and the teacher was acting vice-principal with thirty-three years teaching mathematics at the time of this interview.

As mentioned in the classroom context, the computer in the classroom was equipped with Internet access; however, the teacher said *'No'* when asked if students were allowed to use their own devices for Internet access or any other use. As for other technology, the teacher could not comment on the devices like the Nintendo Wii, Xbox Kinect, or PlayStation. The teacher stated that the students interacted well while using Maths Mission; however, he felt that more devices were needed to ensure that more students could play the game at once. The teacher suggested that five devices would enable more teams with less students per team.

The advantages of using a GBT must outweigh the financial and time costs during the school year; this includes the demands and extensiveness of the curriculum as he stated *'time and completion of the course are other important factors to consider'*. The teacher stated that the students were generally taking foundation level mathematics, which as described in the discussion chapter is the lowest level of mathematics available to students. Usually, foundation level is not an acceptable level to matriculate at a third level institution and overall, as mentioned by the teacher, the expectation was low in terms of achievement motivation in this school.

The teacher referred to students finding it difficult to relate mathematics to real life and explained this by their level of ability, as mentioned by the teacher: *"The Leaving Certs are doing foundation level and would not have a high opinion of maths [sic]."* The teacher alluded to the transition year students being in a mixed ability group and the connection students were able to make in terms of relevance to real life can depend on their own ability. *"A lot see the relevance but some would have differing opinions as to their own ability, and this can reflect on their effort and grade."*

This teacher found that games could be used for different topics in mathematics such as statistics and probability. Gesture-Based games can be used for trigonometry and geometry more than those topics. Overall, the teacher felt that time within the class is a factor in adopting these as well as completion of the course. There is also a potential for these if the game was longer and covered more topics. Maths Mission is a short learning experience and the teacher expressed an interest in Maths Mission if it was extended to cover more topics. The next section outlines the students' experience play-testing Maths Mission during the visit to School A.

8.5.2 School A – Student Play-Testing

Students in School A actively engaged in Maths Mission and were highly participatory discussing both cooperatively with each other and collaboratively trying to solve the problems as set out in Maths Mission. Students moved into groups within the class and used notepads to calculate the different mathematical challenges.

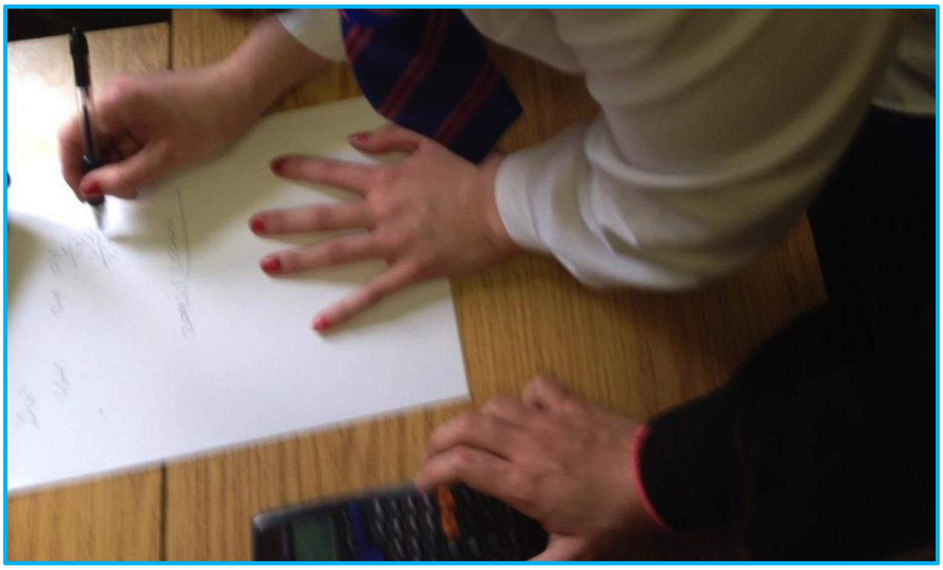

FIGURE 41 - SCHOOL A OBSERVATION IMAGE OF A STUDENT COLLABORATING

As shown in figure 41, the students worked together and used different techniques such as writing out the problem before using a calculator. Students collaborated and communicated the problem to each other before choosing the answer in the game. The teacher commented during the class that any form of resource that gets students engaged and enjoying mathematics is worthwhile. Students generally did not illustrate or draw problems graphically or use images. Instead, they used the paper to do standard calculations.

8.5.3 School B

School B offered a large range of resources to students. Even though there were great strides to envelope different student-centred approaches, there seems to be a teacher-centred approach to teaching mathematics. This is also due to the students' focus on examinations. The student-centred approaches revolve around technology including taking students to a computer room once a week to work on mathematical problems over the Internet.

There was a trust issue with regard to the students carrying out their homework on their own devices. The teacher continually focused on the improvement of students and did not trust students to carry out the intended activity when in the computer room.

Games were not used in these classrooms at all. *Manga High*[25] games were used initially; however, the teachers' technical knowledge was limited and the students were advising the teacher what buttons to press. The teacher advised that the games should be one-to-one. The teachers' view of Gesture-Based Technologies such as the Wii or PlayStation Move is summed up in the quote below:

> *"No, I don't. No, I am very bad for the use of games. There was a website called Manga High. I used to use that but again it wasn't them playing it, it was them advising me what buttons to push to play the game. So, that is undesirable, games should be one-on-one really…Even though the iPad can be that when it wants to be."*

This quote explains some of the teachers' reasoning with regard to technology and suggests that the iPad can be provided as a resource for games. The teacher had focused on teacher led game playing as opposed to student led game playing. There was no mention of team playing within this classroom.

When asked with regard to the GBT in general, the teacher quickly prompted that the iPad is a device that can be utilised and is certainly without a doubt something that is fit for all purposes. The teacher was not sure about the Nintendo Wii or Kinect as this focuses too much on the game playing aspect and refers to the cost associated with these devices.

> *"Again, they are too focused on the game playing aspect. Aren't they? So, it doesn't allow you to edit or create documents like the iPad would. So, I would say the Nintendo is a bad waste of money,*

[25] Manga High is an adaptive games-based mathematics resource designed for the blended classroom. At the time of this study, it had limited adaptive game-based qualities and focused on procedural mathematics tasks such as addition and multiplication. Manga High also focused on speed over accuracy in these procedural games.

> *"so I think something – like if you were creating a game. I would think they are best made for the iPad or the IOS devices. Because people see that there is multi-function use in those."*

The teacher promptly suggested that other uses of games that capture their imagination are important. The teacher also noted that he tells students when they are bad at mathematics and could suggest games focused on procedural mathematics to help them improve. The teacher suggested that games similar to Tetris and Sudoku practice mathematics are examples of what could be used in the mathematics classroom. He suggested that games that engage students are an important initiative, and that games have a lot to offer as a way of practicing procedural style problems.

The teacher suggested that Information Technology (IT) needs to work seamlessly in the classroom and had often used headphones to reduce down the interaction between other students. *'I think headphones are the secret ingredient, it cuts down the interfering senses'*. The other school years in the school that were doing ordinary level mathematics were not as engaged as students doing higher-level mathematics. The teacher mentioned that students did not need activities for engagement in their course.

The teacher spoke about visualising mathematics as a way of helping them become more engaged. He continued to elaborate on the *"...fact of bringing moving visuals of complex numbers or moving graphs from GeoGebra, they seem to kind of find that much more engaging"*[26].

The teacher cited the speed at which IT is employed is another relevant factor in terms of getting students engaged in mathematics. The speed has to do with the seamless technology and whether it works or not can be frustrating and loses time in the classroom.

8.5.4 School B – Student Play-Testing

School B demonstrated a different approach with respect to student participation. As for the participation and students' game play with Maths

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[26] GeoGebra includes students physically moving a two-dimensional equation on a graph while showing the differences in equations and complex numbers.

Mission, students were less engaged until they moved away from their desks and gathered around Maths Mission. In this classroom, the availability of a Macintosh Desktop meant that the game was also available on a number of machines. This allowed for students to participate in small groups. There are only eleven students in one class thus securing small groups. Students completed the game and sought more challenges within the game itself. Students were engaged, participatory and did not use a notepad to calculate answers. Students guessed answers and were initially reluctant to communicate until after the first task was completed. Students found it fun, interesting and wanted to learn more about game development at the end of the activity. School C's data is presented in the following section.

8.5.5 School C

The teacher in School C chose to answer the interview schedule questions by email. Therefore, the results are presented with observations tied into the school visit. In terms of GBT, the teacher had some experience playing with the Wii. Feedback with regard to the interaction was given and noted that teams could be smaller, such as groups of four. The teacher gave good feedback with regard to the game itself that it is accessible to all students which is important and would be nice to have more development of buildings with more advanced mathematics for the talented students.

She noted the restrictions of the Maths curricula when asked if there was a place for such a device in the classroom *"Yes as students enjoy using them but we are restricted by Junior Cert and Leaving Cert curriculum."* As stated by the teacher, time is also an issue with regard to setting up the computer and allowing for progression.

Students seemed to enjoy the experience. Allowing students to see the link between something like this and examinations are important in understanding how it can be used in the mathematics classroom. As well as suggesting that there is a place for this in the mathematics classroom, the teacher gave some useful insight into the activities that it could be used for in mathematics lessons.

> *"For maths involving movement and measurement. In Co-ordinate Geometry, it would be very good for demonstrating and understanding slope, distance and midpoint. In Area and Volume, you could visually see things filling up with water or sand and the space required for area and volume of various 2D and 3D shapes. In Trigonometry, you could see angles of elevation and actually do measurements of this kind without physically going outside which is recommended in the Project Maths syllabus. All kinds of measurement could be done in simulation."*

The teacher pointed out that Maths Mission could act as a revision tool for students. Simulations and movement control are useful for understanding volumes. Not only is movement an option in mathematics, but allowing for students to manipulate a virtual world can influence students' perspectives of angles of elevation, area and volume. Students' attitudes towards mathematics depend on their ability and relevance.

> *"It depends on their ability. It is very difficult to teach weak students (ordinary level and foundation level), as it is a fight to get them to see the relevance of it. They use excuses for not doing it such as 'we'll never use this when we leave school' because they find it too difficult."*

The opposite is reflected in the higher-level class with the teacher having stated, *"They love to see the real world relevance also but also like a traditional algebra question because they are good at it and get satisfaction out of it!"*

The teacher from School C noticed that students' attitudes changed after using Maths Mission and students who liked mathematics continued to ask questions with regard to the game and how it could be developed further.

8.5.6 School C – Student Play-Testing

Students collaborated within the bounds of the classroom, the teacher was positioned at the top of the classroom on a podium and students were initially hesitant in relating to each other. When asked during the class if students usually do group work, to paraphrase the teacher mentioned, 'the students go on activities outside so they went to Petersburg adventure centre in Mayo recently and they do things like that throughout the year'. Initially the class started at 9am that Monday morning and students seemed reluctant to participate. The majority of the class were again given paper to work out the activity. Students gathered away from the machine to work out the mathematics instead of working out the activity around the game itself. This seemed counter-intuitive and students did not seem to want to participate while the teacher corrected their homework at the top of the class. There follows the presentation of the next school's data, School D.

8.5.7 School D

The interview for School D was cut short as the teacher had to attend another meeting. The teacher did mention that *"we need to be like monkeys in here"*, I asked her to clarify the meaning of the sentence, *"we need to keep them active, otherwise they won't pay attention".* Another time for the interview could not be arranged and the teacher was unwilling to participate in the rest of the interview.

There seems to be little support for technology within the school as the teacher required more knowledge when it comes to basic technological skills. This seemed evident from the misunderstanding of the game being available on the iPad and not knowing the difference between a Windows and an Apple machine. The teacher had attempted to place an Apple application on a Windows machine unsuccessfully.

The teacher neglected to participate in an interview after the school visit. As is evident, the teacher seemed anxious with regard to a different teaching pedagogy where the students take centre stage in constructing their own knowledge. Students seemed afraid to engage and participate with the game and were reluctant initially.

8.5.8 School D – Student Play-Testing

School D has not previously had any experience using games within the classroom. During the participatory element of the game, students were asked to discuss the answers to the game. Students did not participate well in this activity. The teacher requested that the game be shown on the overhead projector and while the game was being played some students were left idle. The students that participated were reluctant to play the game in front of their peers. The high level of interaction among students and their collaboration for solving different mathematical tasks left the teacher requesting them to be quieter during the activity. The teacher prohibited the students from any discussion and no collaboration was allowed.

Students started participating and exchanging mathematical ideas of how to address the challenges within the game. Students seemed engaged in collaboration and co-operative learning. However, students in School D seemed to be influenced by the presence of two teachers. Another teacher entered the classroom to maintain some support, one teacher was not happy with the level of conversation among students and continuously requested students to be quiet within the class while both teachers continued with a conversation among themselves. Students continued to participate; however, little to no talking took place within the classroom after the second teacher entered the room. The image below shows a student participating in Maths Mission.

FIGURE 42 - SCHOOL D OBSERVATION OF A STUDENT PLAYING MATHS MISSION

The student's face has been blurred so the student and school cannot be identified from this photograph. In this photograph (figure 42) Maths Mission is shown on the overhead projector. The student was in the latter stages of playing Maths Mission and the options are in the process of falling in front of the player. Following on from this, School E's data is presented below.

8.5.9 School E

8.5.9.1 Teacher 1

The first teacher spoke in depth about linking games to the curriculum more and having the strong link provides a reason to use Maths Mission more. This teacher pointed out that in the non-examination years (1st, 2nd, 4th (transition), 5th) would benefit more than the examination years (3rd, 6th). This is due to the amount of content on the curriculum and perhaps the preference of students wanting to get through the textbook course over spending time doing alternative activities. This harks back to covering the content and ensuring that students have the ability to answer examination questions. A quote from this teacher illustrates the point that there is potential in the non-examination years more than other years within the school and how just one use of the game sparked an interest when students engaged in a discussion about Maths Mission afterwards.

> *"I can't say from just one use of the game, but it definitely sparked interest when we spoke about it afterwards. But I think continued use of it, especially in a module like if you were to use it in transition year, I think it would be brilliant there. You could use it way more than you could say with maybe exam years or even with the 5th years they might just want to focus more on the course itself. But I think with transition year, it would be brilliant to have more games like that."*

Transition year seems to be a year that teachers find the best to change approaches to teaching and has less pressure on students without any state examinations at the end of that school year.

The same teacher also noted that the resources need to be independent of an Internet connection. The resource needs to be available

> *"No, I never go, anything I have will always be downloaded already, because the Internet is there [referring to the Principal and*

> *Reception's offices], there is no Wi-Fi around the entire school you have to do a plug in kind of style, and which isn't very reliable at the best of times. So I generally try to have them before I go in."*

The teacher spoke about resources being available offline and without the need for an internet connection as well as games being used as a way of introducing a bit of fun into the classroom instead of students sitting in front of a book and *"you standing up at the top of the class, it's nice to bring in some games and stuff on the computer itself."*

8.5.9.2 Teacher 2

The next teacher discussed the possibility of using Maths Mission or other games if there were enough resources available. This relates to covering the entire curriculum so teachers can customise the activities to their classroom. The teacher referred to finding it difficult to use unless there are enough resources that are set-up similar to Maths Mission, set-up and ready to go.

> *"I'd find it hard to, unless there was resources available to use it, or automatically set-up and run like games like what you have created yes, then but I don't think making things up, as teachers ourselves, I don't think we'd have a use for it otherwise, it would depend on what resources come with it or what you could put it with, or what games you could use with it. You wouldn't be able to create that standard ourselves."*

The same teacher re-iterated that games aside from Gesture-Based games are also useful as long as there are resources made and the teacher can customise the resources to their own classroom.

> *"We often use activity games, cards things like that, or we can go on Countdown and all of those games alright yes, they can be kind of PowerPoint led and again that has already been created and we can tweak it then to the different classrooms and different topics."*

The teacher also mentioned existing presentations being adapted for each lesson and these can act as a way to present different classes the different topics.

8.5.9.3 Teacher 3

Finally, the last teacher deliberated over the initial encounter and whether it impacted on students' overall perceptions of mathematics. The teacher pointed out that the students enjoyed the game; however, it would not change their attitude if they find mathematics difficult after only one encounter. The teacher illustrated that her students do not see the relevance of mathematics to what they would do in 'real life'.

> *"Yes, well they seem to really enjoy that game, that they were playing the last day with the maths. But I don't know by only playing it once if it will change their total attitude for ever with going into 5th year and leaving cert maths, if they find maths hard and they don't think…. so if they say, why do I have to do this when I don't want to use this ever again in my life, I don't want to do anything with maths. So I do think it was a great game and I do think they enjoyed it, but I don't know if it would change their attitude towards maths for the rest of the year, if they find maths difficult and they have negative attitude towards it in the first place."*

The teacher then notes that their bad attitude towards mathematics is a result of their experience at primary level.

> *"Yes because it depends on primary school really, if they found primary school maths hard and then they come into secondary school, they already have a negative attitude, kind of stays with them all the way up, unless I don't know they have a big, I don't know maths comes to them, they understand better as they get older. I find generally if they come in in first year and depends on how they find it really hard in primary school, they come in gone off maths, even before they start secondary school, they have negative things towards maths…I play games with them doing statistics and probability."*

The same teacher noted that the practice-oriented activities are important within games to make the game fun and enjoyable for students participating in the game.

> *"I found it really good, I think they really enjoyed it, they enjoyed doing something different and the game as well. So to make it fun rather than sitting in the classroom and reaming the stuff off, doing practice after practice making it a game."*

This relates to the teacher ensuring that the students see the benefit as well as learning through games and practicing mathematics. There follows a description of student play-testing in all three classes. As all three classes reacted similarly, the description is short and presents the data as a result of these visits.

8.5.9.4 School E – Student Play-Testing

In terms of students' game play, students were engaged with the game and seemed to focus on the game. All students completed the game and were very happy to be involved with the activity. The majority of students in all three classes used pens and paper to calculate each question. A minority of students guessed answers and tried until they got the correct answer. Students participated quietly and the entire year of students whispered amongst themselves to complete the tasks. Students in this school seem to be generally quite reserved students with a studious approach to learning.

8.6 Design features of Maths Mission

Now focusing on the teaching and learning tool role of Maths Mission, this section presents the findings in relation to the design features of the game and looks at the answer to the following research question;

> *"What design features inform the creation of a Gesture-Based game in the mathematics classroom?"*

The answer to this question is presented according to each school visit. Each school implementation represents results gained that inform the continuous refinement of the design features of Maths Mission after it was initially developed in phase three of the study. Phase four represents the visits to schools and any feedback gained as a result of these visits that inform the direct improvement of Maths Mission.

The key design features were established as the working game from phase three was implemented in five schools during in phase four. This was an iterative process and the data collected with each implementation indicates the inclusion and omission of features, improvement of features and overall contribution to the design and development of Maths Mission.

Students in each school were asked a number of questions about the game regarding its improvement as a whole class evaluation at the end of each implementation.

The practical issues of implementation were accommodated before phase four. These issues included network access in schools, increasing the speed of the player and including a map to know where the player is going in the three-dimensional world. Below is a breakdown of students' led improvements after each play testing of the game.

List of features continuously improved throughout the school implementations		
Red and blue box counters	Colour of player capsule	Miniature map
Starting position	Speed and sensitivity of controls	Viewpoint of player capsule
Audio	Lighting	Include Nunchuck to move camera
Improved Multiple-Choice Options in the game regarding their size and position	Add checkpoints and instructions	Improved instruction for students to connect to the WiiMote

TABLE 20 - LIST OF FEATURES

The table above – table 20 – shows the continuous improvements made to Maths Mission through the design improvements. Each school implementation shows the consecutive series of sharpening the look and feel of Maths Mission and its functionality based on feedback gathered from each school. School A started with the feedback from students regarding the calculation of area and perimeter. The image below shows the version taken into the school in School A.

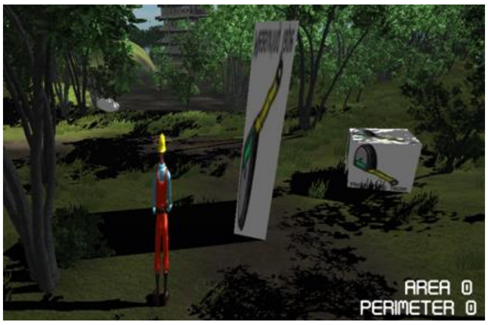

FIGURE 43 - SCHOOL A

Box counters

Box counters that count the collection of red and blue boxes in the scene and therefore the perimeter of the building were added to the game as a result of feedback. The previous design did not have counters and focused on student's memory of the perimeter to progress to future questions in Maths Mission. Students thought it could be improved with the addition of these box counters.

The image below (figure 44) shows the addition of these box counters to the game for School A. Students can now see the incrementing figure when collecting each box around the perimeter of the building. The initial counters were transparent in grey as shown with white writing and appeared on the top left corner of the scene.

FIGURE 44 - ONE OF THE INITIAL PERIMETER COUNTERS IN MATHS MISSION IN SCHOOL A

The above figure (figure 44) shows the first design of the box counter.

School B, the box counters were amended to include a red and blue colour as well as writing indicating that the perimeter incrementing was for the blue or red building.

FIGURE 45 - RED AND BLUE BUILDING PERIMETERS IN MATHS MISSION IN SCHOOL B

These box counters were block colours in blue and red as shown in figure 45. The box counters were again reviewed throughout the school implementations and resulted in a transparent blue and red box counter in order to avoid blocking an area of the scene.

The figure below (figure 46) shows the new improved version and remained in this design for the last two schools.

FIGURE 46 - TRANSPARENT BOX COUNTERS IN SCHOOL C

Multiple-choice options, audio instructions and initial starting position

The multiple-choice options used to drop in front of the player wherever they were located in the three-dimensional world. The image (figure 46) illustrates the three options in front of the camera as 5, 6 and 7 being the three options at an early stage in the game with the text message questioning the student playing the game. These were small boxes separated apart and would appear after each question in Maths Mission.

FIGURE 47 - OPTIONS IN FRONT OF CAMERA IN MATHS MISSION IN SCHOOL B

The second school – School B – saw the size of these increases to a larger size after tumbling from the sky. They were still placed in front of the player wherever they were in the scene. The following image shows School D's implementation and a change from dropping in front of the player at any point to dropping only at a collection point in the game. Therefore, every time a player collected boxes or answered questions, the player would then need to go back to the collection point to see the multiple-choice options appear. This avoided any options disappearing in awkward places, such as the side of a building where the player cannot gain access in the three-dimensional world.

FIGURE 48 - COLLECTION POINT OF MULTIPLE CHOICE OPTIONS IN SCHOOL E

After school D, the collection point remained as shown in figure 48 and there were no further adjustments to this feature. Aside from the collection point, the instructions were delivered through audio as well as text message. The audio along with the game initially had the sound of a helicopter as the player dropped into the scene to start their mission in the destroyed world. Unfortunately, the helicopter audio was too distracting and School A's feedback dictated its removal based on the fact that the helicopter was out of sight so it did not make sense to hear it in the scene.

Audio

Aside from the helicopter audio, the audio instructions themselves were completely removed after the School B's visit as the audio was not enabled in the school and students could not hear it. This was as a result of the classroom settings; therefore, students needed more instructions on screen instead of audio. Therefore, the only audio in the game from School C's visit onwards is a mix of audio from Kirby's Dreamland, a game originally available on the Nintendo GameBoy in the 1990s. This audio was mixed and slowed down to suit the pace of the game. This audio acts as background music as opposed to audio instructions and therefore, students playing Maths Mission are not missing any instructions for the game itself.

As mentioned, the helicopter audio was enabled at the start when the player was dropped into the scene from a height to make it sound as though a helicopter was transporting the player. The initial starting position then impacted upon where the player would land in the world. The image below shows the initial starting position in School A of Maths Mission. After students played the game, the students went in an incorrect direction and therefore the starting position was changed.

Initial Starting Position

FIGURE 49 - INITIAL STARTING POSITION IN MATHS MISSION IN SCHOOL A

As the image above shows (figure 49) the initial starting position of the game hid the player from the view of the building site. The player needed to navigate through the scene to find where the buildings were to be built. Students then spent more than the allocated time needed navigating through the scene. A new starting position was arranged and for School B, the starting position looked like the image below. The player did not drop from a height but appear in the scene as the image below depicts. Signposts were also added after School C's visit, to guide the player in the destroyed city. These were placed along the outskirts of the world to ensure students remain within Maths Mission.

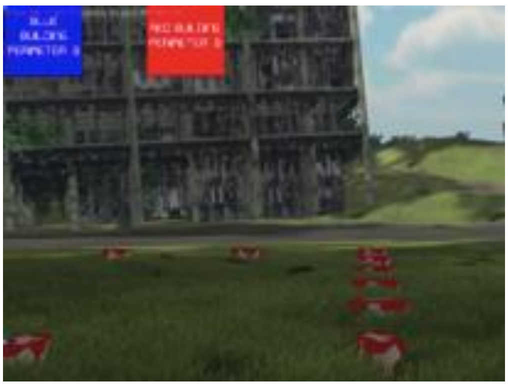

FIGURE 50 - STARTING POSITION OF MATHS MISSION IN SCHOOL B

FIGURE 51 - STARTING POSITION OF MATHS MISSION SCHOOL C

The new starting position as a result of School B’s implementation is more explicit and starts the task immediately. The new starting position avoided students losing their way in the scene. However, improvements to the starting position took place in School C’s implementation and saw the player again start from the sky as if being dropped in to the game scene.

FIGURE 52 - FINAL STARTING POSITION SCHOOL E

As shown in the picture above (figure 52) School D’s implementation shows the new starting position. The player drops from a height so the student can view the entire world. The collection point is on view as well as the boxes that they need to collect and shows an overview of the entire world. The player can see everything in the world and the signposts in the destroyed city then guide the player.

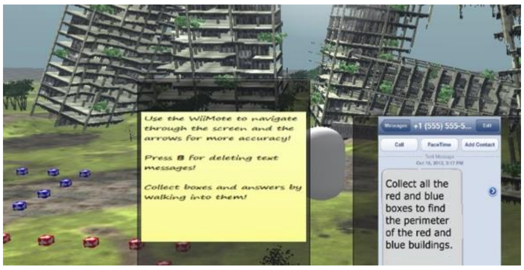

FIGURE 53 - THE ADDITIONAL LIGHTING AND DIFFERENT INSTRUCTION IN MATHS MISSION

Lighting, character, instruction and map

As shown in the above image (figure 53) the game was lightened and increased lighting made the game textures lighter across the world. The image shows the lighter textures used in comparison to the earlier schools. After School A, the white capsule was inserted to guide the player. The elimination of the avatar was a conscious decision visiting schools whereby students needed a construction worker avatar to be neither male nor female and according to the wheel of colour, white is a neutral colour and represents the colour of the WiiMote itself.

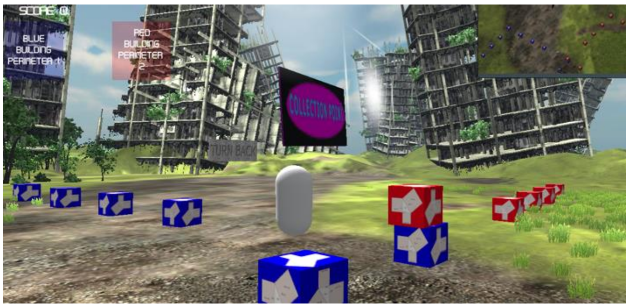

FIGURE 54 - MATHS MISSION WITH WHITE CHARACTER IN SCHOOL C

It was only after School D that the capsule changed colour, as the WiiMote used was initially white in colour. The WiiMote used in the latter schools was black and students wondered why a white capsule represented a black WiiMote. Therefore, in order to stay with the gender neutrality and choose a colour aside from blue or pink, green was chosen by students.

FIGURE 55 - MATHS MISSION WITH GREEN CHARACTER IN SCHOOL E

Aside from the capsule, other design changes took place with regard to the map used. Initially, the static map acted as a guide and after the School B, students gave feedback entertaining the idea of a dynamic map instead of a static map to guide them through the three-dimensional world. These changes were a direct result of students' feedback and perspectives while playing the game. Some of the features described are also referred to in more detail in phase three. There is some crossover as a result of refinement of Maths Mission and continual improvement. The opening and hint buttons were also eliminated due to time constraints of mathematics classes. Sample images of these are available in appendix one – Game Design Document.

The inclusion of different instructions to connect to the WiiMote made it more clear for students to understand what to do in order to establish the Bluetooth connection. The initial instructions were small and appeared on the top left of the screen as shown in the image below.

Current instructions

Previous instructions

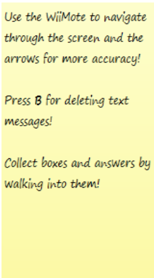

FIGURE 56 - WIIMOTE CONNECTION INSTRUCTIONS

Maths Mission was a time trial and the time was presented in the game alongside the box counters. Students questioned what score they were achieving throughout the School C's visit and the scores were added to the game as a result. Students can see the increment of the score on the top left corner of the screen.

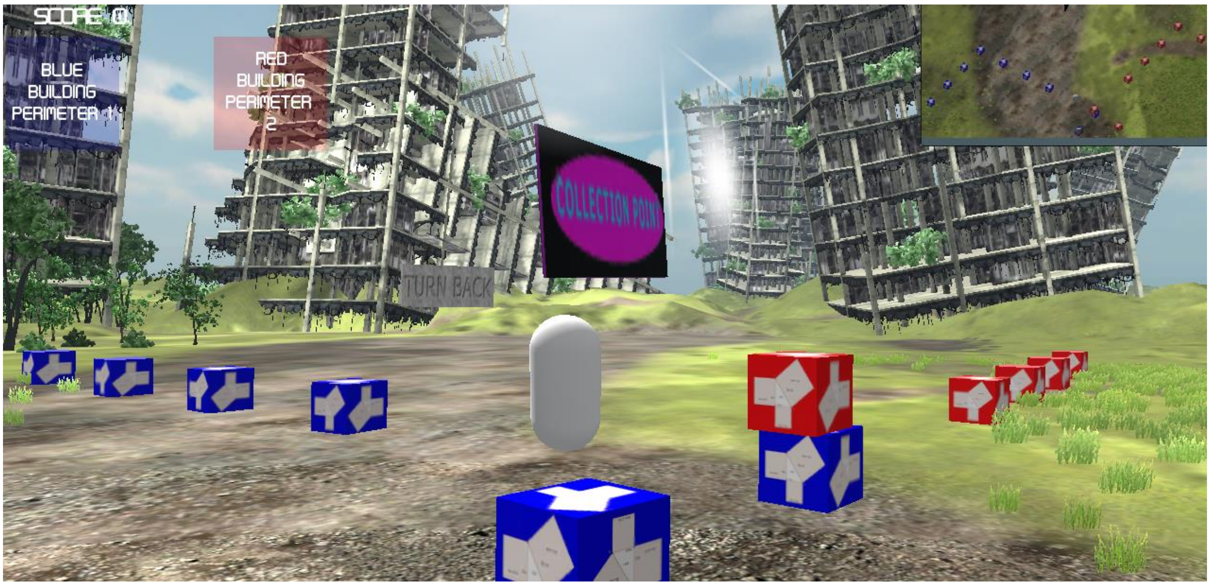

FIGURE 57 - SCHOOL E'S MATHS MISSION

Overall, the image above (figure 57) represents Maths Mission in School E. The image shows the transparent box counters that are still in red and blue although allowing the player to see through these boxes and are not as stark on the eye. The score is added in addition to the dynamic miniature map and the capsule that represents the WiiMote moves through the game itself. The collection point is in view in the scene and this is where the options for the multiple-choice questions are shown. The player also needs to go through checkpoints after each answer to ensure they are inspecting the buildings being built. This is an important feature to ensure that players visualise the buildings and make connections that their answers have impacted on the three-dimensional world.

Prior to going into School E, a few changes were made with regard to checkpoints within Maths Mission. These checkpoints ensure the player follows the development of the building after each question.

FIGURE 58 - CHECKPOINTS

The image above (figure 58) shows one of the checkpoints; there are six in total that are scattered around the outskirts of each building. The image appearing on the checkpoints was taken from the website: http://www.architectsap.com/blog/sap-abap/sap-abap-checkpoint-group/ and used with permission. Upon answering a question, the student needs to retrieve all checkpoints, thus showing the development of the building after each question. From researcher observations, the students were skipping stages in the game without seeing the development of the buildings. The checkpoints were then used as a way to ensure the player moves through the game and sees the buildings being built. The game design elements were as a result of cyclical improvements of Maths Mission. The images below show four different points in the game while collecting checkpoints, showing the progression of the buildings and the options appearing under the collection point after another question was asked. These are the result of the five school implementations regarding slight changes of the game. An online video of the game prior to the character colour change is available at:

http://www.youtube.com/watch?v=CyXphsjR5_Ahttp://www.youtube.com/watch?v=CyXphsjR5_A

FIGURE 59 - MATHS MISSION AT DIFFERENT STAGES OF THE GAME

8.7 Chapter summary

Overall, this chapter of the study highlights both the constraints and improvements that are needed for smooth and effective implementation of a game using GB technology within a mathematics classroom. The lessons learned have implications for practitioners, educators, and professionals developing resources for the Irish classroom.

Based on the context of each school, the results and lessons learned within each school are not surprising. School A was an under-privileged school and the cost of implementing a game like this was one of the main considerations. School B was similar in those respects and considered buying a console a waste unless it is multifunctional in its uses. School A and B seemed to lack a certain trust with technology in general and its benefit for learning; however, the teacher in School A during the play-testing mentioned that anything that gets students to co-operate and collaborate is worthwhile. School B's teacher was less interested in the play-testing and ignored the activity. School B's students were less engaged until moving away from their desks and reluctant to communicate at first. However, while playing Maths Mission, the students were more engaged and interested in game development.

School C's students were also hesitant and moved away to calculate the mathematics while playing Maths Mission. Students did not seem to want to participate in play-testing. School D did not participate well as more than one teacher was designated to the classroom. These teachers impeded the conversation and collaboration among students by enforcing a no talking policy. School A, B, C and D all have teachers that adopt different styles of teaching. School B differed in teaching pedagogy in terms of adopting some aspects of democratic styles of leadership, however, it was task-centred without relationship building qualities.

On the other hand, in School E, all three teachers adopted an empowered teaching pedagogy. Despite the limited mathematics-oriented subjects available to students, students liked mathematics.

The design of Maths Mission came from the improvements made by students while playing the game. These improvements are part of the design process and focus directly on changes for player functionality as well as sharpening the look and feel while playing Maths Mission within different contexts.

The following chapter discusses the results and ramifications they might have for developers of Gesture-Based games for the mathematics classroom as well as teachers and others who wish to integrate Gesture Based games in the mathematics classroom.

Chapter 9: Discussion

9 Introduction

This chapter discusses the findings from all four phases as described in previous chapters. In carrying out this research a Gesture-Based game, Maths Mission, was developed using agile software processes and it was subsequently implemented into the mathematics classroom within schools. During this implementation small iterative changes were made to the game based on teachers' feedback in response to implementation within their mathematics classroom. Phase one of the study focused on the feasibility of designing and implementation a GBT game. The main conclusions from this phase include an expressed desire from teachers that the technology be applicable, flexible and adaptable to learner needs. Phase one also confirmed that the project was worthwhile and therefore this informed a decision to continue to proceed with developing a GBT game for the mathematics classroom. In order to address the outcomes of phase one, a survey questionnaire was developed in phase two to investigate further the design features of the game. The outcomes of phase two indicated that the development of the game should focus on geometry and trigonometry and should tie in aspects of civil engineering and construction in order to build careers focused element. Phase three took the outcomes of phase one and two and targeted student motivation aspects and perspectives through the development of the Maths Mission game which was then piloted in two schools and amended in order to communicate to the WiiMote. From phase three a number of recommendations were gathered from students and teachers, these include the game remaining within a 3D world, the camera within the game should have an orthographical viewpoint to act as a miniature map, the opening scene could be amended, the interim scenes should be removed, automatic calculation should be kept, no help buttons are needed, school networks should be avoided at all costs due to time and network unknowns. Phase four involved the implementation of the game in five schools across Ireland.

This research study is the first of its kind to be explored in Ireland and thus provides lessons learned as well as practical guidance for both designers and teachers who wish to use Gesture-Based games in the mathematics classroom in Ireland. The discussion of findings is organised below according to the three research questions.

9.1 Research Question 1

Research question 1 relates to the key design elements of a Gesture-Based game and the key challenges for mathematics classroom implementation. The question is:

What are the key design elements of a Gesture-Based game and the key challenges for mathematics classroom implementation?

The key design elements emerge as an outcome of the teacher and student responses; their expressed desires application and implementation approaches within the classroom. The key challenges of implementation within the mathematics classroom primarily relate to school and pedagogical factors.

As per the ECG framework in figure 60, the key design elements emerged as an outcome of the literature review. This framework represents the theory that guides the Gesture-Based game, however, it is within this that teacher and student responses form the practical lessons learned.

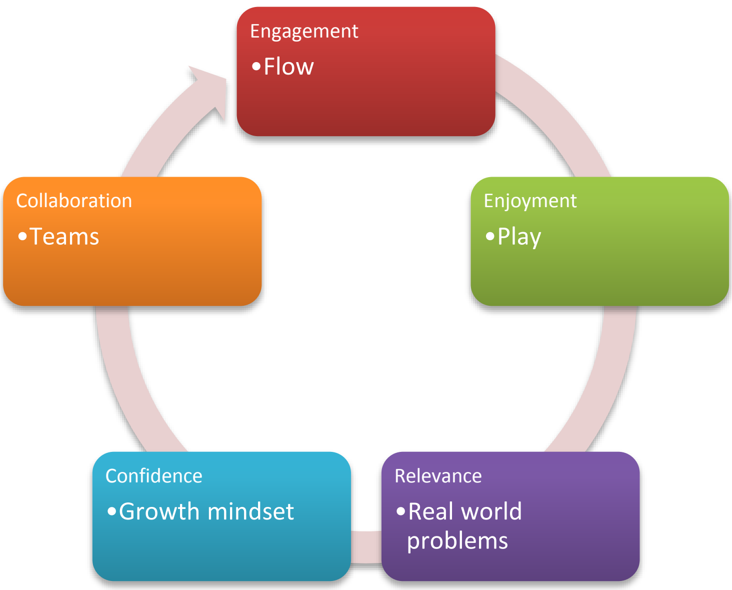

FIGURE 60 - ECG FRAMEWORK

Students in schools as presented in the findings were engaged upon their first interaction with Maths Mission and this engagement did not vary with their affinity or success in mathematics as a subject. As shown in chapter 8, students liked mathematics more in School B and E than in the other schools. School B, C and D value mathematics more than the other schools in terms of doing well in mathematics to get the job they want. The less distracted the players the more 'flow' that can be incorporated into the game. As shown in the literature, Bai *et al.* (2013) used a 3D game and found that arousal, persistence and curiosity can impact upon sustained motivation for a subject after game play. Players in that study could view their own score as they proceeded with the game. This aided 'flow' as the individual is balancing between challenge and skill (Kiili, 2005).

Relevance of the Gesture-Based game as a teaching and learning tool within the classroom is another key design element. As outlined by the Project Maths curriculum and Silseth (2011), a meaningful experience in the classroom is one where the learning resource and in this case study Maths Mission is relevant. The design goal set out in this study is therefore to focus on the relevance of the game for learning mathematics for the students. Relevance as a key design element was incorporated through connecting with the career aspirations and with real world contexts for students; the game features. As reflected by School A's teacher relevance is an important part of students connecting to real life. Likewise, literature, theory and practice have identified relevance as an important game feature for the teaching and learning of mathematics.

Building motivation for learning within the mathematics classroom through the use of career aspirations envelops areas of extrinsic motivation, it has been shown that drawing these lines between a goal from an individual and mathematics can help students' learning. Career aspiration is influenced by students' success expectations. It is the relationship between a students importance placed on a task and ability to do well on that task (Watt *et al.*, 2012).

Research-surrounding motivation indicates a relationship with students' interest. Games play a significant role in promoting curiosity (Huizinga, 1955). Interest stems from curiosity and when an individual places high value on an activity they are said to be interested and curious and so stimulating, students' further participation in mathematical activities (Middleton and Spanias, 1999). Building engagement and simultaneously piquing students' interest in mathematics through incorporating challenge and feedback was the second key design feature.

Student engagement with a task, in this case a game, is related to instant feedback. Instant feedback within the game matters considerably as flow occurs when the task is achievable although it is also challenging (Admiraal *et al.*, 2011). Therefore, students engage on a deeper level with the game. They are in a situation of 'flow' (Abuhamdeh and Csikszentmihalyi, 2012). In order to accomplish flow within the game, the following were incorporated little or no interruption for individuals playing the game in teams with clear goals, clear feedback and a sense of control. According to Admiraal *et al.* (2011), in order to incorporate flow no interval screens or distractions should be in the design of a game. As mentioned by Ke (2008), straddling between the game and learning goals can be challenging. It is for this reason that the game used text messages to communicate with the individual playing the game. These communicated the task and these tasks were enveloped within the learning goal. As shown in phase four for the design, the text messages are a capability of modern games to communicate with players. These text messages incorporated growth mindset feedback to encourage students (Dweck, 2008). A straightforward storyline was also incorporated into the design of the game (Annetta *et al.*, 2009) as it was found the original storyline was distracting. The final storyline was short and not elaborated and this added to individuals' enjoyment of the games as observed by the researcher.

Positive claims have been made regarding Gesture-Based games and their potential using the Kinect with literacy games (Homer *et al.*, 2014). Research has also been conducted regarding GBL and its benefits such as flow and deep absorption to the teaching and learning of other subjects (Admiraal *et* *al.*, 2011). Therefore, the ultimate and overriding factor is the accommodation of ‘flow’ within the design features of a GBT game for the Mathematics classroom. As is with the ECG framework that guided the development of Maths Mission, this accommodation is ubiquituous in nature and shows a connectiveness and embedded within all the design features.

The key design elements incorporate the literature, theory, and practice and offer a framework for future researchers to incorporate into their design. The second part of the question – the key challenges – are addressed in the next section.

9.1.1 Key Challenges within the Mathematics classroom

A significant feature is that the research findings support the argument that an existence of an ICT strategic plan and guiding vision within the school is a strong indicator of successful integration of technology based learning within a classroom (Niemi *et al.*, 2012). Related to this is the existence of a supporting and up-to-date ICT infrastructure (Pelgrum, 2001).

As many schools are facing increasing technology demands and as society is demanding that more individuals be competent in the use and application of technology, a guiding plan and vision for each school is a management issue at school level (Adu and Olatundun, 2013). The schools in this study reported infrastructural issues related to ICT and timetabling in relation to the implementation of the Gesture Based game into the mathematics classroom. The constraining effects of the more traditional timetabling structures that exist in school and a need for longer classes and designated classrooms with the appropriate ICT infrastructure were the main constraining issues. The use and integration of technology in teaching and learning puts additional demands on the teacher and whole school (Stack, 2008). Therefore, a significant question for teachers who wish to implement GBT games or similar teaching technologies within their classroom is whether it is worth the effort and disruption to ‘normal’ and teaching and learning approaches and habits. Although by their nature, teaching technologies are disruptive, the challenge here is to minimise disruption at classroom level and work within the constraints of existing structures and systems.

The researcher found that some school classrooms within the study were better equipped and ready for the use of the Gesture Based game than others. One classroom could be described a being ready in terms of technology advancement and support while the majority of others were under resourced and equipped. Most teachers in this study still need to use their own laptops and set up the technology without any support or dependable infrastructure, be it Internet availability or hardware. Budget allocations in relation to technology are limited in the schools (Strudler, 2001). Similarly, budgets are also limited, and so work to prevent some schools adopting such technologies.

Availability of hardware and its maintenance was a concern for most schools in this study. Pelgrum (2001) states that teachers complain about the lack of availability of technology and this becomes an obstacle to its implementation. Lack of hardware and maintenance is the most significant barrier for teachers attempting to integrate ICT in their classrooms in Turkey (Goktas, Gedik and Baydas, 2013) and this study corroborates with this finding. The cost of hardware and software within schools is not necessarily included in a financial management and budget plan at school level. This corroborates with the literature from the ICT report for schools, the focus on finance for the maintenance and provision of hardware is one of the key factors in successfully integrating technology in schools (Stack, 2008).

Another challenge within the mathematics classroom was teacher knowledge of technology and teacher competency and ability to integrate the technology into their teaching. School B’s teacher wanted one-to-one technology for students; this is both financially and resource draining resulting in an inefficient way to implement technologies for most schools.

Issues regarding teacher’s technology skills with respect to their experience, knowledge and familiar with technology is another challenge. This is not an issue confined to an older generation; this is evidenced in phase one of the study only two of the forty-eight pre-service teachers commented on novel forms of using GBT. Reasons for this, teachers’ mentioned, were due to the confines of the curriculum and the constructions of the timetable. However, in transition year there is little emphasis on state examinations at schoo and teachers acknowledge that it allowed for more manoeuvrability and opportunity for teachers to support student led learning and responsibility with the use of technology. The interviews carried out in phase four indicate that teachers' mainly engage with ICT for lesson planning. A whole school poicy that supports and advocates innovative ICT integration will help support an ecosystem that facilitates technology integration within the classroom. The environment dictates the possibilities on whether teachers can use these technologies effectively or even at all (OECD, 2001). Phase 4 mirrored this and the majority of teachers mentioned traditional use of ICT. A study conducted in 2014 in Ireland states that less traditional methods of using ICT do not currently get any traction with teachers (Devitt, Lyons and McCoy, 2014).

Building collaborative practices and engagement of the students was an issue for some teachers and especially those who felt uncomfortable with the use of ICT. It has been shown in McDonagh and McGarr (2015) that teachers have a positive perspective of technology although lack strategic vision on how to integrate it for the purpose of enhancing their teaching practices. Support for teachers is needed regarding its integration and these supports should focus on the TPACK model as a framework for developing teacher practice. As mentioned in the literature review, TPACK incorporates all three components (technology, pedagogy and content) and these form the basis for effective teaching while using technology (Mishra and Koehler, 2006). Integrating technology in a way that aligns coherently with both contant and pedagogy is a growing concern in classroom practice and a significant challenge for teachers as the demand for the use of technology in increasing (Dogan, 2012).

Subtle changes were made in design of the final Maths Mission game throughout each stage in phase four and these changes related to students' engagement, ability to manipulate game, classroom environment, connection with prior knowledge, and ICT infrastructure and teacher competencies. In summary implementation challenges relate to teacher competences, familiarity with the technology, ICT infrastructure including classroom environment, teaching approach and relevance of the game to the curriculum.

9.2 Research Question 2

Findings in terms of Maths Mission and its potential are shown in terms of prerequisites and functional requirements that need to be taken into consideration prior to using it. A reminder of the question is:

What is the potential for a Gesture-Based game to be used as a tool in the mathematics classroom?

Yes, Maths Mission has potential as a tool for the mathematics classroom. However, this potential is dependent on certain prerequisites being in place. As stated in the previous section, these prerequisites are classroom environment, ICT infrastructure, timetabling factors, student readiness and teacher competencies. The findings indicate that the full potential of the GBT game was not reached in this study due to the some or all of these classroom environment constraints.

A particular constraint from this study is teaching style and approach and therefore by inference the teacher-student relationship. This relationship influences directly on how students engage with each other and the quality of their collaborations within the classroom. Banks and Smyth (2015) state that the quality of student-teacher interaction impacts on a student's well-being and therefore levels of interaction. Using technology to increase collaboration among students is a well established teaching strategy in the literature (Oblinger and Oblinger, 2005). And, this study indicates that GBT games have the potential to bridge the gap between individual and collaborative student engagement. Traditionally technology would focus on individualised learning. Where students usually have access to a computer in a designated computer room, on a one-to-one basis (Oblinger and Oblinger, 2005). This potential for supporting collaboration is corroborated by (Annetta *et al.*, 2009) when discussing games and noting their influences on motivational and cognitive engagement. They also note their authentic, inquiry-based and collaborative features. Collaborative mathematical discussion is a central feature of the Project Maths classroom (Brosnan (2008).

9.3 Research Question 3

The development of Maths Mission was an arduous process and certain features informed its creation. The research question 3 is now discussed and a reminder for the reader is below:

What design features inform the creation of a Gesture-Based game in the mathematics classroom?

While playing the game the individuals were put into groups as there are multiple advantages to collaboration within the classroom including the cooperation and discussion among students. Collaboration through mathematical discussion is said to aid a positive learning experience (Keong *et al.*, 2005). It was found that in all schools in this study that students playing Maths Mission collaborated with each other to solve the problems in the game. When designing the game certain feature considerations were made when developing the game and the following section discusses these.

9.3.1 Game Engine

The decisions surrounding the game engine related to what exact way the game is going to be developed. The game engine dictates if the game will be two-dimensional or three-dimensional. The game engine also dictates the programming language and whether or not the game will function using drag and drop two-dimensional buttons or a three-dimensional functionality. The entire game engine functionality determines what features the game will have. Unity3D is the game engine used in this doctoral research, however, the Unreal game engine is also another three-dimensional game engine that is popular in the development of commercial games now. Unity3D engine can develop three-dimensional games and key design feature of Maths Mission is its three-dimensionality. As discussed by Bai *et al.* (2013), three-dimensional games for mathematics can bring more benefits than two-dimensional games. The game included an environment that connected to real world mathematics and context and content was aligned coherently with the curriculum (CurriculumOnline, 2015). This was achieved through the use of Unity3D.

Although Unity3D was challenging to use and most game developers would initially start with a two-dimensional game the scope of this development could include this feature – although time constraints were a factor in its development.

9.3.2 Game features

Developments of the game's features changed and were amended based on the technological requirements of the game. The development of the initial SIP flight in this project was done using XNA Game Studio 4.0 while connecting the WiiMote to a laptop. The change in the project once the game engine was included involved the amendment of the game to use another piece of code that allowed for the capability of using the PlayStation and eventually a MacBook Air.

Key features for the creation of Maths Mission are dictated to by the continuous refinement throughout this case study research. The creation of Maths Mission constituted the evolution the game itself based on student and teacher feedback. A number of key elements include:

- Elimination of instructional audio
- Addition of a dynamic map
- Addition of checkpoints
- Transparent buttons
- Starting position
- Speed and sensitivity of the player
- Lighting and instruction.
- Embedded feedback

These key elements include the vital feedback from students and teachers that need to be in line with the resource development for it to be a success in the Irish mathematics classroom. The guidelines from Project Maths as per the literature review illustrate that the game needs to be in line with the syllabus (NCCA, 2011b). Teachers agree that resources need to be in line with the curriculum and explicit links shown in the game. Feedback from students and teachers continuously in the design process represent the evolutionary nature of the design of Maths Mission. Teachers also noted that experiential learning is important and the demands of the game need not be too complex. However, Maths Mission is context rich and emphasises fun and engagement.

The instructions within the game aimed to ensure that there was a success only focus and so supports a growth mindset approach that encourages engagement (Dweck, 2008). This means the students can continue to play the game even though they may have incorrectly answered the previous question. The negation of the audio feature and so the requirement for audio speakers allowed for implementation within most schools. The miniature map allowed for better-improved usability as well as the consideration of speed and sensitivity of the controls. All of these design features contribute to the design and development of the game using GBT within the context of the Irish mathematics classroom.

9.4 Chapter Summary

The key challenges identified for the implementation of the GBT game for the mathematics classroom relate to individual classroom teaching and learning practices and whole school ICT policy. Challenges faced include a time constraints, the presence of a strategic plan and adequate support for implementation. The potential of the game was recognised by the teachers in the study and factors that may impacted on its potential include environmental, student, teacher and game design factors. The design factors that informed the development of Maths Mission include factors relating to the tools used for creation and time constraints.

Chapter 10: Summary and Conclusion

10 Introduction

This chapter summarises the thesis, discusses the key findings, identifies the limitations, draws conclusions and finally, presents recommendations for future design and implementation of GBT games within the mathematics classroom. This chapter also identifies future research possibilities and to complete this chapter, my own personal reflections as a researcher on the process and outcomes are presented. Before outlining the summary of the thesis, a reminder of the three main research questions is:

1. What are the key design elements of a Gesture-Based game and the key challenges for mathematics classroom implementation?
2. What is the potential for a Gesture-Based game to be used as a tool in the mathematics classroom?
3. What design features inform the creation of a Gesture-Based game in the mathematics classroom?

10.1 Summary

In an effort to answer the main research questions, the research had to first demonstrate that a GBT could be developed. In doing so, SIP flight formed the prototype for the study and was used to gain an insight into teachers' perspectives of GBT in the Irish mathematics classroom. Aside from this, the preliminary studies using SIP flight showed Gesture-Based games' initial potential on a smaller scale game. The preliminary studies helped to highlight the positive results regarding its potential and showed the opportunities available when developing the 'larger' game.

Questions regarding operational skills, potential for GBT and teachers' personal attitudes were asked. Preliminary research questions were formed based on the digital skills framework. These answered the question of progression; whether such a low-cost GBT could be developed. Following on from this, the theoretical framework was chosen to guide the survey questionnaire development. The survey was then distributed to over three hundred schools across Ireland and a majority of these students confirmed that engineering was a career choices of students that could be coherently linked to mathematics education and learning within the classroom. An exploration of literature led to guidelines for the design element of the development of GBL and the key principles of mathematics education literature. In addition, motivational literature that underpinned the theoretical frameworks of the study both guided survey questionnaire development as well as the game design.

The development of Maths Mission ensued with the discovery of the particular game engine required for development. Design then focused on relevance and upon completion the game was trialled in two schools as part of initial testing. Upon completion of the development of the game, five schools were selected and Maths Mission was fully field-tested. The game was iteratively changed upon each school implementation. Design elements were added or removed based on its practicality and views from both teachers and students in the individual schools. The previous chapter highlighted the findings, now the conclusions for each research question is presented and its significance in terms of answering these questions for future developments of a GBT game for the mathematics classroom is explored.

10.2 Conclusions from Research Question 1

- What are the key design elements of a Gesture-Based game and the key challenges for mathematics classroom implementation?

Relevance builds motivation and piques students' interest; therefore, making the game relevant is an important design element. A straightforward storyline without complex steps in completing the game is a second design element. Finally another is the accommodation of flow within the game.

The study found that, the key challenges stifle the implementation of the GBT game successfully within the mathematics classroom. Traditional timetables within schools; the short length of classes, the scheduling of classes and finance for the maintenance of hardware are specific school level challenges. Teacher related challenges are competency and familiarity with technology and an emphasis on a pedagogical approach that includes an ability to integrate these technologies creatively

Relevant Game

Make a game that is relevant to the real world. This relevance is one of the main objectives of Project Maths curriculum. The real world narrative that is given in Maths Mission ensures students associate their answers with impacting in the world and within the game itself. The virtual checkpoints in the game ensure that the player walks around the buildings being built. The player has access to these checkpoints after each question and they are a way of showing the progress of the game. Students are offered a chance to step into the shoes of an engineer and investigate problems that are the equivalent in real life within this virtual destroyed city. Therefore, it was important to look at existing problems in textbooks as well as encapsulating the curriculum to ensure that students could discover a new alternative GBL approach to the teaching and learning of mathematics.

Engagement and Enjoyment (fun)

Make the game engaging and fun by incorporating different game design elements. Targeting certain attributes of students' engagement can be done through incorporating certain known design elements. For instance, enjoyment is targeted through flow and the promotion of flow occurs by safeguarding that the game has a clear goal, immediate feedback, is challenging and does not have distractions. The game is designed with a clear purpose in mind and the students are told the goal of the game which is to build a destroyed city. The feedback is part and parcel of adopting the growth mindset and provides positive clear immediate communication to the student after answering each question. The scaffold resource ensures the game starts at an easy level and increases in difficulty throughout. The game also has one clear goal and there are no advertisements or distractions such as monsters or zombies that pop out in front of the player within the game itself. Students become interested in the game through curiosity; enjoyment and engagement are promoted through the growth mindset and the promotion of flow.

The game follows the characteristics of play and allows for the freedom to fail in the activity without negative consequences. This provides a positive and supportive learning environment for students especially students that suffer from anxiety towards mathematics. The game is seen as an engaging element without a test at the end of the game or interfering aspects of the game asking questions throughout. The game has rules that are applied and this is where play differentiates from games even though, according to Hwang and Wu (2012), play is a form of game. The interaction with the game itself through the WiiMote is used as a way to play with the game prior to accumulating scores within the game and focuses on the process over the end result.

Collaborative Learning

Make the game collaborative, as a way to promote mathematical discussion. The game promotes active and collaborative learning through the use of the WiiMote and allocation of team play within the mathematics classroom. As mentioned in the rationale for focusing on collaboration, collaboration through mathematical discussion is said to promote positive learning experiences in the classroom (Keong *et al.*, 2005). Collaboration is student-centred and thus promotes motivational factors by putting the responsibility of learning on the student. The student is solely responsible with his or her team to make decisions regarding the game and thus promotes active learning. For an active, positive and collaborative environment to occur in the mathematics classroom, teachers needs to be comfortable with their own technical knowledge and trust that students can learn in a technologically enabled lesson. It is important to note that collaboration took place even in the least collaborative classroom with a game and therefore prompts mathematical discussion among students. Ideally, students would be encouraged to collaborate by the teacher.

Teachers' Technical Knowledge

Exposure to the benefits of using technologies can impact on how teachers implement these in their classroom. From this research, teachers' own technical knowledge can be limited and this impacts on trusting technologies.

Teachers' Teaching Styles

Students' benefit from a **supportive and encouraging environment** and this does not mean standing back and watching students use technologies. This means actively encouraging students to use particular technologies effectively. Students thrived in this study when teachers actively encouraged and did not act as a barrier to mathematical discussion.

Adopting technologies can be challenging and another recommendation would also be to use the game as an after school activity to provide extra practice to students. This could be a way to boost contributing percentages towards their overall school year grade in the non-state examination years.

Strategic Plan

A strategic plan is beneficial in relation to ICT development and use should be in place in the school. At the school level, there needs to be a strategy in place for the adoption of learning technologies into the teaching and learning. This strategy should focus on both the infrastructural requirements and recommended pedagogical approaches. Every classroom would benefit from having a clear outline of how technology can be implemented and also that they are purposefully designed for particular subjects in a way that aids and supports integration. These can include posters and other supports as well as the fact that the technology is available and ready to use without any set up time.

Technology Champions

Create a team of technology champions in the school. While technologies generally need support, it can be beneficial to have a team of teachers responsible for this instead of a single designated teacher. This allows for teachers to become owners and drivers of these technologies in their schools through collaborative engagement in teams.

Artificial Intelligence in the game

It is recommended for future researchers to ensure there is some level of **artificial intelligence in the game.** An Intelligent Tutoring System (ITS) would be beneficial to students and collect data for teachers. This was a limitation of the study due to the graphics issues within the three-dimensional world. A suggested way to develop this further could the inclusion of a feature that would allow graphics read in an eXtended Mark-Up Language (XML) to file the different options and choices for the players. The text messages themselves are also full standalone graphics that could be swapped in and out with an XML driving a group of inputs based on the players' responses.

Artificial Intelligence (AI) is not a basic part or central to the idea of Maths Mission. Maths Mission set out to answer two main research questions, the potential for Gesture-Based Technology (GBT) and the design of GBT for the mathematics classroom while targeting students' engagement while also understanding teachers and students' perspectives. Therefore, Maths Mission was not solely responsible for integrating elements of AI throughout the game itself. The answers are hardcoded within the game due to the size and time for development of Maths Mission. In terms of engagement, students may remember the same questions appearing in the game and therefore this is a limitation. The questions and answers do not change so after a few interactions with the game it would be difficult to see benefits in terms of engagement, as the tasks would be repetitive.

10.3 Conclusions from Research Question 2

- What is the potential for a Gesture-Based game to be used as a tool in the mathematics classroom?

The second question refers to the capacity for Maths Mission and other Gesture-Based mathematical games to be adopted into the mathematics classroom. There was potential in schools where teachers were open to integration of Maths Mission in their classrooms. Students being free to engage collaboratively with each other evidenced this potential as well as the culture of the school supported innovative technologies throughout whilst being flexible and ready to accommodate this novel technology. As shown in research question 1, the key challenges need to be addressed prior to posing this question; there is potential and it is dependent upon the challenges addressed in the previous research question – challenges such as an ICT plan, class length and schedule, finance, teacher competency and familiarity with technology, pedagogical approach for integration of technology and ability to integrate these technologies creatively. The capacity for Maths Mission was not reached due to the shortness of class periods; however, this factor was reduced in schools that had a subject specific classroom.

The potential is also premised on the existence of teacher approaches including a constructivist principles and active learning. TPACK competencies are central to this research as it includes technological pedagogical content knowledge. Moreover, teacher TPACK competencies focus on the integration of technology and that includes Maths Mission and GBT. It can be concluded that TPACK needs to be used as a framework for teachers when looking at the different areas in the classroom. TPACK is such that it includes technological pedagogical content knowledge. Teachers are challenged to think of technology, pedagogy and content together in order to support and enhance the teaching and learning of mathematics with technology.

10.4 Conclusions from Research Question 3

- What design features inform the creation of a Gesture-Based game in the mathematics classroom?

The design features that inform the creation of a Gesture-Based game include the technological details that were incorporated throughout each school implementation. The design features are also drawn from research question 1, these include the focus on relevance of the game, engagement and enjoyment, collaborative learning, teachers' technical knowledge, teachers' teaching styles, strategic plan, technology champions in schools and artificial intelligence within the game. Overall it can also be concluded that the technical details for the creation within the game itself can be listed as:

- Elimination of instructional audio
- Addition of a dynamic map
- Addition of checkpoints
- Transparent buttons
- Starting position

- Speed and sensitivity of the player
- Lighting and instruction
- Embedded feedback.

As discussed in the previous chapters, each feature within the game brought with it an enhanced user experience as the game focused more on usability. Conclusively, this study informs the design of computer games using GBT. Even though, Maths Mission is more simplistic than commercial games, it was effectively adapted to the mathematics classroom and engaged students actively in mathematical problem solving in a novel way. The study presents a new dimension to teaching mathematics and overall teachers agreed that this can bring a new quality to the teaching of real world problem solving activities within the mathematics classroom. The impact on students was an increased curiosity and interest. The conditions for successfully integrating Maths Mission need to be highlighted. As shown above, collaboration can only take place in a positive and supportive environment; students can therefore only engage with Maths Mission and enjoy their experience of it in this environment.

10.5 Contribution

This research study highlights the need for constructivist resources for the mathematics classroom. It also draws attention to GBT as a novel and innovative technology that brings its own benefits and challenges to classroom implementation. As well as GBT, GBL holds particular characteristics that when implementated within the game can create a game that is goal-specific, adopt traits of flow and collaborative practices among students. Previous research has been conducted in terms of GBT and mathematics by way of a 2D game named scoop for primary school students (Isbister *et al.*, 2012) and other research has been carried out in relation to literacy and numeracy again targeted at primary school students (Homer *et al.*, 2014), not as much research has been conducted in GB games and mathematics (Ke, 2008). As shown by Hwang *et al.* (2012), the number of journals focusing on GBL and mathematics is increasing as its potential as an area is explored by research. Johnson *et al.* (2013) also shows some of the capacity for embodied learning within mathematics by the use of the Kinect and Bourgonjon (2015) stated students' perspectives towards GBL is dependent on varying factors based on teachers classroom implementation of video games. These international research studies sheds light on the many areas that can be explored within different contexts. This study focused solely on the Irish context and as a case study provided an in-depth perspective of classroom implementation across five schools in phase five. While the main research has been conducted throughout phases, the main contribution has been the development of Maths Mission where it is now being used in schools by the teachers that were involved in this study. The researcher provided teachers copies of Maths Mission that could be used on computers without the use of GBT, this was to facilitate the various classroom environments. The main contributions of this study are listed below.

- This research has drawn attention to the disconnect within the Project Maths curriculum emphasis and design and the reality within classrooms. The challenge lies with creating pedagogical innovations that are customised to the Project Maths classroom. As is evident from the findings, these can still be seen as entertaining and something for the non-examination classroom.
- The design and development of a Gesture-Based game for the mathematics classroom customised to the Project Maths curriculum.
- Not only has this research addressed developing a customised resource for the mathematics classrooms, it has also shown the different teaching styles currently in a number of classrooms. In addition to this it has brought a focus into the ever-changing technology demands put on teachers by society.
- Teachers currently are not equipped with a fully functional reliable ICT environment and as mentioned in the literature review, these environments are complex in nature and the main change agents are teachers. The influence of teachers within the classroom is echoed by research conducted by Bourgonjon (2015). Teachers have more challenges when setting up their environment and this research has shown the diverse range of mathematics classrooms across Ireland.

- This research also corroborates with Niemi *et al.* (2012) regarding an ICT strategic plan for the entire school. These can influence the adoption of technology in the classroom. School-wide practices can somewhat influence adoption and should therefore be part of the policy for the school to encourage teachers to adopt novel resources into their classroom.
- While games can be used within schools and aspects of teaching can be gamified, it is important to consider when developing a GBL solution that it is actually relevant for the student. In order to align students with their own goals and future intentions, students can be engaged by providing resources that encourage constructivist classroom practices.
- The researcher identified key designs from the literature review for game design that can be useful in developing resources for the mathematics classroom. These include, engagement, enjoyment, relevance, confidence and collaboration. Figure 61 below shows the game design for this study. Engagement was encouraged by the use of flow theory, enjoyment used play, relevance used real world problems and career interests, confidence used growth mindset and collaboration used teams within the schools.

FIGURE 61 - GAME DESIGN FOR THIS STUDY

10.6 Limitations

The technology was the central focus of this study as without the technology no research into GBT and GBL would have taken place, therefore, the limitations of this study lies within the realms of the technology. These are discussed in chapter 7 in more detail, however, these include player login system, intelligent tutoring system and artificial intelligence. There was also no path-finding system for students to navigate through the game.

Limitations regarding case study include rigor and generalisability; this case study overcomes the question of rigor by using systematic approaches to collecting data, case study can be generalisable in terms of theoretical propositions (Yin, 2014). Limitations regarding case study are described in more detail in chapter 4 – research methodology.

10.7 Future Research

It is important to focus on the improvement of mathematics education in Ireland. The drive for students to critically engage with problems and discuss methods of solving these can be challenging and it is imperative that Irish classrooms promote this activity by whatever means possible, including using GBT games. The researcher also strongly agrees with the needs for a whole school approach to technology integration and the development of a strategic plan (at least 5 years) for the implementation and use of technology in a school. Future research can focus on the many applications of Gesture-Based games within the broader context of the curriculum and education generally.

10.8 Final Comment

This research has brought attention to the area of GBT in the mathematics classroom in a study conducted for the first time in Ireland. The idea of this research initially came from the researchers' own experience as a software engineer working in the technology sector. She was also influenced to undertake this research by the growing impact mathematics has on Irish society and the vital part it plays across all areas of life. This research has shown the many complexities involved when supporting an ICT mediated classroom and these complexities are wide-ranging - incorporating whole school management - policy and practices, the classroom environment, the teacher, the student and a game played using GBT. This study has highlighted the capacity for such a technology to impact on students' engagement with mathematics. Although challenges lie ahead in terms of adopting technology in many diverse classroom contexts, there is a need for schools to go beyond the immediate technology related problems and facilitate improved, positive, engaging and enjoyable learning experiences for students through allowing exploration of the potential of the technology as a valuable teaching and learning tool within the classroom. This research again proves that it is important to explore possibilities of all forms of technology.

"Progress is impossible without change, and those who cannot change their minds cannot change anything."– George Bernard Shaw

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11 Appendix 1: Game Design Document (GDD) – Requirements Specification and Design Specification

The game design document is organised in terms of layout, navigation, interactions and system feedback, colour and typography, sample content and positioning of elements. Prior to discussing the Game Design Document (GDD) - requirements specification and design specification, an outline of how Unity3D operates is described below. This allows the reader to understand the rest of the GDD document.

11.1 Unity3D

Unity3D operates using object-oriented programming and the scripting utilises both JavaScript and C# in this project, however, boo is also allowed for use within the scripting elements. The core concepts of Unity are the game object, components, assets, graphics and scripting within the game. The following are brief descriptions of each.

GameObject – anything that is in the player's scene but has a transform function including position, rotation and scale

Components – this includes adding components such as mesh colliders, audio and physics (for example using a rigidbody gives the GameObject mass and applies the physics engine to do this as well as adding gravity to the component) to the GameObject, adds functionality to a GameObject. Examples of GameObjects Sphere and Boxes will have mesh filter (shape), sphere collider (interactions with other objects), mesh renderer (looks). The user can add a rigidbody allowing the sphere to fall.

Assets – (assets anything that goes into the assets folder that are used to make up the game i.e. graphics. Assets are composed of the graphics, lights, cameras, terrain and scripts for implementation within the game.

Graphics – Anisotrophic level (filtering), wrap mode (how it is displayed), texture type (changeable to other functions, sizes).

Lights – Three lights were used in this project; spotlight, point light and directional light. Each have different uses, the spotlight is for effect showing a light on a specific object. The point light is to cast light over a certain distance. The directional light casts light in a direction and the intensity can be controlled by the angle it is configured.

Cameras – There can be multiple cameras in the scene to follow the player. Two types of cameras were used in this project. The first camera was attached to the player and allowed for a first person control to be enabled. This camera also had the audio listener attached to this gameobject. The audio listener works like ears for the player. The second camera was above the game and acted like an overview. This allowed for a miniature live map to be displayed. This was only enabled through emergent design by visiting schools. Prior to that it was a static map that was an image of the layout of the game.

Terrain – This is the ground that the player can walk on. Usually elements of the physics engine need to be enabled or the developer needs to write code to allow the player to interact with it.

http://answers.unity3d.com/questions/47613/difference-between-collider-and-collision.html

Scripting – Scripts are added as components in the inspector window of Unity3D as a component. Once a script is added, colliders, rigidbodies and other elements can be added. For now, the player behaviour script is added to figure 62 below. Then sample scripts in both JavaScript and C# are shown.

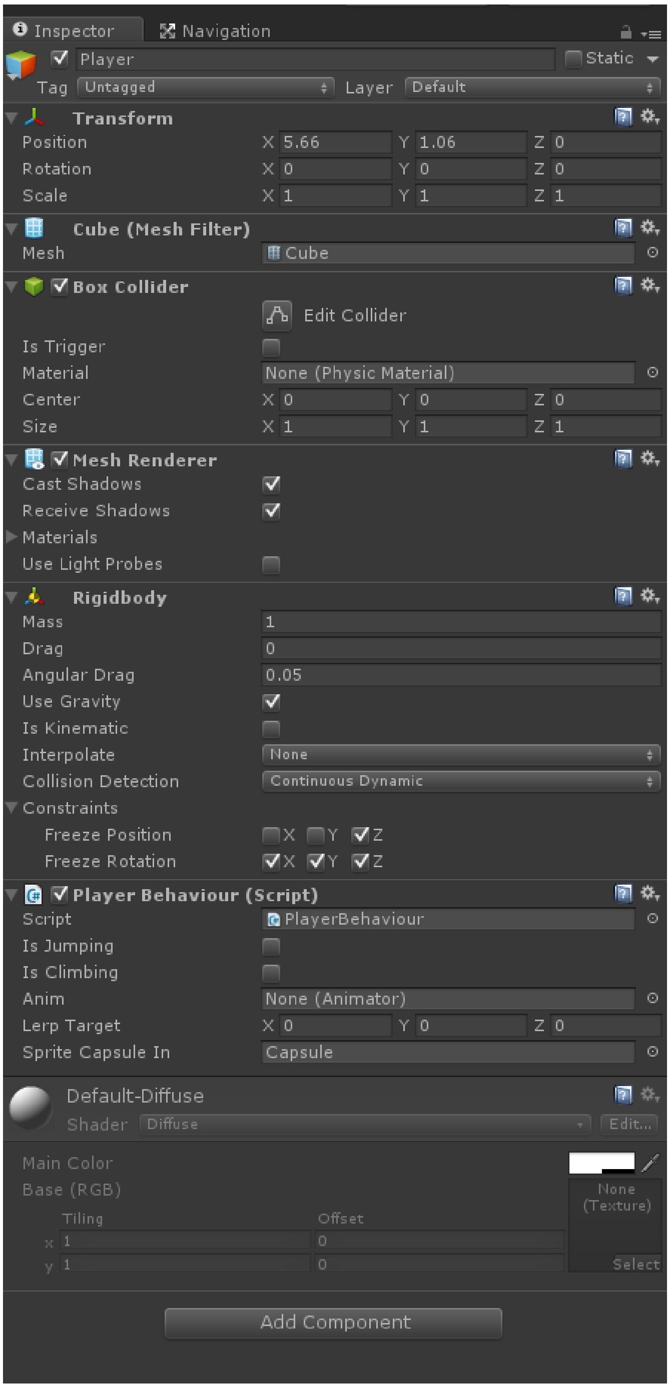

FIGURE 62 - UNITY3D INSPECTOR WINDOW

JavaScript - this script contains an if statement that collides with the floor and the text “Hit the floor” appears in the console window, otherwise, the player has hit the wall and the text “Hit the wall” appears on the console window.

```
Function OnCollisionEnter (collision: Collision){
    If(collision.gameObject.name == “Floor”){
        Debug.Log(“Hit the floor”);
    }else if (collision.gameObject.name == “Wall”){
        Debug.Log(“Hit the wall”);
    }
```

This C# script is also for collision and upon colliding with MeasuringCube10 a method called moveControllerData() is called and the collision by the player to MeasuringCube10 destroys the object MeasuringCube10.

```
void OnCollisionEnter(Collision col)
   //OnCollisionEnter collisions is equal to MeasuringCube what is entered in the hierarchy
{
   if(col.gameObject.name == "MeasuringCube10")
   {
      //      audioData ();
      moveControllerData();
      Destroy(col.gameObject);
      //      SetRumble (3,13);
   }
```

This C# script creates a new object of the MoveControllerData and calls it move within this particular script. This object then inherits the properties and methods used within MoveControllerData.

```
Void moveControllerData(){
    MoveController move = new MoveControllerData();
}
```

11.2 Software used throughout the PhD

In order to understand the GDD, the following table – table 21 – of all the software used throughout the PhD project. These include a range of diverse software available to the researcher for the production of Maths Mission.

Graphics, audio and game development are the three main areas of game development. The table below shows each area in terms of the software used, a description of the software used and a website where it can be downloaded. These were all accessed at the time of development and some of the software may now be retired.

	Software name	Description	Website
Graphics	GIMP	Graphical manipulation software - it is open source and being developed by software engineers worldwide with more and more features.	http://www.gimp.org/
	Adobe Photoshop	Another software for graphics - it is free or paid for software (both options available on their website) and superior to GIMP in that it has more features in the software and therefore can do more things.	http://www.adobe.com/ie/products/photoshop.html
	Adobe Flash	Flash based games were popular briefly until Apple and Google won the war. The software has now been replaced with animation software.	http://www.adobe.com/ie/products/animate.html
	Paint.NET	Graphical manipulation software similar to GIMP and also free.	http://www.dotpdn.com/downloads/pdn.html
Audio	Audacity and LIMP extension	Free audio manipulation software, it is open source and free editing of audio recordings are available.	http://audacity.sourceforge.net/
	YouConvertIt	Free conversion software - conversion to MP3 format necessary for Unity3D.	http://youconvertit.com/ConvertFiles.aspx

Game Development	**Unity3D**	**Multiplatform game engine used to develop 2D and 3D video games for PC, mobile devices, consoles and websites.**	https://unity3d.com/
	Monodevelop	**This is an extension of Unity3D and used as the Software Integrated Development Environment (IDE) in order to compile C#, JavaScript and Boo code into the game.**	http://www.monodevelop.com/
	PlayStation Move Software Development Kit (SDK) - Move.Me	**The software development kit in order to connect the PlayStation Move to the Windows machine and PlayStation console. This is available upon request from Sony.**	https://www.playstation.com/en-us/develop/ and the user guide is available http://ie.playstation.com/media/IO0_qmi1/moveme-userguide_0223.pdf
	UniWii	**UniWii was a dynamic link library file that worked as an extension to Unity3D so communication to the WiiMote was possible.**	http://wiki.unity3d.com/index.php?title=UniWii and downloadable at ByDesignGames http://ww.bydesigngames.com/
	XNA Game Studio 4.0	**Originally developed by Microsoft as a game engine. This was then**	http://www.microsoft.com/en-

		retired and is now maintained by Microsoft. It can still be downloaded from their website, however, no new features to the game development have been added. This was also only publishable to Windows devices such as Xbox, Windows Phone and Windows Operating Systems.	ie/download/details.aspx?id=23714
	Microsoft Visual Studio Express C#	**An IDE free from Microsoft.**	https://www.visualstudio.com/en-us/products/visual-studio-express-vs.aspx
	Notepad++	**A free source code editor available on Windows.**	https://notepad-plus-plus.org/download/v6.8.8.html
	WiiMoteLib	**A plugin/extension for WiiMote manipulation using XNA GameStudio 4.0. A managed library for WiiMote.**	http://brianpeek.com/post/wiimotelib-v1-7-released https://wiimotelib.codeplex.com/

TABLE 21 - SOFTWARE USED DURING PHD

11.3 Initial prototype development using PS Move Sharp!

Using PS Move Sharp was an application used on Windows 7 in order to test the connection between the PlayStation console interacting with the Windows machine. This tracked everything via the IP address and port in order to connect for communication. The positions would then change on screen based on the movement of the PlayStation Move remote in your hand.

The rumble control also allowed for the vibration of the Move. This demonstrated the communication was live between the PlayStation and Windows machine using the Move controller.

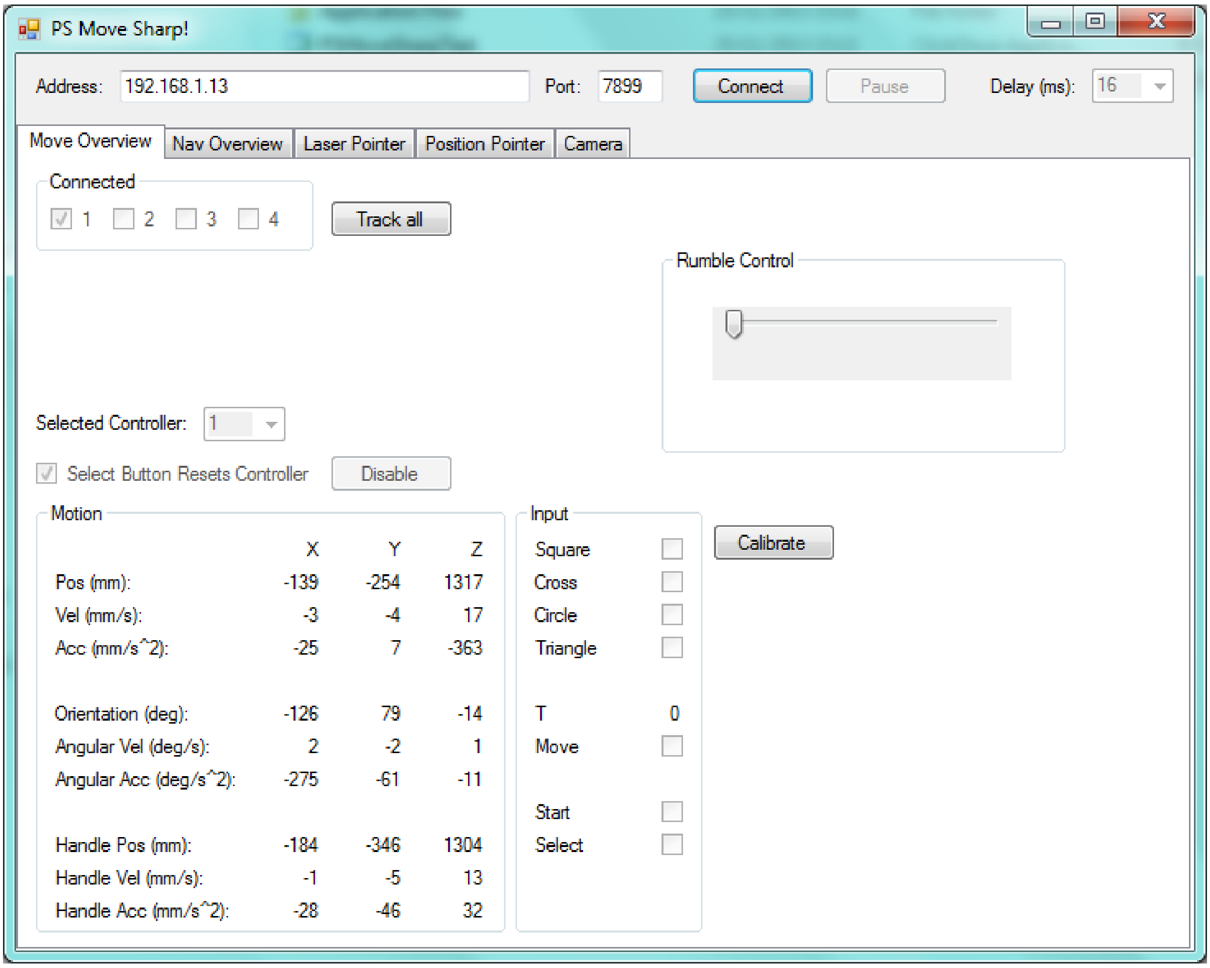

FIGURE 63 - PS MOVE SHARP DEMONSTRATION OF SOFTWARE

Figuring out when someone is walking is when the orientation on the y-axis is moving between 100 and -100.

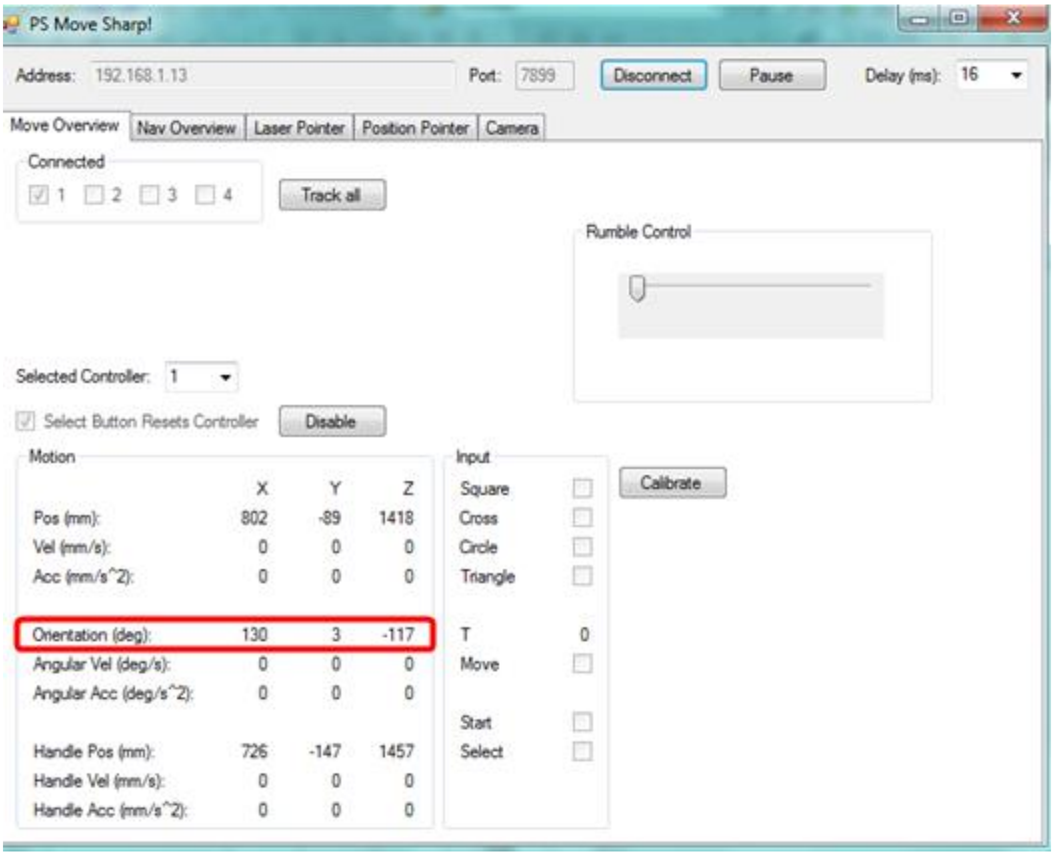

FIGURE 64 - PS MOVE SHARP ORIENTATION

The following is the code written in order to move the acceleration and orientation of the controller.

```
if(PSMoveInput.IsConnected && PSMoveInput.MoveControllers[0].Connected) {

    Vector3 gemPos, handlePos,accel,orient;

    MoveData moveData = PSMoveInput.MoveControllers[0].Data;
    gemPos = moveData.Position;
    accel = moveData.Acceleration;
    orient = moveData.Orientation; ….}
```

This piece of code is gathering data from the class PSMoveInput and calling the IsConnected method and getting the number of move controllers that are connected. If it is connected then four variables are declared as vector 3 types, meaning that they contain information about x, y and z. The MoveData moveData = new moveData(); is declaring a new object of class MoveData and assigning the data from the moveControllers from the PSMoveInput class to moveData object. After which Object.Method() and Object.Properties are called from that class. The Position of the moveData is assigned to gemPos vector3 variable in order to use it in this class namely PSMoveSample class. The PSMoveExample script was attached to the Unity3D inspector window and as shown in figure 65 - this shows the handle, target, text and speed of the move along with other variables to test the device connection via the Windows application Unity3D.

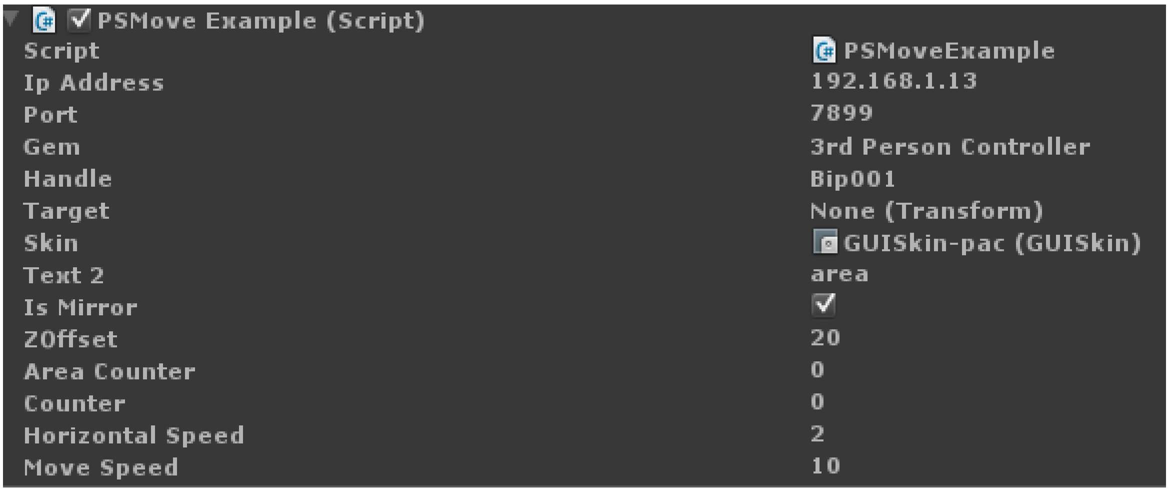

FIGURE 65 - PS MOVE EXAMPLE

The following are skeletal screens for the proposed game level. These were used as early design to test the functionality of Unity3D and connecting it to the PlayStation Move.

11.4 Skeletal screens or mockups of the proposed game level

The Initial two-dimensional development of the game consisted of looking out through a window of a destroyed city. Unfortunately at the time Unity3D only handled three-dimensional development and it was not until later versions that two-dimensional development was a feature of the game engine.

FIGURE 66 - TWO-DIMENSIONAL WINDOW DESIGN

The initial versions of the game also focused on tools that students may use throughout the game. The following table – table 22 – shows the initial elements of the game. Each element was rasterized in Adobe Photoshop to show the cartoon like image of a photograph.

		

TABLE 22 - INITIAL COMPONENTS WITHIN THE GAME

The focus is on area and perimeter (the areas of weakness for most primary children entering into second level). The game progresses to show how

Pythagoras' theorem can be used in a real life example when trying to find out the area of a square on the hypotenuse when the sum of the other two sides of the squares is known. The initial classroom saw students being transported into another world by clicking on one of the computers.

TABLE 23 - INITIAL CLASSROOM DESIGN

The initial classroom contained computers, as shown in table 23 above, where students could click on the screens of these in order to go onto the next scene. These were eliminated due to time constraints within the classroom and these scenes were, therefore, not feasible for classroom implementation.

FIGURE 67 - CLASSROOM WITH GUI TEXT TO PLAY

Initially the classroom scene was adjusted to include a play button on screen. This scene was also eliminated. Further versions of the scene were also iterative developed as the game progressed in its development and included an option for students to click on engineering in order to go to the next scene. Again, this was also cut from the pilot game.

FIGURE 68 - CLASSROOM WITH AUDIO AND ENGINEERING LINK TO THE NEXT SCENE/LEVEL

While the classroom scenes were cut, the engineer's office was still integrated and this evolved throughout to show just a scene with a desk to that desk being in an office where the player would go after the classroom scene was completed.

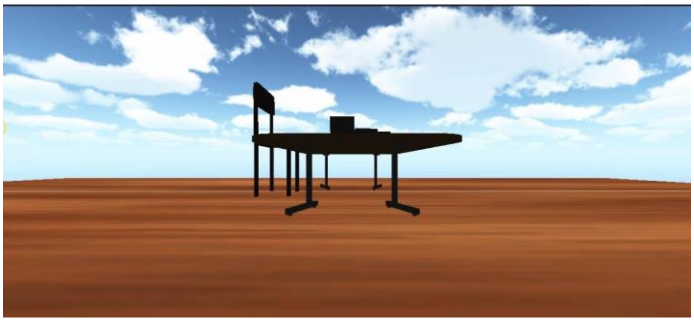

FIGURE 69 - INITIAL ENGINEER'S OFFICE

The engineer's office was quite dark and did not allow for much manipulation within the game – as shown in figure 69. Upon realising further time constraints within the classroom, it was then decided to eliminate this scene as well.

FIGURE 70 - ENGINEER'S OFFICE

FIGURE 71 - GETTING TO THE ENGINEER'S OFFICE

11.5 Layout

An overview of the initial destroyed city layout shows the three-square buildings without a terrain underneath. These were adjusted throughout development. This was a case of testing the boundaries of Unity3D and ensuring these were all correct and could be in alignment with each other.

Area and perimeter

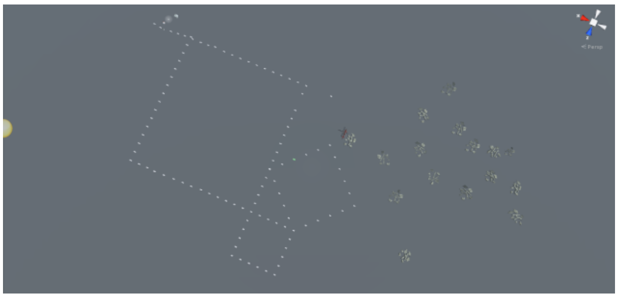

FIGURE 72 - DESTROYED CITY BOXES

A further iteration of the game design layout led to the elimination of one of the squares and a creation of a square within a large square. The large square was then eliminated, as this was not in line with the other squares.

11.6 Interactions and system feedback

Interactions

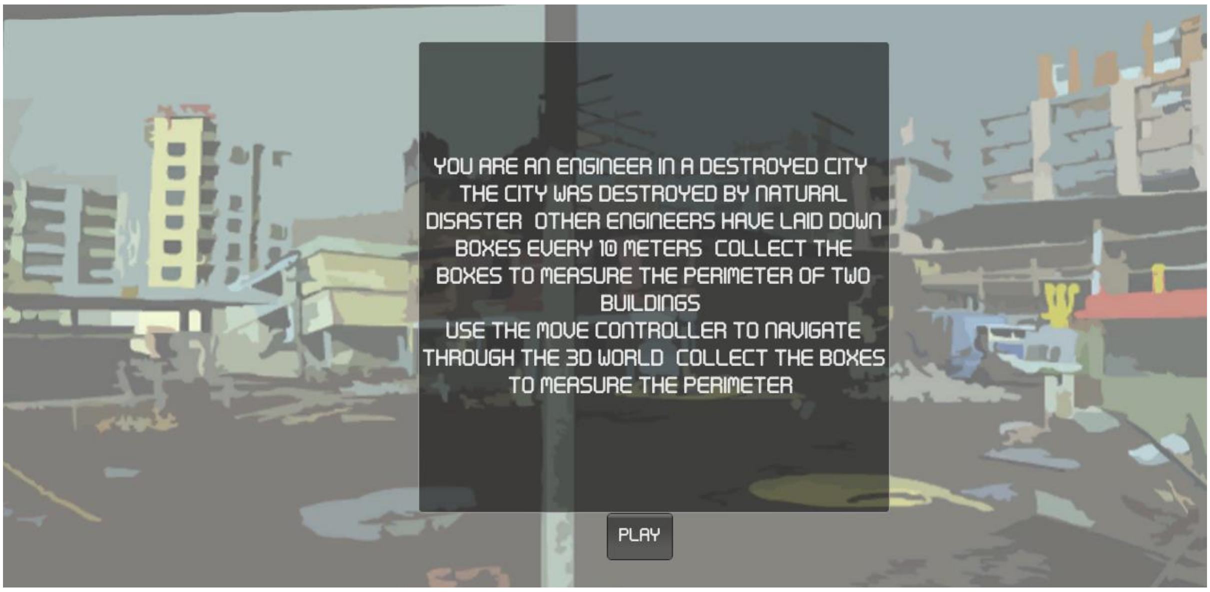

FIGURE 73 - INITIAL SCREEN INSTRUCTIONS

http://www.fontspace.com/qbotype/digital-tech

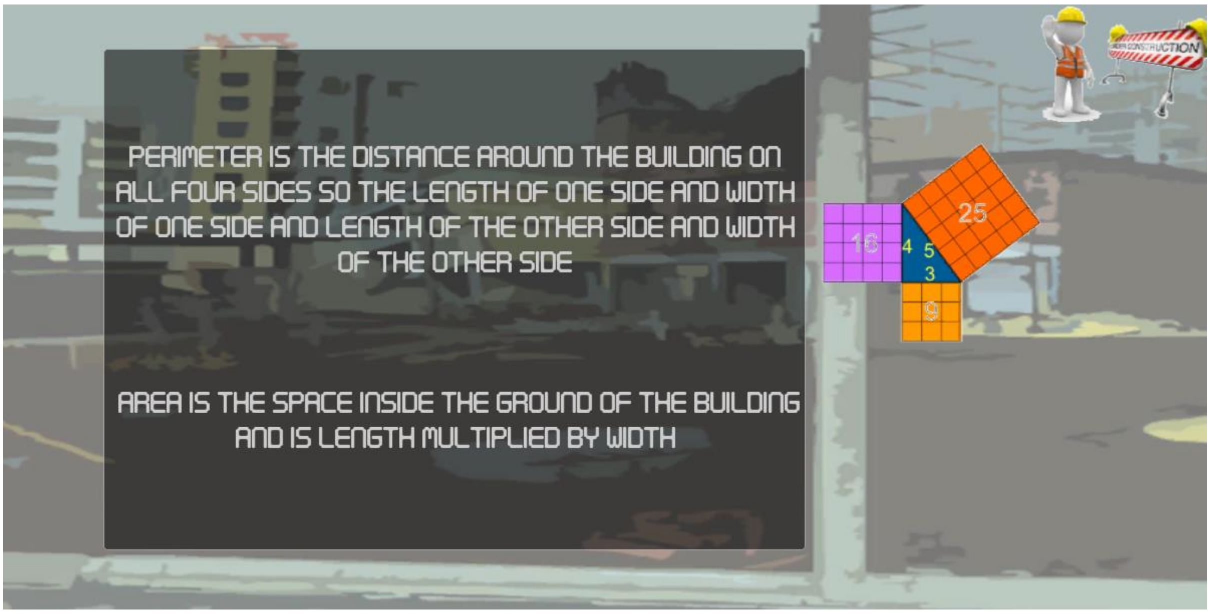

FIGURE 74 - HELP BUTTON POP UP

Initial game feedback was given through audio as well as text. This was rendered infeasible due to constraints of technology within the classroom.

The sound effects were changed numerous times to allow for helicopters to be heard in the background. This gives the effect that the person is being dropped from a helicopter. There can only be one audio listener in a scene which acts as the ears so for the development of this game, the researcher placed the audio listener on the player GameObject. There are many *audioSources* throughout the scenes. Some audio is added using add component and add audioSource, put audioClip on audioSource.

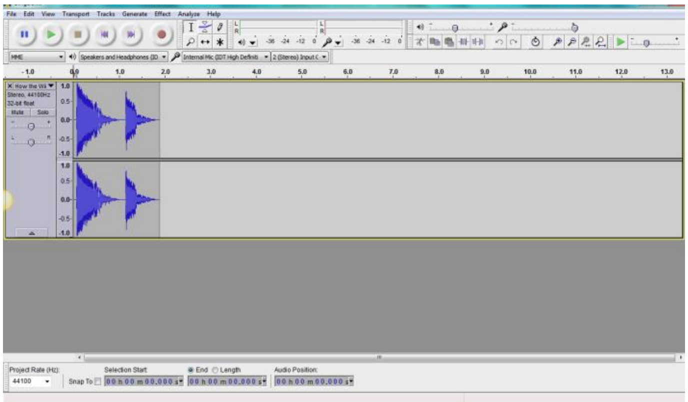

FIGURE 75 - AUDACITY SOUND TOOL

Medio.io and youconvertit.com converted the audio into mp3 files.

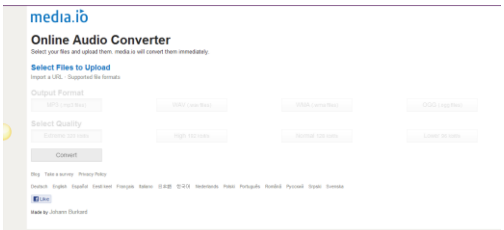

FIGURE 76 - MEDIA.IO AUDIO CONVERTER

11.7 Colour and Typography

The font used in the game is Digital Tech. A downloadable version of the font can be found at [http://www.fontspace.com/qbotype/digital-tech.](http://www.fontspace.com/qbotype/digital-tech) This website was accessed in October 2014. The GUI skin in Unity3D allowed for its implementation within the game engine. The GUISkin-pac is created in Unity and font is downloaded elsewhere to assign to the skin. The user can then adjust the skin at each level or when an event occurs such as pressing a button or hovering over an image.

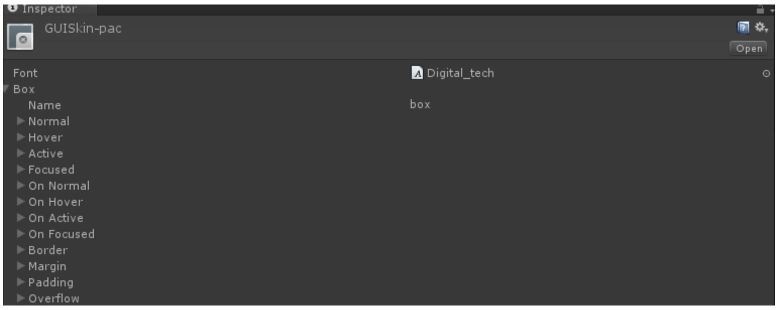

FIGURE 77 - GUI SKIN TO CHANGE GUI

Upon entering the destroyed city, the initial design of the colour and typography used digital tech font on the buttons and on the bottom of the screen to show the accumulation of area and perimeter results.

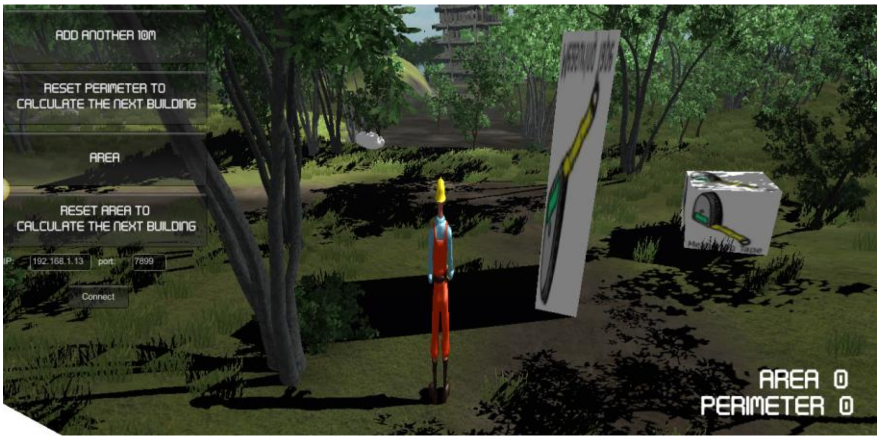

FIGURE 78 - DESTROYED CITY

The text on screen has been adapted using the code GUI.Skin = new Skin() within the GUI Class and Skin method. Public GUISkin skin; is declared as a new skin at the start of the script. GUI.skin = skin; is then used when the controller is connected and the text appears on screen. In Unity the GUISkin is assigned to the Skin variable from the code.

Appendix 2: Phase One: Survey Questionnaire

Technology Questionnaire

Survey of students' experience and knowledge of different software.

This survey is split into **six** different sections.

1. Section one is an understanding of your **background** of *Project Maths.*
2. Section two is to gain an understanding of your **understanding of computers.**
3. Section three is to gain an insight into your knowledge of **Word processing software**.
4. Section four is to find out how comfortable you are with **Excel or spreadsheet software.**
5. Section five is to find out if you have used or are comfortable with using the mathematical software **GeoGebra.**
6. Finally, section six is to find out if you have previously used **Gesture-Based computing** devices such as the **PlayStation 3 Move, Nintendo Wii or the Xbox Kinect**.

Please complete **all** the survey. If you have any questions please ask.

Age	
Nationality	
Please circle	Male/Female
Second level institution attended	
Year sitting Leaving Certificate *(If sat more than once please state*	

years)	
Did you take **Higher Level** or **Ordinary Level Mathematics** at Leaving Certificate Level? *(If other please state)*	

Computers

1QA Please tick the box which best represents your skill level with using computers

I am not comfortable using computers and need help when doing things on my own	I only use it for the internet and basic tasks	I feel comfortable using computers for many different things	I am very comfortable and can do advanced tasks on my own

Microsoft Word

2QA Please tick the box, how often have you used **Microsoft Word or another** word processing software?

Never (If you tick this box, please skip to the next section, Microsoft Excel)	Rarely	Sometimes	Often

2QB What did you primarily use the word processing software for?

Writing letters	Essays/Assignments	Recreational	Business	Applications	Other

2QC If other please state:

2QD Please tick the box which best represents your skill level with using the word processor

I am not comfortable using word and need help when doing things on my own	I use it for the basics only	I feel comfortable using word processors for many different things	I am very comfortable and can do advanced tasks on my own

Microsoft Excel

3QA Please tick the box that best represents how often have you used **Microsoft Excel or another** spreadsheet software?

Never (If you tick this box, please skip to the next section, GeoGebra)	Rarely	Sometimes	Often

3QB What did you primarily use the **Microsoft Excel** or other spreadsheet software for?

In Maths class (Project Maths content, the Teacher used it)	In Maths class (Non- Project Maths content, the Teacher used it)	Homework (We were given tasks to do using this software)	Personal (Budget, sports, organisation)	Other

3QC If other please state:

3QD Please tick the box which best represents your skill level with using the spreadsheet software

I am not comfortable using word and need	I use it for the basics only	I feel comfortable using Excel for many different	I am very comfortable and can do advanced

help when doing things on my own		things	tasks on my own

GeoGebra

4QA Please tick the box, how often have you used **GeoGebra**?

Never (If you tick this box, please skip to the next section, Gesture-Based Computing)	Rarely	Sometimes	Often

4QB What did you primarily use **GeoGebra** for?

In Maths class (Project Maths content, the Teacher used it)	In Maths class (Non-Project Maths content, the Teacher used it)	Homework (We were given tasks to do at home on our own)	Personal use (Drawing angles at home independently of homework)	Other

4QC If other please state:

4QD Please tick the box, on average, using GeoGebra, I am…

I am not comfortable using word and need help when doing things on my own	I use it for the basics only	I feel comfortable using GeoGebra for many different things	I am very comfortable and can do advanced tasks on my own

Gesture-Based Computing (Wii, Xbox Kinect, PlayStation 3 Move)

5QA For each of the Gesture-Based devices mentioned below, please tick the box that best represents your experience with using it.

	Never	**Rarely**	**Sometimes**	**Often**
Nintendo Wii				
Xbox Kinect				

PlayStation 3 Move				

5QB Please tick the box that best represents **<u>your</u> primary use** for the Gesture-Based devices.

	Exercise (Sports, Yoga, physical activity game)	**Games**	**Internet**	**DVD**	**Education**	**Other**
Nintendo Wii						
Xbox Kinect						
PlayStation 3 Move						

5QC If other please state for each console mentioned:

____

____

____

5QD Please state in detail any potential ways in which you feel these devises could be used for Mathematics Education.

____

____

Appendix 3: Phase Two and Four: Survey Questionnaire

NUI Galway
OÉ Gaillimh

Student Questionnaire

CONFIDENTIAL

SURVEY OF STUDENTS' INTEREST AND PERSPECTIVES OF MATHEMATICS

Dear Student,

This set of questions is to collect very helpful information for understanding your interest in mathematics. The purpose of this research is to develop a Gesture-Based device, for example, a game using the Nintendo WiiMote and assess the capacity and impact of such a device on the students' perspectives regarding mathematics.

The questionnaire will take approximately **5 minutes** to complete. The answers you give will not be shared with your teachers, your school or anyone else other than myself and my supervisor. There is no way for us to trace your answers back to you. Your participation is voluntary and you are free to decide not to complete the survey at any time.

I appreciate your help in answering these questions and I am very grateful that you are taking the time to complete this survey.

Should you want any further information regarding the survey, my contact details have been given to your principal.

Wishing you the very best for the rest of the school year.

Thanking you in advance for your cooperation,

Alison Mc Namara

SURVEY OF STUDENTS' INTEREST AND PERSPECTIVES OF MATHEMATICS

School:____

Please tick the box

☐ Male

☐ Female

Please tick the box

☐ I am in Second Year

☐ I am in Transition Year

At what level are you studying mathematics?

☐ Higher level

☐ Ordinary level

☐ Foundation level

How much do you agree with these statements about learning mathematics?

	Agree a lot	**Agree a little**	**Disagree a little**	**Disagree a lot**

I enjoy learning mathematics				
I wish I did not have to study mathematics				
Mathematics is boring				
I learn many interesting things in mathematics				
I like mathematics				
I usually do well in mathematics				
Mathematics is more difficult for me than for many of my classmates				
Mathematics is not one of my strengths				
I learn things quickly in mathematics				
Mathematics makes me confused and nervous				
I am good at working out difficult mathematics problems				
My teacher thinks I can do well in mathematics class with difficult material				
My teacher tells me I am good at mathematics				
Mathematics is harder for me than any other subject				
I think learning mathematics will help me in my daily life				
I need mathematics to learn other school subjects				
I need to do well in mathematics to get into the course of my choice				
I need to do well in mathematics to get the job I want				
I would like a job that involves using mathematics				
It is important to do well in mathematics				
Learning the information is useful for me to learn				
I expect to do well on my end-of-year exams this year in				

mathematics				
I expect to do well on the activities and work that we do during mathematics class				

Thank You! Thank you for taking our survey. Your response is very important to us.

Appendix 4: Phase Four: Teacher Interview Schedule

NUI Galway
OÉ Gaillimh

Interview Guide for Teachers

Teacher background information

How many years have you been teaching mathematics?

What class are you teaching at the moment?

Tell me a bit about the school you are in? (mixed, females only, males only)

Teacher technology background

How often would you say you would use your computer for class and in general?

Do you go on the Internet much in the classroom or at home?

Is there a computer in your classroom?

Do you have Internet in the school?

How about the classroom, could you tell me a bit about how the classrooms are set-up? (Do they have interactive whiteboards, does the school give you a laptop, and how technology friendly is your school?)

Are the students allowed to use their own devices in class?

Teacher Gesture-Based Technology background

Do you play with any devices like the Wii, Xbox Kinect or PlayStation?

Could you tell me a little bit more about using these? What do you know about them?

On reflecting on the use of the game in the classroom, how did you find it?

Teacher opinions and attitudes

Is there a place for Gesture-Based Devices in the classroom?

Would you see a use for this technology in the classroom?

How do you think students would find something like this in the classroom?

Would you consider using this if you had all the facilities necessary in your school?

Activities

What do you think Gesture-Based Devices could be used for in your lessons?

Are there any other ways you can think of to use games like this in the classroom?

Students' attitudes and motivations

Could you tell me about the students' attitudes towards maths in the class that you're teaching at the moment?

After using the game in the classroom, did you notice any differences in the students' attitudes towards mathematics?

Signed:____________________________________

Interviewer: Alison Mc Namara

Interviewer signature: _________________________

Date: _____/_____/_____

Question guide students phase two of the study after observation of using the game in the classroom in the presences of a teacher –

- How useful do you believe maths is?
- How useful is what you learn in maths?
- What did you find interesting about playing the game?
  - [prompt] could you tell me a bit more about how you found playing the game?

- What did you think when you played the game?
- Compared to other activities, how important is it to you to be good at maths?

Appendix 5: Background Context Tables

These are a sample of background context tables from the results taken from the survey questionnaire.

Correlation Matrix[a]

		Enjoy Learning Maths	Not Study Maths_RE	Maths Boring RE	LEARN INTERESTING THINGS	LIKE MATHS
Correlation	Enjoy Learning Maths	1.000	**.815**	.724	.706	**.883**
	Not Study Maths_RE	**.815**	1.000	.724	.478	.763
	Maths Boring RE	.724	.724	1.000	.541	.798
	LEARN INTERESTING THINGS	.706	**.478**	.541	1.000	.725
	LIKE MATHS	.883	.763	.798	.725	1.000
Sig. (1-tailed)	Enjoy Learning Maths		.000	.000	.000	.000
	Not Study Maths_RE	.000		.000	.009	.000
	Maths Boring RE	.000	.000		.003	.000
	LEARN INTERESTING THINGS	.000	.009	.003		.000
	LIKE MATHS	.000	.000	.000	.000	

a. Determinant = .010

TABLE 24 - SCHOOL A LIKE LEARNING SCALE FACTOR ANALYSIS

Correlation Matrix[a]

		I enjoy Learning maths	Wish did Not Study	Maths is boring	Learn interesting things	I like maths
Correlation	I enjoy learning maths	1.000	.602	-.076	.555	.465
	Wish did not study maths	.602	1.000	.170	.527	.701
	Maths is boring	-.076	.170	1.000	.060	.215
	Learn interesting things	.555	.527	.060	1.000	.608
	I like maths	.465	.701	.215	.608	1.000
Sig. (1-tailed)	I enjoy learning		.000	.351	.001	.006
	Wish did not study	.000		.194	.002	.000
	Maths is boring	.351	.194		.380	.136
	Learn interesting things	.001	.002	.380		.000
	I like maths	.006	.000	.136	.000	

a. Determinant = .155

TABLE 25 - SCHOOL C LIKE LEARNING MATHS CORRELATION MATRIX

Correlation Matrix[a]

	USUALLY DO WELL IN MATHS	Maths is difficult for me	I LEARN THINGS QUICKLY IN MATHS	Maths makes me confused and nervous	BSBM16F	MY TEACHER THINGS I CAN DO WELL	MY TEACHER TELLS ME I AM GOOD	Maths is harder for me

Corr	BSBM16A_DOWEL	1.000	.638	.621	.603	.759	.711	.774	.553
	Maths is difficult for me	.638	1.000	.691	.720	.626	.543	.589	.669
	BSBM16D_QUIC	.621	.691	1.000	.552	.801	.610	.685	.315
	Maths makes me confused and nervous	.603	.720	.552	1.000	.565	.415	.565	.600
	BSBM16F_GOOD	.759	.626	.801	.565	1.000	.717	.795	.437
	BSBM16G_DOWEL	.711	.543	.610	.415	.717	1.000	**.832**	.369
	MY TEACHER TELLS ME I AM GOOD	.774	.589	.685	.565	.795	.832	1.000	.403
	Maths is harder for me	.553	.669	**.315**	.600	.437	.369	.403	1.000
Sig. (1-tailed)	BSBM16A_DOWEL		.000	.001	.001	.000	.000	.000	.003
	Maths is difficult for me	.000		.000	.000	.001	.003	.001	.000
	I LEARN THINGS QUICKLY IN	.001	.000		.003	.000	.001	.000	.067

	MATHS								
	Maths makes me confused and nervous	.001	.000	.003		.002	.022	.002	.001
	BSBM16F_GOODD	.000	.001	.000	.002		.000	.000	.016
	BSBM16G_DOWEL	.000	.003	.001	.022	.000		.000	.038
	MY TEACHER TELLS ME I AM GOOD	.000	.001	.000	.002	.000	.000		.026
	Maths is harder for me	.003	.000	.067	.001	.016	.038	.026	
a. Determinant = .001									

TABLE 26 - CONFIDENT SCALE CORRELATION MATRIX

Component Matrix[a]

	Component		
	1	2	TIMSS DATA United States
USUALLY DO WELL IN MATHS	.874	-.057	0.77
Maths is difficult for me	.835	.335	0.74
I LEARN THINGS QUICKLY IN MATHS	.819	-.211	0.81
Maths makes me confused and nervous	.762	.414	0.71

WORK OUT DIFFICULT PROBLEMS	.885	-.238	0.76
MY TEACHER THINGS I CAN DO WELL	.807	-.375	0.61
MY TEACHER TELLS ME I AM GOOD	.877	-.303	0.61
Maths is harder for me	.645	.629	0.79

Extraction Method: Principal Component Analysis. a. 2 components extracted.

TABLE 27 - SCHOOL A CONFIDENT SCALE COMPONENT ANALYSIS

Correlation Matrix[a]

		HELP IN DAILY LIFE	LEARN OTHER SUBJECTS	DO WELL GET COURSE	DO WELL GET JOB	JOB INVOLVES MATHS
Correlation	HELP IN DAILY LIFE	1.000	.657	.680	.659	.661
	LEARN OTHER SUBJECTS	.657	1.000	.602	**.539**	.672
	DO WELL GET COURSE	.680	.602	1.000	**.968**	.729
	DO WELL GET JOB	.659	**.539**	**.968**	1.000	.701
	JOB INVOLVES MATHS	.661	.672	.729	.701	1.000
Sig. (1-tailed)	HELP IN DAILY LIFE		.000	.000	.000	.000
	LEARN OTHER SUBJECTS	.000		.002	.005	.000
	DO WELL GET COURSE	.000	.002		.000	.000
	DO WELL GET JOB	.000	.005	.000		.000
	JOB INVOLVES MATHS	.000	.000	.000	.000	

a. Determinant = .006

TABLE 28 - SCHOOL A VALUE SCALE FACTOR ANALYSIS

Component Matrix

The components are extracted by the factor analysis and each component can also be read similarly to a correlation. The first components are extracted and are shown as School A - E.

Component Matrix[a]

		School A	School B	School C	School D	School E	TIMSS DATA United States
1	Enjoy learning	.942	.888	.771	.796	.897	.89
2	Wish did not have to study	.863	.807	.866	.776	.714	.78
3	Maths is boring	.862	.634	.183	.452	.822	.81
4	Learn interesting things	.775	.424	.806	.728	.845	.77
5	I like maths	.951	.898	.853	.757	.888	.90

Extraction Method: Principal Component Analysis.

TABLE 29 - LIKE MATHEMATICS FACTORS ALL SCHOOLS WITH TIMSS UNITED STATES DATA

School A Components– Like Learning Mathematics Scale

The table for School A – table 29 – above shows all components are close to each other and are therefore associated with each other. The lowest is .775 with ‘I learn many interesting things in mathematics’. The highest is .951 ‘I like mathematics’ and the component extracted ‘I enjoy learning mathematics’ is highly associated with each other.

School B Components– Like Learning Mathematics Scale

The matrix shows that the highest component is .898 for ‘I like learning mathematics’ in component 1 and the direction is positive for this component. The component score can be interpreted as factor 1, ‘I enjoy learning mathematics’, correlates strongly with factor 2 and 5 the factors, ‘I wish I did not have to study mathematics’ and ‘I like learning mathematics’ respectively.

School C Components– Like Learning Mathematics Scale

In the component matrix, the highest component extracted is .866, students wishing they did not have to study mathematics. The lowest is .183 as mathematics is boring is not as associated with ‘I enjoy learning mathematics’ as ‘I wish I did not have to study mathematics’.

School D Components– Like Learning Mathematics Scale

The component matrix shows the extracted component, in this case, ‘I enjoy learning mathematics’ and its relationship with the other variables. The highest statistics in this case is ‘I enjoy learning mathematics’ at .796 and following that ‘I wish I did not have to study mathematics’ at .776.

School E Components– Like Learning Mathematics Scale

The component matrix shows the figures are relatively high among all question items in this construct. .897 for ‘I enjoy learning mathematics’ correlates the strongest with ‘I like learning mathematics’ at .888. .845 is the second highest correction and is ‘I learn interesting things’ so students who enjoy learning mathematics, like mathematics and find it interesting. Interest is then something to be targeted in relation to this construct.

Component Matrix – Confident in Mathematics Scale

The component matrix illustrates the factor scores across all schools by each of the cases listed by all factors. This composite variable shows the outliers in a construct. In this case the lowest factor score in the first component is for ‘Mathematics is harder for me than any other subject’. This factor is seen in the previous correlation matrix where the correlation scores are taken into consideration to compute the components. The principal component analysis of the items in the TIMSS 2011 Students Confident in Mathematics Scale, Eighth Grade is comparable with the factor loadings for each item below. The factor loadings for the items ‘My teacher thinks I can do well in mathematics’ and ‘Mathematics is harder for me than any other subject’ is comparably different from the United States data listed below. This is making a comparison with a country versus one particular school in order to show the context of the school and the relationships that are strongest and weakest.

	School A	School B	School C	School D	School E	TIMSS DATA United States
Usually do well in maths	.874	.965	.743	.689	.877	0.77
Maths is difficult for me	.835	.839	.531	.728	.763	0.74
I learn things quickly in maths	.819	.908	.838	.785	.760	0.81
Maths makes me confused and nervous	.762	.548	.743	.588	.729	0.71
Work out difficult problems	.885	.910	.730	.656	.790	0.76
My teacher things I can do well	.807	.812	.811	.413	.712	0.61
My teacher tells me I am good	.877	.831	.852	.399	.748	0.61
Maths is harder for me	.645	.502	.772	.715	.605	0.79

TABLE 30 - CONFIDENCE FACTORS ALL SCHOOLS WITH TIMSS UNITED STATES DATA

School B, the strongest component is ‘I usually do well in mathematics’ and the weakest component is ‘Mathematics is harder for me than any other subject’. The second weakest questionnaire item is mathematics makes me confused and nervous. In School C, the first three components were also extracted. The strongest relationship is between ‘I usually do well in mathematics’ and ‘I learn things quickly in mathematics’. ‘I am good at working out difficult mathematics problems’ also correlates to the second strongest in the component matrix at .842. School D also extracted the first three components and had the same strongest relationship as School C, ‘I usually do well in mathematics’ and ‘I learn things quickly in mathematics’. The components extracted were less than School A as shown in the table above – table 30. The weakest factor extracted is School B at .502 for ‘Mathematics is harder for me than any other subject’. The following section discusses the Students Value Mathematics Scale.

Component Matrix – Value Mathematics Scale

The amount of factors extracted across each school varies between one and two factors. School A shows that only the first factor has been extracted, the factor I think learning mathematics will help me in my daily life. The strongest correlation with this factor is I need to do well in mathematics to get into the course of my choice at .926. School B extracted two factors and also has same correlation as school A. School C extracted two factors and has a correlation with I need to do well in mathematics to get the job I want.

Component matrix[a]

	Component					
	School A	School B	School C	School D	School E	TIMSS DATA United States
Maths helps daily	.822	.118	.788	.659	.651	.77
Learn other subjects	.799	.536	.282	.759	.759	.72

Need for the course	.908	.850	.625	.832	.823	.71
Need for the job	.884	.845	.852	.849	.887	.76
Job uses maths	.883	.739	.531	.601	.742	.62
Important to do well	.541	.663	.723	.563	.685	.66

TABLE 31 - VALUE FACTORS ALL SCHOOLS WITH TIMSS UNITED STATES DATA

The component matrix illustrates the comparison among five schools and the country-wide data collected by TIMSS in 2011 for the United States. School B shows the lowest mark when it comes to 'I think learning mathematics will help me in my daily life'. The other schools seem to think that 'mathematics helps in daily life'. Across the United States, the factor loading is relatively high. As shown in the table – table 31 – School B scores low in relating mathematics to mathematics in daily life and School A scores this as the highest.

Appendix 6: Nintendo Communication

Re: Development in the Wii

Kenji Hirata <Kenji.Hirata@nintendo.de> 21 April 2011 at 16:36
To: ali mcnamara <mcnamaraali@gmail.com>
Cc: Martin Buchholz <Martin.Buchholz@nintendo.de>, Rob Bakie <Robeba07@noa.nintendo.com>

Hello Allison,

This is Kenji from Nintendo Developer Relations.

Thank you for your email regarding the availability of the Wii Development Environment. Unfortunately, there is no academic scheme currently available to enable student access to the development materials and equipment necessary to create games on Nintendo platforms. Nintendo treats it's technical information as highly confidential and as such, only authorises professional, experienced developers or development companies.

Typically, in the case of Universities who are undertaking research involving Nintendo platforms, the Univerisity will work with an existing authorised developer on these projects. I understand this is not the most ideal solution to your question, but it is the closest match to your plans.

Please let me know if you have any other questions.

Best Regards and good luck with your PhD,

Kenji

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Software Development Support Group

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