The use of Mobile Applications to support the development of arithmetic skills in visually or hearing impaired children at Key Stage 1 level

A dissertation submitted in partial fulfilment of the requirements for the degree of Bachelor of Science (Honours) in Computing

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Declaration

I hereby declare that this dissertation entitled The use of mobile applications to support the development of arithmetic skills in visually or hearing impaired children at Key Stage 1 level is entirely my own work, and it has never been submitted nor is it currently being submitted for any other degree.

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Abstract

This research project is designed to explore the usage of mobile applications which can be used to support the development of arithmetical skills among visually impaired and hearing impaired children studying at Key Stage One level, typically between the ages of five and seven years old.

The research project looks at issues surrounding the topic area at hand, such as looking at what constitutes a visually or hearing impaired person, the teaching of mathematics to those with visual or hearing impairment as well as children in general, human-computer interaction considerations for children and visually or hearing impaired as well as the area of mobile technologies in a learning environment. The project aims to critically evaluate literature about topics such as those detailed above to develop an understanding of whether mobile applications can be used to help the development of mathematical skills amongst visually or hearing impaired children at Key Stage One level, with the creation of a prototype application being developed using storyboarding to develop paper prototypes, followed by the development of high fidelity designs which were tested using participants, who were selected due to them being experienced teachers of children with special educational needs, who were able to provide valuable feedback to the project and help with the improvement of the high fidelity design in to a second and final high fidelity design of a prototype application.

The interviews and testing of the application provided the project with a greater insight in to areas surrounding the topic as well as the creation of a working prototype application which could be used to aid the development of arithmetical skills once fully developed, with the participants positive about the worth that a prototype application could add to the education of a visually impaired or hearing child, whilst a further statistical and evidence based discussion discovering the increasing desire of schools to introduce mobile technologies and applications in to the classroom.
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1. Introduction

This research project is based on the usage of mobile applications to support the development of arithmetical skills amongst children studying at Key Stage 1 level with either visual or hearing impairment issues.

The aims and objectives of this project will be to identify the educational targets for children aged between five and seven-years-old and to see what differences, if any, there are between what is expected from a perfectly able child to a child with visual or hearing impairment. The project will be looking at mobile applications and the wide range of experiences they can be used to enhance, the use of mobile applications within a classroom environment, and whether it is an effective tool that can help aid the learning of a visually or hearing impaired child as well as what barriers exist to the integration of mobile applications in to the classroom environment, in particular looking at ways in which they can be used to help with the development of arithmetical skills with the visually or hearing impaired. As well as this, the project will be looking at human-computer interaction concepts and concerns as well as also looking at mobile application design for children and for visually or hearing impaired children and the different design techniques that are used to create applications that are more accessible and usable for special needs children. In order to achieve these aims, the project will look to create a prototype application that will be designed in line with the National Curriculum guidelines with the intention of creating an application that can enable a child to improve their arithmetical skills, with a critical evaluation of the application prototype being undertaken by experienced teachers with experience of working with visually or hearing impaired children. The project will also critically review literature within the fields of human-computer interaction, mobile application design and mobile education, as well as the teaching of mathematics to children in general as well as those children with special needs in order to gain an all-round insight in to the topic area, whilst the project will also be looking at information from schools who have adopted the usage of mobile technologies in the classrooms and what barriers are faced in the introduction of mobile devices to the classroom environment.
The first part of the project will be looking at relevant literature surrounding the topic of the use of mobile applications to support the development of arithmetical skills amongst children aged between five and seven-years-old to gain an insight into past studies and theory that have taken place around the subject, which will form the backbone of this project. The literature review will look at the topics mentioned in the above paragraph, surrounding the issues of mobile application and the usage of mobile applications in a classroom environment, as well as looking at the issues surrounding the education of special needs children, as well as human-computer interaction and mobile application design techniques for children in general and for children with visual or hearing impairment, accessibility of devices and applications for visually impaired or hearing impaired children and any barriers that exist preventing the use of mobile applications on a wider scale, as well as looking at literature on the platforms for application development and the features provided by them.

The second part of the project takes an in-depth look at the research methodology that has been used throughout the development of this project, looking at the research philosophy that was adhered to and the type of research that took place. Beyond this, the project will look at the types of sampling that led to the recruitment of participants for interviews which provide a greater depth of knowledge to the project. As well as these matters, this part of the project will also look at the types of data that has been gathered throughout the research of the topic areas and will provide a greater insight into how the overall project was set out from early research to finished project.

The next part of the project will be looking at the results that have been gained through research and through interviews and testing of a prototype application with people from within the education sector who have experience of working in a classroom environment with visually impaired or hearing impaired children. This part of the project will follow on from the literature review earlier in the project, reviewing each of the earlier discussed topics and providing a greater depth of analysis from relevant sources to give a wider representation of the topic areas related to the project with the aim of providing an answer to the question posed by the project title. This will be done by looking at information from a variety of sources and by looking
at both statistical information and qualitative data to substantiate whether mobile applications can be an effective tool in assisting the learning of arithmetical skills amongst Key Stage 1 level children with visual or hearing impairments. Furthermore, the project will be identifying the most recognised and popular theories and strategies to overcome the issues within accessibility and usability of these applications for those with disabilities or special educational needs and their effectiveness. The project will then provide a physical interpretation of what the theory and data obtained means, with the creation of a prototype application that can run on a mobile device and will be able to support the arithmetical learning of a visually impaired or hearing impaired child. This will go through a low fidelity and high fidelity design stage, which will then be evaluated during the interview and testing stage, gaining valuable insight and expertise from the participants which will then be used to create a refined final prototype. The project will then be concluded with the summing up the findings and discussion taking place in the main project body and providing a summary of the results from the project, as well as providing a clear answer to the question posed by the project title.

2. Literature Review

The literature review section of this project will look at existing literature covering a wide array of topics which can be used to gain a valuable insight in to the areas surrounding the project area. The first of these areas that the project is going to look at is mobile applications in general and the many uses of mobile applications as well as what they can be defined as and what a mobile application typically consists of.

2.1 Mobile Devices and Applications

Mobile devices such as smartphones, netbooks and tablets are becoming increasingly popular worldwide, exerting a great influence in the way people communicate and access information (Borcea and Iamnitchi, 2008; Sharples et al., 2008, cited by Alvarez et al, 2011). Due to this increasing popularity in using mobile device hardware, the usage of mobile applications software that is designed to run on mobile devices such as smartphones and tablet computers has constantly grown. Hoekman (2011) looked at what makes a great application, stating that an application should have a clear and defined purpose using only features that are
necessary for the user to complete the activity that the application is designed to
support, whilst applications should also make it easy to recover from mistakes as
well as being designed to help the user avoid mistakes.

2.2 Mathematics Education

When looking at the topic of the use of mobile applications devices to aid the
learning of visual impaired children and hearing impaired children in mathematics at
Key Stage One, it is important to gain an understanding of what knowledge a child is
supposed to have gained at the end of this period of their education. From a
teaching perspective, Pratt (2006) states that there are four intended outcomes of
teaching primary mathematics, which are that pupils have developed mathematical
ideas with knowledge of smaller identifiable units such as times tables as well as
procedures such as computing the product of multi digit numbers, pupils ability to
see relationships between ideas such as why multiplication is commutative, pupils
ability to identify when mathematics can be used to solve problem situations
presented to them and finally pupils adoption of mathematical dispositions. This is
from a teaching perspective however, and therefore it is also important to look at the
National Curriculum set out by the UK government in order to identify the intended
ability level expected of children at Key Stage One level. The mathematical
expectations at the end of Key Stage One can be seen in Appendix E. Another
subject that it is important to look at when discussing the education of a visually or
hearing impaired person is the role that the classroom teacher plays. It is important
that the classroom teacher is able to make sure the child is treated the same as any
other member of the class, with the teacher acting as a positive role model to every
child in the class to encourage them to accept a child who may have a visual or
hearing impairment (Ravenscroft, 2016a, cited by Peer and Reid 2016). With regards
to visual impairment, the teacher may be able to gain support and assistance in their
role of working with a visually impaired child through the use of a Qualified Teacher
of Visual Impairment or a QTVI, who will be able to provide the classroom teacher
with support and to raise their awareness about the problems that a child with visual
impairment might face (Ravenscroft, 2016b, cited by Peer and Reid 2016). This will
provide the teacher with guidance that may be important, especially to teachers who
have little to no experience of working with visually impaired children. Then moving
on to hearing impairment, there are four strategies that can be used in order to help the classroom teacher to educate a hearing impaired child, which are firstly, to allow classroom teachers to gain an understanding of family perspectives on the child’s education, secondly to provide hearing related pre-service or in-service opportunities to teachers to provide them with adequate training and knowledge for teaching children with impairments, thirdly to ensure teachers have adequate planning time for lessons and communication with a specialist practitioner who can help them and finally to provide a meeting place for teachers to communicate with each other and to help share their experiences (Duncan, 2016a, cited by Peer and Reid 2016). These strategies should enable the teacher to gain an understanding of what is required for the child to learn effectively in line with the curriculum as well as for the teacher to gain valuable experience that can be used when they next work with a hearing impaired child. As well as the classroom teacher, it is also important to look at the classroom environment. There are several different elements to the classroom environment that can be changed to aid a child with visual impairment, such as the introduction of desks that have a sloped surface which can reduce visual stress, having plain coloured backgrounds to help avoid distractions and to make sure the lighting in the room is even to avoid distraction for the child (Duncan, 2016b, cited by Peer and Reid 2016). As well as this, Salisbury (2008a) states that the positioning of the pupil is vitally important, keeping them amongst other pupils but in a suitable position to see learning aids being used by the teacher, as well as removing reflective surfaces and covering up all windows with blinds to reduce glare.

2.3 Problems faced by Visually or Hearing Impaired Children Learning Mathematics

The project will now look at the ways in which hearing impaired and visually impaired children learn mathematics and the types of problems they face. Children with visual impairment often miss out on a number of early life experiences that sighted pupils get, as those with sight are able to better interact with reading books and television programmes at an early age which provide a learning experience, for example, with counting. This can make it difficult for visually impaired pupils to be able to grasp concepts such as whole numbers and counting, matching and ordering (Salisbury, 2008b). Another concept of mathematics that visually impaired students struggle with is that of estimation, as they have no visual reference and therefore unless using real
objects, they will not be able to develop these skills (Salisbury, 2008c). For hearing impaired children, it is important to focus on the language used when teaching mathematics, making sure that words are used within the context of maths to avoid confusion with words that have everyday meanings so that difficulties are avoided for the child (Farrell, 2006a). Also, it is important to place emphasis on teaching those with hearing impairments to count whilst avoiding confusions between counting and signing, as it has been suggested the sequence of counting is a significant predictor of performance with more complex mathematical problems (Nunes and Moreno, 1997, cited by Farrell 2006).

2.4 Classifications of Visual and Hearing Impairment

Moving forward, the project will benefit by taking a more in depth look at what constitutes a child who is visually impaired or hearing impaired, and some of the different types of impairment that exist. Starting off by exploring visual impairment, in the United Kingdom there is legislation that provides an explanation of what constitutes a person who is visually impaired. The Copyright (Visually Impaired Persons) Act 2002 defines a visually impaired person as someone who is either blind, has an impairment of visual function that cannot be improved with the use of corrective lenses to an acceptable level for reading, who is unable through physical disability to hold a book or to focus or move their eyes to the extent that would normally be acceptable for reading (Salisbury, 2008d). In contrast to this, there is no legislation in the United Kingdom that provides this kind of definition with regards to hearing impairment and what hearing impairment can be lawfully defined as. This may possibly be because hearing impairment is not taken as seriously because human beings rely so heavily on sight, whilst for those with normal vision, hearing is considered the second most important sense after sight (Faulkner, 1998a). Hearing impairment is described by Farrell (2006b) as people who range from mild hearing loss to complete deafness, whilst stating that educationally, hearing impairment can be defined as those who require the use of a hearing aid, adaptations to the environment as well as those requiring teaching strategies to be put in place to provide them with access to the curriculum.
2.5 Types of Visual Impairment and Hearing Impairment

Looking more in depth at visual impairment, there are a wide array of impairments that will affect the way that people live and their education from partially sighted through to full blindness. Partially sighted is a widely used term to describe those with visual impairments which includes those with minor impairments through to those whose conditions are likely to deteriorate further, then there is visual acuity which is where the clarity and sharpness of the image seen through the eye is affected, central vision loss which affects the ability to detect fine detail, making tasks such as reading and writing difficult, peripheral vision loss which is the opposite of central vision loss, with the person having tunnel like vision which makes moving around and locating objects difficult whilst reading and writing may be unaffected, irregular vision in which people may suffer from picking up information in disjointed fragments which can make many visual tasks impossible and be very frustrating for the suffering person and finally to full blindness (Salisbury, 2008e).

Moving on to hearing impairments, Farrell (2006c) states that defects that can cause deafness are normally caused by injuries sustained during birth, infections during development at the foetal stage of development or congenital because of an inherited fault in a chromosome, with the most common hearing impairment being that of otitis media, also known as glue ear in which fluid collects in the middle ear causing hearing loss.

2.6 Mobile Education and Mobile Devices

Leading on from types of impairment, the project will now look at mobile learning and using mobile applications and devices in the education of children in general, without focusing on just those with visual or hearing impairments. As the adoption of mobile devices in society has grown, the benefits of using mobile devices to support learning in the classroom and aid students with individual and collaborative learning activities has grown (Dillenbourg and Jermann, 2006; Hernandez-Leo et al, 2006, cited by Alvarez, 2011). There are however different types of mobile devices and that can affect the type of experience the user gets. As stated by Garg (2011), the nature of the tablet experience is different to that of a smartphone and Quinn (2011) that the dimensions of the different devices, say a smartphone and a tablet, affect the way in which the device is used, such as the proximity to the device that is required for the user and the
speed of which the device can be accessed. This shows that it is important when creating educational applications that it is clearly defined in which way the application is supposed to be used and which device the application is suited to and designed for as otherwise it may create a frustrating experience for students and teachers alike, especially if the learner has special educational needs. Another issue that needs to be taken into consideration when using mobile learning is that learners need to be given tasks that are meaningful, and that they can work on individually to aid their learning to as well as working with others to provide them with a wider insight to the task being attempted (Quinn, 2004, cited by Berge and Muilenburg 2013). One of the major benefits of using mobile technologies is that they are able to assist in providing educational avenues to individuals who have struggled in traditional education environments, of which many people with disabilities are a part (Roberts, Crittenden and Crittenden, 2011, cited by Berge and Muilenburg 2013).

2.7 Accessibility, Universal Design and Access Technology

A major consideration for designers and developers creating mobile devices and applications is accessibility and the use of access technologies as well as the incorporation of universal design concepts in to what they are developing. Accessibility is the design of any product, including software, mobile applications and mobile devices that allows people with disabilities to access them. There are many questions in terms of accessibility amongst mobile learning, where learners must have access to devices with accessibility features or that are capable of interacting with assistive technology to accommodate the learners needs (Roberts, n.d., cited by Berge and Muilenburg 2013a). Another consideration is the course itself, from the point that when setting out a course you must consider the unique learning needs of those with disabilities at the start in order to guarantee that all users will be able to access all course materials and any devices required to be used, which can be tackled by using devices with in built accessibility features (Roberts, n.d., cited by Berge and Muilenburg 2013b). Then there is access technology, also known as assistive technology, which are ranges of equipment that enable people with disabilities to interact with technology, including adaptive software or hardware specifically designed to be used by those with disabilities (Salisbury, 2008f). Examples of access technologies are software such as screen magnifiers to enlarge the detail on the
screen, screen reader software which reads text aloud for the user, scanner software that can turn printed text into digital text which can then be manipulated by a screen reader or magnifier, and then there are braille displays that present the information from the screen in braille for a visually impaired person and braille note takers which allow text to be entered in braille (Salisbury, 2008g). There are problems with using these access technologies however. One of these is that devices with assistive technologies included or with devices that are compatible vary from having many features to having very few, as companies may choose not to implement the features to due to it making the products less profitable (Vanderheiden, 2008, cited by Nussbaumer 2012). As well as this, in the United Kingdom there is no legislation regarding the design of mobile devices and applications requiring the ability to be used with or to include access technologies. Another problem is that devices with assistive technologies often come at a higher cost due to the nature of implementing the extra features, but if the features are not included then those with disabilities may not have the same access as others within the same learning environment (Vanderheiden, 2009, cited by Nussbaumer 2012). This can also be an issue with regards to funding within educational establishments, due to the expense of devices that are capable of using or that are inclusive of access technologies may not be possible within the budgets they have for purchasing mobile devices. As well as this, mobile devices are not considered as assistive technologies despite the fact they can act as so, and therefore cannot be funded by the Disabled Students Allowance (McKnight and Davies, 2012). When talking of the design of applications and devices, a different concept is that of universal design. Universal design is a strategy that attempts to design and create different products or environments useable for everyone, so that is there no need for adaptation and can accommodate people of all ages, sizes and abilities (Null, 2014). There are seven key principles to universal design, which are simple and intuitive use meaning the design is easy to understand regardless of knowledge or experience, equitable use which is that no groups of people are disadvantaged or stigmatised, perceptible information which means the design communicates information necessary to the user, tolerance for error which minimises accidental errors that can be made and allows them to be corrected, flexibility in use which means a wide range of preferences can be accommodated, low physical effort meaning the design can be used efficiently and comfortably and with a minimum of fatigue and lastly, size and space for approach and use meaning size and space
should be appropriate for reach, manipulation and use, regardless of users ability, size or mobility (Imrie and Hall, 2001). Each of these principles can be taken and applied to creating an application for a child with either visual or hearing impairment to aid their learning of arithmetical skills.

2.8 Human-Computer Interaction

The next part of this project will be looking at human-computer interaction and its importance when developing or designing mobile applications and devices. As detailed by Faulkner (1998b), human-computer interaction endeavours to provide an insight into users and computers in order to improve the way they interact with each other to create an experience that is both easy and satisfying. With regards to human-computer interaction, there are three main parts to consider, these being the user, the computer and the interaction (Dix et al, 2004a). The first part that will be looked at here is that of the user, at the user is at the forefront of the discussion due to the fact that interactive systems are designed for them. The requirements of the user are the first priority in design, and their capabilities and limitations must be understood, as must the users experience, the things they find difficult or impossible and what they find easy (Dix et al, 2004b). When gaining an understanding of the user and their requirements, it is important to be aware of individual differences between users so that they can be accounted for amongst designs. For example, long term differences such as gender, as well as physical and mental capabilities need to be taken into account, as well as short term differences such as stress or fatigue of the user and finally issues that change through time such as age (Dix et al, 2004c). Following on from this there is the computer, which is the actual physical piece of technology being used. As stated by Dix (2004d), technology drives the interface as the interface needs to be designed with the limitations of storage capacity and computational power taken into account, although this information is irrelevant to the user. The final part is that of the interaction, which is how the user uses the computer to complete or simplify a task, by communicating the requirements of what they want to achieve to the computer. There are different types of interaction, such as a task which is an operation to manipulate the concept of a domain, whilst you can then have goals which is gaining the desired result from a task (Dix et al, 2004e). Another important part of human-computer interaction is that of usability. Usability means being
able to complete a task easily and naturally without danger of error. There are three main principles of usability, which are learnability, which is the ease in which a user can learn how to effectively use and interact with an application or device, flexibility which is the number of ways in which the user can interact with the system and robustness which is the level of support the user is provided with in achieving its end goal (Dix, et al, 2004f).

2.9 Human-Computer Interaction for Children

From taking a wider look at human-computer interaction and its importance in the development of mobile devices and applications, the project will now take a look at human-computer interaction concepts that are most important when designing for children. Designing for children presents many varying challenges, as the needs and requirements of children are always changing as they grow in both age and stature, and the likes and dislikes they have will also change vastly in short periods of time. The diversity of these needs that children have are particularly important when it comes to technology, as the requirements of a three-year-old child and a twelve-year-old child will be different, and as such so will the methods that will need to be taken advantage of in order to meet these requirements (Dix et al, 2004g). As well as this, when it comes to the design of mobile devices, the devices are generally built for adults as opposed to children as it is adults and parents that will be purchasing them, however many parents buy the devices to be used by their children as well as themselves, and therefore it can be important to take that in to account at the design phase. Designers are presented with challenges as children have different goals they wish to accomplish when using the device or application to adults, and therefore including the thoughts of children at the design stage is important, which in itself provides another challenge to the designer as children may struggle to discuss their thoughts in a way that is constructive to the designer (Dix et al, 2004h). This project looks at the design of mobile applications for children between the ages of five and seven-years-old, and so now the project will look at design and human-computer interaction concepts for children of this age. Children at this age generally have short attention spans and can only hold one piece of information in their memory at a time, however it is at this stage that children are able to begin to use technology and will be able to interact with an interface provided the items in the interface they need to
interact with are large enough (Bruckman et al, n.d., cited by Jacko 2012). This means that an application designed for children at this age can be effective as long as it is designed taking into account the mental and physical limitations of the child. There are various different methods for designing with children, that give children different amounts of power in the design stage, from treating children as co-designers to using them more for usability testing (Bruckman et al, year, cited by Jacko 2012). Druin (2002a, cited by Jacko 2012) devised a method that provided four different roles that children can play in the design of new technologies, being the user, tester, informant or design partner. The most reactive of these roles is that of the user, in which a child is required to use existing technologies to provide recommendations on possible new technology. Then there are testers, where children provide feedback about technology during development in order to aid refinement before release. Informants help to determine the goals and features of new technologies by interacting with the designers, providing them with information with which they can decide what needs inclusion and what doesn’t. And finally as design partner’s children are stakeholders in the design process, possibly contributing less in the design process but playing a bigger part of the development of the technology. The next design method for children that the project will look at is participatory design. Participatory design was an approach devised by Schuler and Namioka (1993, cited by Jacko 2012). It is an approach in which the people who are going to use a system play a critical role in the design of it. This is even more important with children, as they are mentally and physically different from adults and their participation may offer insights that an adult may not have, however including children in the process in the same way as an adult would be used in the process can be difficult due to the relationships between children and adults, with the adult naturally taking charge of the process which can limit the impact of using children within the design process.

2.10 Human-Computer Interaction for the Visually Impaired

Moving on from looking at human-computer interaction and design for children in general, the project will now look at human-computer interaction concerns with regard to those with visual impairments. As declared by Dix (2004i), graphical interfaces are on the rise and as such the possibilities provided to visually impaired people has decreased compared to the possibilities provided by text based interaction where
screen readers or braille output devices could be used to provide complete access to technology. This means that with regards to a mobile application, due to the type of interfaces developed to make use of the capabilities of the mobile technologies available, there are more complex graphical interfaces being created for the wider population, however this may exclude those with visual impairments who are unable to interact with them properly. Also, the use of screen readers come with a different set of problems, as they provide the user with a large amount of information and this puts a heavy strain on memory (Dix et al, 2004j). There are however, approaches to improving the access to these technologies with the most commonly used approach being the use of sound. Sound is used to provide access to graphical interfaces for the visually impaired as it is the second most important sense for communication and there are various ways in which sound can be used to help those with visual impairments, such as speech, earcons and auditory icons (Dix et al, 2004k).

2.11 Human-Computer Interaction for the Hearing Impaired

The final area that will be looked at in the literature review will be that of human-computer interaction and design for those with hearing impairments. Dix (2004l) stated that a hearing impairment may appear to have little impact to the user when using an interface as it is unlike a visual impairment where the impact is obvious, but that the incorporation of sound in to graphical interfaces is widespread, and is often used to help provide the user with feedback. This means that the design must be able to provide the user with feedback whilst using an application in a visual form as opposed to an auditory form. One way of providing hearing impaired users with a channel in which to communicate with an application is through using gesture recognition to translate sign language to speech or text to improve communication (Dix et al, 2004m).

3. Research Methodology

The project will now look at the research methodology applied in order for the project to reach a successful conclusion. This part will look at research philosophy and research methods, the data that will be collected and how it will be analysed, as well as the reasons why this data was important to the project, the use of interviews, testing and the sampling of the participants, ethical issues that are important to be considered when researching the topic of the project and how this all of these factors
will be pieced together to create a project that fulfils the aims and objectives it set out to achieve.

3.1 Research Philosophy

This part of the project will first look at research philosophies, and then more in depth at the research philosophy that has been used for this project. Research philosophies are a belief about the ways in which data should be collected, analysed and pieced together, based around epistemology and ontology, with epistemology being what is known to be true and ontology being what is believed to be true (Davison et al., 2011). The research philosophy that has been applied to this project is that of interpretivism. The interpretivist research approach is based around an approach of using interviews and observations as a crucial part of data collection, as well as the use of secondary data to conclude the research project with greater depth (Dudovskiy, 2016a). This is fitting for the research project that is being undertaken as each of these parts will be used throughout this project, with primary data sources such as interviews being undertaken with teachers that have experience working with children with visual and hearing impairments. These interviews will also involve the testing of a prototype application for a mobile device that can be used to help with the development of the arithmetical skills for five to seven-year old children. As well as this, the project will be looking at secondary data surrounding the topic area to come up with conclusions based around the use of mobile applications to aid children with visual or hearing impairments in their mathematical learning at Key Stage One level. As the teachers who are being interviewed will be being asked for opinions and feedback regarding a prototype mobile application, the project will be making use of the phenomenology aspect that comes within the interpretivist research approach, which is based around developing understanding from the experience of an event, which will in this case be the testing of the prototype application (Littlejohn et al, 2009). From an ontological point of view, the interpretivist approach is based on relativist ontology which considers reality as information that is based on the understanding of that people have about the topic area (Dudovskiy, 2016b). And from an epistemological point of view, the approach is based around the belief of subjectivism, meaning the research project and the research project are explicitly linked as they cannot be separated from the
knowledge that participants have developed within the topic areas (Dudovskiy, 2016c). The benefits of using an interpretivist approach to research are that it is particularly useful for qualitative research which is what this particular project is built around, as well as providing a level of validation for primary data that the project collects as the data gathered is the honest opinion of the participant (Dudovskiy, 2016d). However, this honest opinion of the participant could also be considered a negative aspect of the approach as it reflects on the personal views and values of the participant which may impact negatively on the reliability of the data, whilst bias may also need to be taken in to consideration (Dudovskiy, 2016e).

3.2 Research Approach

As well as using the interpretivist research philosophy, the research project will also apply an inductive research approach in order to develop accurate conclusions to the data that is collected by the researcher. The inductive research approach is based around developing conclusions from observations, with the researcher provided freedom to direct the study in any way with which they feel is appropriate (Dudovskiy, 2016f). The inductive approach to research aims to develop theories from data that is collected, whilst also allowing the researcher to explore other theories that can aid the project (Saunders et al, 2012). This is particularly useful for this research project as the project is built around qualitative data which will be collected during the research for this project, with data being collected from interviews and the testing of the prototype with the participants, and from the data that is collected, a theory on the use of mobile applications with visually or hearing children will be developed, with a wide range of topics being considered whilst making use of theory on the topic that already exists. The interviews that take place within the project will also involve open ended questions of a semi-structured nature as stated above and this lends itself perfectly to the inductive research approach as the researcher has the freedom to ask the user questions that may not have been planned beforehand based on the feedback provided by the participant. The inductive research approach is referred to as a bottom-up approach to research, as the data is collected, analysed and then theory is developed, as opposed to a top-down approach where theory is developed and then research takes place to prove the theory correct or incorrect (Dudovskiy, 2016g).
3.3 Data Collection

The research project has been designed to use qualitative data collection methods in order to develop an understanding of the topic area and to create a project that will achieve the aims and objectives it has set out to achieve. The qualitative research that is undertaken within this research project is done with the participants of interviews and testing of a prototype application for a mobile device, asking the participants for their thoughts about the application, its positives and the ways in which it would be able to be used to help a visually or hearing impaired child to improve their mathematical skills, as well as to find out any pitfalls within the application that can be improved within the final design of the application. The interview format that will be applied within this research project is that of semi-structured interviews. This means that there will be a set of questions that will be asked to all participants, which will aid this research project by helping to gain an understanding of the participants experiences of working with visually impaired or hearing impaired children in the classroom and any experience they have of teaching using mobile devices, with this part of the interview being followed by the testing of the application, where the questions were tailored to match the responses provided by the participants whilst testing the prototype application. Using interviews within a research project can be of major benefit to the project as a whole as they give the researcher a greater opportunity to collect detailed information from experienced people within the topic area, as well as giving the researcher a chance to gain clarification over information gathered which you are unable to gain from literature alone (Dudovskiy, 2016h). However, the interviews must take place in a relaxed environment (Dudovskiy, 2016i), and the researcher must be clear about what information they are looking to gather in order for the interview to be successful and valuable to the research project. There will also be a minimal use of quantitative data within the project with the inclusion of statistics that will be used to reinforce points developed from the findings of the qualitative data, as well as providing more information with regards to the use of mobile technologies in schools and the prevalence of visually or hearing impaired children in schools aged between five and seven-years-old. These statistics will help to provide the project with more background information to help justify its aims.
3.4 Sampling

The sampling technique for choosing the participants within this project is that of purposive sampling, in particular the homogenous sampling technique. Purposive sampling is a technique in which the researcher chooses participants to take part in the study based on their own judgement in order to develop a sample that is representative of the type of study taking place to gain a better insight in to the topic area (Dudovskiy, 2016j). Homogenous sampling is a part of purposive sampling which focuses on a particular group in which the sample participants are similar and share similar backgrounds (Dudovskiy, 2016k). This is the case within this research project, where the participants will all be chosen on the basis that they have experience teaching visually or hearing impaired children, and this will help to gain a better insight in to the application that is being prototyped and the ways in which it can be improved and whether it will be of value as a learning aid. The benefits of using this type of sampling is that it provides the researcher with a sample that can best represent the topic area they are researching therefore the participants will offer more value to the project, as well as being able to save time within the project as a smaller, more concentrated sample will be used. However, the researcher must be wary of making errors within the development of the sample as this can have a profoundly negative effect on the research project.

3.5 Prototyping, Interviews and Testing

As stated above, the project will be aiming to develop a prototype of a mobile application that will be able to be developed to help aid the learning of visual and hearing impaired children with their mathematical skills, with the prototype being created using the feedback of participants during interviews and testing. The type of prototyping being used within this project is that of storyboarding, to give the participants a realistic interpretation of what the final application will look like and how it will work. Storyboarding helps to visualise the design, and show the users the interaction and the features that are included in the prototype, which helps towards getting valuable feedback from the participants (Lemmelä et al, 2008). Storyboarding is particularly important within the realm of human-computer interaction, as it allows the developer of an application to work out early on how they want the application to work and how it will look (Madsen and Aiken, 1993, cited by Jones, 2008).
Storyboarding has also been used within education as a means for designing online learning tools, similar to what this prototype will be looking to achieve, replacing documentation with a visual design of the software (Jantke and Kauf, 2005, cited by Jones, 2008). There are many different methods of testing that can be applied when developing mobile applications, however for the purpose of this project I have decided to use the method of usability testing in order to gain the best possible feedback from the participants towards the application and the overall project. The usability tests that take place within this project will not however be typical of a usability test, where in the ideal situation you would be testing with participants who would also like be the future users of the application, however due to the ethical considerations of this product it was not considered to complete the testing with visually or hearing impaired children. Usability testing is useful for the development of mobile applications because it gives participants the opportunity to use an application and develop an idea of how it works, what functionality it offers and allows the developer to gain information from the participants about the features which need to be improved or removed altogether. As well as giving feedback on the overall design and quality of the application (Rubin et al, 2008a). There is a standard basis on how usability tests should be conducted, with research questions being developed by the interviewer and used to quiz the participants on their usage of the application, using a sample representative of the end users, which was not possible during this project but the use of teachers with experience in the field still offers valuable feedback, observation of the users as they engage with the prototype, and the collection of qualitative data from the participants which provides feedback on the positives and the problems within the prototype which can then be addressed (Rubin et al, 2008b).

3.6 Ethical Issues

One of the most important parts of any research project is the ethical considerations that need to be made during the duration of the research, especially when the research involves the usage of participants in interviews in order to provide the primary data aspect to the project. Bryman and Bell (2007) devised ten principles of ethical guidelines that should be followed in any research project, which includes making sure participants are not subjected to harm and are respected, that full
consent is obtained from all participants, that participants privacy is protected and confidentiality ensured as well as anonymity, deception of participants being avoided, and that information provided will not be used in a misleading or biased way. This research project follows these guidelines closely in order to maintain its ethical responsibilities, with the information provided by the participants being kept secure on a password protected computer system, anonymity being provided to the level required by the participant, consent forms being filled out before the interviews take place, whilst the project will aim to make best use of the feedback provided by the participants by representing it in a balanced way. All information provided within the project that has been gathered from already published literature will also be fully referenced to the Harvard standard referencing system to provide the author or authors with credit for their work that has provided this project with some vital information.

3.7 Research Limitations

Throughout this research project, there are limitations that affect the project and the research as a whole. In this part, the project will look at some of the limitations that were faced and some of the risks that the project faced and how the project addressed these limitations. One example of a limitation within the research project was finding relevant literature and theory already in existence regarding the topic, as it is based on the use of mobile applications to help with the education of visually and hearing impaired children, of which is a relatively new concept as the popularity of mobile technologies has grown rapidly. This was addressed by looking for literature on a broader scale, such as mobile technologies for educating children in general, or for educating children in mathematics, and then using this literature to be able to formulate a relevant discussion. Another example of a limitation within this research project will be the data collection, especially that of primary data. Primary data within this project, as stated above, was gathered from using interviews and testing, and one of the most important issues within these interviews is the choosing of participants, and as the mathematical education of visually or hearing impaired children is a specialised topic requiring a participant to have some experience with children who have visual or hearing impairments, the selection of participants can be difficult to correctly put together. The project has overcome this limitation by sourcing
teachers with experience of working at schools for special needs children, or who have had experience within state schools of working with visually impaired and hearing impaired children, who would be interested in contributing to the project. In terms of the data collection from secondary data, the research project will be looking at relevant literature to the subject to gain an insight into the topic area, whilst there may be a use of statistics from validated sources as a means of quantitative data within the findings of the research project to provide a clear overview of the result of the research. With statistics, it is important for them to be up to date as otherwise they would offer no benefit or added insight into the topic area, and this project will look for its use of statistics to be minimal, only using statistics that have been recently gathered or that add value to the research.

4. Results & Findings

This part of the project will be looking at the development and testing of a prototype mobile application created to be used as a learning aid for children with visual or hearing impairment with their arithmetical skills, looking at the different stages of the prototypes development, from low fidelity paper prototype designs to a high fidelity final prototype which shows the application after a stage of testing with participants with experience of working with visually impaired and hearing impaired children. This part of the report will also look at the issues surrounding the topic area that carry importance when gaining an understanding of the project, as it will be looking at data detailing the prevalence of children in UK schools who suffer from visual or hearing impairment, as well as looking at the usage of mobile technologies in a classroom environment and the barriers that exist to having access to these technologies within the school environment. This part of the project will also look at previous methods used for teaching those with visual impairment and hearing impairment and compare them to the use of mobile technologies and access technologies, looking at the benefits and disadvantages of more technological learning aids as opposed to the methods that have been used in the past.

4.1 Statistical Background to Topic Area

This section of the report is going to look to provide a quantitative outlook on subjects attributed to the topic area in order to provide a broader outlook on the
issues which this project is based on and looks to address. The first area which the project will look at in this regard is to look at the prevalence of visually impaired or hearing impaired children within the UK school system, who the prototype application that has been devised and will be detailed in a later part of this section is designed to accommodate. According to a January 2016 UK Government, between state-funded primary and secondary schools as well as special schools, there were 34,393 in education in England suffering from visual or hearing impairment, or a multi-sensory disability that may be impairment in both vision and hearing who require additional support through traditional special educational needs support or with an education, health and care plan to support their education, which makes up about three percent of all special educational needs children in England (Gov.uk, 2016). Whilst three percent seems fairly low, it is important that the educational tools that are available to children without special educational needs, or children whose disabilities do not affect them at a sensory level are also available to those with sensory impairments in either the same form or a more suitable form which is the basis on which the prototype application being developed by this project is for, as an application that can be used by all children to help with their mathematical skills at Key Stage One level, including those with special educational needs. Further to this, a 2015 report by CRIDE stated there are 17,661 children in primary school education in England who suffer with deafness or hearing impairment, which makes up forty-four percent of all deaf children in the UK (Consortium for Research in Deaf Education, 2015), whilst a report by RNIB showed that in 2012, 10,476 children within primary education suffered from blindness or visual impairment, making up around forty-two percent of all visually impaired children within England in education (RNIB, 2015). This shows that the area of visual and hearing impairment within education is an important topic to look at, and the ways in which children suffering from these impairments can be educated is valuable.

Moving on from focusing on hearing and visual impairments prevalence, the project is now going to look at the usage of mobile technologies in education, looking at the occurrence of schools who actively use and have access to mobile technologies within classroom environments and the barriers that are in place preventing the usage of mobile technologies in class. One of the key aims of the project was to develop a prototype application that could be used in a classroom environment that
matched the requirements of the National Curriculum and could therefore help five to seven-year-old children to improve the mathematical skills that are required at Key Stage One level. Due to this application being developed for use within a classroom environment, whilst also being able to be used at home, the project can gain valuable insight in to the validity of the future development of the application by looking at this topic area. This part of the project will start its insight in to this are by looking at how children use mobile devices in the school environment, as well as in their home environment to establish whether the use of a mobile application for learning is plausible. A 2015 study by Techknowledge showed that the most commonly used device amongst primary school children was a tablet, and that sixty percent of primary school children who used a tablet daily as part of their education felt they were more aware of internet safety than before (Techknowledge, 2015). Another aspect of this project is that the application prototype is in the form of a game, and the Techknowledge report also states that ninety-four percent of primary school children are likely to play games at home, although this considers all games and not purely educational games (Techknowledge, 2015). A final important point from the Techknowledge report regarding the children and the usage of mobile technologies is that thirty-seven percent of children believe that whilst using a mobile device to complete school work that they get easily distracted by other applications or features on the device, which would obviously be a negative point when discussing bringing mobile devices in to the classroom (Techknowledge, 2015).

Following on from this, the project will now take a look at the introduction of mobile devices in to education in the UK. A 2012 report by GSMA looked at the issue of mobile education, stating that the use of laptops, netbooks and tablets on a basis of one per student was increasing and the benefits presented by the usage of these devices was becoming clearer, however there were still hurdles to overcome, one of the major ones being the suspicion of teachers about devices in the classroom being more of a disruption than vehicle that can enhance learning and teaching (GSMA, 2011). In 2014, a Techknowledge survey of schools showed that sixty-eight percent of primary schools were using tablets in the classroom, with five percent of these schools using tablets on a one-to-one basis (Techknowledge, 2014). The survey also showed that forty-nine percent of schools were thinking about introducing tablets into lessons and that eleven percent of these schools were planning to introduce tablets on a one-to-one basis (Techknowledge, 2014). This shows that the usage of mobile
devices such as tablets is growing in popularity amongst primary schools, meaning that applications which can help to develop educational skills in children would be valuable to teachers. The Techknowledge survey also asked schools what the biggest challenge was to the introduction of mobile devices on a wider scale, with the majority of responses being that funding was the biggest issue being faced by the schools, especially regarding the introduction of tablets on a one-to-one basis (Techknowledge, 2014). This issue of funding is looked at in a 2015 report by School Zone, which looked at trends in funding for schools as well as the trends for spending by schools on technology and IT services. The report stated that as the economy is helped by having a workforce with greater skills gained from education, the government endeavour to protect funding for education, and therefore even during the recent past of economic uncertainty, educational funding was sustained (School Zone, 2015). However, the report also detailed that education spending fell in the five-year period between 2010 and 2015, and that whilst overall funding amounts are increasing, so are student numbers and therefore the funding needs to be spread wider, whilst the political standpoint of the government at a certain time can also have an effect on educational funding (School Zone, 2015). In contrast to overall spending falling, money spent on IT has grown year on year in the period, with primary school spending on IT and technology growing by seventy-five percent per pupil, with this spending equating to the school spending three times more on IT spending than on any other resource (School Zone, 2015). Another significant barrier with regards to the introduction of mobile technologies into schools is a lack of suitable bandwidth, especially in schools in rural areas of the UK where the bandwidth is inadequate (BESA, 2015).

4.2 Comparison Between Previous Teaching Methods for Visually and Hearing Impaired Children to Using Mobile Technologies

As detailed above, the use of mobile technologies and mobile applications within classrooms is a growing phenomenon within the educational landscape, with more schools deciding to put funding in to the area to provide their students with a learning experience which is different from what they have experienced before, and one which may also be able to help children greatly with their education moving forward. This section of the project will look at the some of the teaching methods currently used for educating children with visual or hearing impairment and will look to see if
these methods can be implemented in similar ways with the usage of mobile applications, providing children with the same or better quality of learning using the same methods.

With regards to learning methods and materials, Salisbury (2008g) provides a valuable insight into the challenge teachers face when teaching visually impaired children, notably the teaching of a small group of visually impaired children in a classroom where the majority of children will be sighted pupils. There are a number of different materials that can be used in order to aid these visually impaired children, ensuring they do not fall behind the other pupils, such as increasing the size of the font used on learning materials, providing children with additional time to complete tasks, using colour within the learning materials to make them easier to see and read, and keeping the layout of learning materials clear (Salisbury, 2008h). As well as these methods, there are also more technical methods that require the use of additional technologies, such as the use of braille and tactile diagrams and books, to enable the child to use their other sense to gain an understanding of a concept, the use of audio rather than large chunks of text, such as a book or a play, allowing the visually impaired child to have headphones and an audio representation of what can be read by the sighted pupils, as well as access technology software such as screen readers and screen magnifier software (Salisbury, 2008i). Mobile technologies can imitate the majority of these methods and materials, with screens generally being able to be zoomed in, in order to make items on the screen appear bigger, whilst most mobile devices also have the provision to increase the standard font size set on them. Also, the use of a mobile device can be used to play video and audio to the child in place of large chunks of text that may be used by other members of the class. Most mobile devices are also able to make use of access technologies such as screen readers, however the use of braille and tactile diagrams would have to be used in their current form. This means that mobile devices are capable of taking the place of many of the materials currently used and used in the past, meaning the teacher could save valuable time in the preparation of lessons that is taken up preparing extra materials for the children with visual impairment.

Moving on to look at materials and methods used for the teaching of hearing impaired children, the most commonly used are the use of sign language interpreters
and the use of visual aids (Newcastle University, n.d.). Clearly, a mobile device would be unable to take the place of a sign language interpreter, but a mobile device could be used if a lesson has been planned and can be provided via the means of video through the mobile device with the use of subtitles, whilst visual aids used in the classroom such as handouts and diagrams can also be implemented within the mobile technologies.

4.3 Development of Prototype Application, Testing and Interviews

This section of the project will be detailing the development of the prototype application that has been created for a mathematics application designed to help children at Key Stage One level with their arithmetical skills, with the designs being based on an application that is best operated on a tablet device. The application has been based around the four main mathematical operations of add, minus, divide and multiply, all of which are a part of the National Curriculum for Key Stage One Mathematics, with the application being designed to be able to be usable and accessible for students of all ability levels, including those with visual and hearing impairments. The application takes the form of a game called Maths Paths, with the idea of the game being that the child or teacher can choose one of the maths operations, where they will then be met with a screen which features a path with various levels moving along the path, each of which will be of increasing difficulty. Once a level has been chosen, the game screen will then come up featuring four boxes of different colours, one box will flash followed by another box flashing, and the child must then apply the chosen mathematical operation to the two numbers to get a correct answer. Following this, the application will take you back to the levels screen to move on with the next level of the game. The following sections will detail the stages of the low fidelity prototype design using paper prototypes which were used in order to gain an understanding of how the application was to look and feel, and about how it would work. Following this, there is the high fidelity design which has been created to give greater detail to the earlier created paper prototypes and to provide a basis for testing in order to gain further improvement before moving on to a final design stage with another high fidelity being designed in greater detail again, with the idea being that this final high fidelity design will show how the game works in its finalised form. The following sections will also provide an insight in to the
information that was gathered from the testing phase of the development as well as the valuable information that regarding the use of mobile technologies that the projects participants provided. Finally, this section will take a brief look at different mobile development platforms to see the features that are available for creating applications that are accessible and usable for everyone, and to see if there are any differences between them that could be addressed moving forwards.

In the literature review section of this project, the concepts of inclusive design and participatory design, as well as other methods such as the method that was theorised by Druin (2002b, cited by Jacko 2012) which used children as part of the design methods in a variety of different roles. During the development of the prototype application for this project, the theory of inclusive or universal design was applied, with the prototype application being designed to be able to be used by user of all types, whether with special educational needs or not. This is an important note with regard to the project, as mentioned in section 4.1 of this report, the number of children with visual or hearing impairment in primary schools in the UK is not a particularly large percentage, but there are a number of educational tools out there that are not available to them because of their disabilities, and by creating an application that caters to their needs whilst not taking anything away from the education of children without special educational needs, nobody falls behind with regards to their development of arithmetical skills. The methods of participatory design, or designing using children in various roles across the process was not possible during this project due to the nature of them being children, whilst also those with special educational needs may have been a particularly difficult to incorporate due to their more vulnerable nature, and therefore whilst these methods may have significantly benefitted the project, they were unable to be used and other methods were applied.

4.3.1 Low Fidelity Prototype Design

Below are the paper prototypes that were created as a starting point for the application that is being designed as part of this project (see Figure 1). It features a main menu page, shows the pages for the individual operations levels screen and examples of the game that the user will interact with.
The design process behind the designs was to use paths as a way to advance the game with increasing difficulty through the levels and as a way for children, teachers and parents to keep a track on the progress of the child through the application. It is designed to be simple to use, with the use of colour designed to be visually appealing to children and for those with visual impairment, the colours are there to make the features of the application more visible. Also, there will be the use of sound within the application, such as the child being able to use speech to identify which operation they want to use and what level they want to play, whilst the application itself would use sound to provide the child with feedback, such as to say aloud the number which flashes as well as to tell the child what level they have completed and also to provide feedback as to the result of the answer such as a well done or a try again. For users with hearing impairment, the application is still usable without the sound features, as it is simple to use and has a button based interface which is easy to get to grips with, with the colours and the flashing numbers easy to see and therefore the game is usable for them.
4.3.2 High Fidelity Prototype Design

The first of high fidelity designs are based upon the paper prototypes shown above in Figure 1 and these are the designs that were used in testing with the participants, which provided the information leading to the final design of the prototype (see Figure 2). The high fidelity designs were created using Microsoft PowerPoint, which is software not generally used for a task such as this however, it offered all the tools required to put the prototype together for this project. The designs were based on the application being used on a tablet in the portrait orientation, however the functionality of the application was difficult to show within these designs due to time restraints on the project, and therefore the application had to be extensively explained to the participants in the testing phase of the development, which possibly negatively affected some of the feedback that was received. The application again uses bright colours to ensure it is visually appealing and that the features are easily distinguishable, with the premise of the game staying the same from the low fidelity designs into the first set of high fidelity designs.

Figure 2: High Fidelity Prototype Designs
4.3.3 Interviews and Testing

For the purposes of this project, and to help the researcher to gain a broader understanding of the topic area, as well as to gain insights the perspective of people with experience of working with children with visual or hearing impairments, the project made the use of an interview stage which was then followed by testing of the prototype application, from which the feedback would be used in order to develop a final prototype application as part of the project.

The interviews began by finding out from the participants the level of experience they had in working with children with special educational needs, as well as any experience they had in working with children who suffered with visual or hearing impairment. Each of the participants had a moderate level of experience of working with SEN children, with between two and five years of experience, whilst each of the participants had worked with visual and hearing impaired children. The interviews then moved on to discuss with the participants their experience of using mobile applications within the classroom environments, of which two of the participants had some experience. The participant said that they had worked in a classroom running the applications with tablet devices, but that there was a lack of devices with children working in groups of four, and that the lesson did not work as well as it possibly could have if the tablets had been distributed on a one-to-one or one between two basis, as some children switched off from the lesson and did not participate. All three participants stated that they had more experience using whiteboards and pens during lessons, in which there was more access to resources, however they were limited in what they could teach using them, whilst they also had daily experience of
using interactive whiteboards at the front of the class, which is useful for getting children to come up to the front and interact, but obviously you cannot have each member of the class using it at the same time. The participant who had experience of taking a class with tablet devices expressed that the use of the devices during lesson time would have been beneficial to them as a teacher and to the students, however it would require additional monitoring on the teacher’s part as to the progress the children were making on tasks, however it provided them with access to more learning materials that would otherwise have been unavailable.

Following on from the interviews, the participants were then asked to take part in a testing stage of the high fidelity prototype shown above. The participants were shown how the application would work and asked to follow through the prototype before being asked about their thoughts on the prototype and the way it would work. The first question that the participants were asked was whether they felt the prototype would be usable as an application to children with visual or hearing impairment. Due to the nature of prototyping, the audible elements of the application had to be explained to the participants as the prototype was examined, so that they could grasp fully how the application worked. The participants felt the design was very clear and that the application was easy to use, with the use of colour creating a visually aesthetic appearance, however some of the colours clashed slightly and made some items harder to see than others. The participants also noted that there was a lack of feedback for the user, such as a well done message if the user gets a correct answer, as well as there being a lack of an input mechanism such as a keyboard which was missed out in the prototype. The participants were then asked whether the application met the requirements of mathematical skills at Key Stage One, which they detailed that it did, however at a basic level more likely to be experienced at the start of Key Stage One, however they noted that this was an example of the first level and that subsequent levels would increase in difficulty. The participants were then asked which features they liked and which features could be added or improved, stating that they liked the idea of children being able to use it to progress through increasingly difficult levels, and that it would be ideal as a learning aid to be used as homework for the children, as it would allow parents and teachers to track the children’s progress, but they did note that the application could benefit from including other mathematical topics that are taught at Key Stage One level such
as fractions. They were finally asked whether they felt the prototype application, if developed and changes that have been recommended through the testing were applied, could be used within a classroom environment, the participants felt that it could be used within a classroom lesson, but it would be dependent on whether the resources were available for each child to have a device of their own, as they felt an application such as this one would only be beneficial in that case.

4.3.4 Final Prototype Design

This section will show the final high fidelity design stage and the final stage of design that has been undertaken for this project. This final stage of prototyping took place following the testing and interviews with participants with experience in the field and provided the project with valuable knowledge. From the testing stage to the final prototype being created, the decision was made to turn the orientation of the screen from portrait to landscape to provide a wider interface which allowed new features to be added in to the application.

These new features that have been added to the game come as a result of the knowledge gained from the testing and interview stages, with the introduction of positive and negative feedback screens which show based on the result of the users’ feedback, as well as a keyboard to aid the input of answers, as well as tweaking of the colour scheme to improve the look and feel, removing any perceived colour clashes which may have resulted in some parts of the application being more difficult to see than others. As well as these changes, there has been a change in the design to approve the aesthetics on the main menu. The premise of the game has remained the same, with the aim still being to complete the increasingly difficult puzzles going along the path until the game is completed, whilst no more operations have been added despite the feedback from the participants due to the time constraints of the project, however it is something that could be added in to future versions of the application. A visual representation of the application prototype and how it works will be available using prototyping tool POP, with a link provided in Appendix E. There is still a lack of sound within the prototypes due to the nature of prototypes and the tools that have been used to design and model them, with the assumption being made throughout that the user when looking at the prototype will understand that
sound will be used. As well as sound being used to speak to the user, the application would also include the functionality to allow the user to speak the answer to the question, to increase the ease of which the application can be used, as it has been designed to be accessible for everyone, from children without disability to those with visual or hearing impairment, whilst it should also be accessible for those with other disabilities who may be unable to interact with the interface.

Figure 3: Final High Fidelity Prototype Designs
5. Conclusion

This project has taken an in depth look at the issues surrounding the usage of mobile technologies as an educational tool for children with visual or hearing impairment to help with the development of their mathematical skills. The project has progressed through a number of different stages, such as the evaluation of literature, an overview of a research philosophy that has underpinned the formulation of the project, followed by the development and designing of a prototype mathematics application that can be used by children of all abilities, whether fully sighted or a person who can hear fully, through to those with special educational needs who may require the use of additional learning mechanisms in order to be able to follow the same educational goals of their peers.

The project started with the examination of literature surrounding various topics that are related to the subject area. These topics formed the backbone of the research for the project, with the knowledge gained from the understanding of theory that was developed in this part of the project contributing largely to the creation of the prototype application that came later on in the project. Some of the concepts looked at within this section were concepts within human-computer interaction and mobile application design, namely universal design concepts and participatory design concepts which will be discussed later on in this conclusion. The literature review also provided information regarding accessibility, as well as further knowledge of mathematics learning at Key Stage One level and the challenges faced by teachers in educating children in general at this level, especially those with special educational needs. Another of the key issues that was discovered through the evaluation of literature was the concept of the growing nature of mobile devices, as
they are now becoming increasingly common in the world today, with the majority of people within the UK having access to a smartphone, whilst the market for tablets is currently growing at a rate faster than ever before, with this being seen within education as well as with recreational users. This growing usage within education is largely down to the fact that mobile devices are able to provide learners, teachers and educational establishments access to learning materials and methods that were previously unattainable, however barriers to these devices still exists, although they are being overcome at a rapidly growing rate.

The project then identified the research methodology that would underpin the project, ensuring that the project would follow a philosophy and a research approach that would enable the project to gain the best possible results from the research, interviews and testing that were taking place, whilst also ensuring that all limitations upon research were minimised, ethical considerations were made and abided by and that the project would be completed by the set deadline. Within the realm of the ethical nature of this project, the testing phase of the project was hindered slightly by the inability to test the application prototype with children, specifically children with visual or hearing impairment. This would have been of significant risk to the project, as the feedback gained from children may not always be the most conclusive, as well as the ability to find willing participants who fit the profile that was required, whilst the sensitive nature of working with children in general, not just those with visual or hearing impairments was risky and therefore it was safer to use teachers of special educational needs children instead. This also meant that the project was unable to follow a participatory design philosophy, which may have improved the quality of the final prototype design. The prototype developed was that of mathematical skills game that require children to answer questions on different mathematical operations, making use of flashing buttons to provide the children with questions, and the adoption of levels-based system to ensure there was progression in the difficulty of the puzzles throughout the game. The interviews and testing that took place was overly positive, providing feedback that was able to drive the final prototype design to be of an application that worked, was easy to use, and could be used in a classroom environment or at home by a child to help with the development of their mathematical skills.
6. References


7. Appendices

Appendix A – Ethics Approval
Ethics Approval Number - 2016D04805

When undertaking a research or enterprise project, Cardiff Met staff and students are obliged to complete this form in order that the ethics implications of that project may be considered.

If the project requires ethics approval from an external agency (e.g., NHS), you will not need to seek additional ethics approval from Cardiff Met. You should however complete Part One of this form and attach a copy of your ethics letter(s) of approval in order that your School has a record of the project.

The document *Ethics application guidance notes* will help you complete this form. It is available from the Cardiff Met website. The School or Unit in which you are based may also have produced some guidance documents, please consult your supervisor or School Ethics Coordinator.

Once you have completed the form, sign the declaration and forward to the appropriate person(s) in your School or Unit.

**PART ONE**

<table>
<thead>
<tr>
<th>Name of applicant:</th>
<th>Mark Goddard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supervisor (if student project):</td>
<td>Catherine Tryfona</td>
</tr>
<tr>
<td>School / Unit:</td>
<td>Cardiff School of Management</td>
</tr>
<tr>
<td>Student number (if applicable):</td>
<td>ST20063632</td>
</tr>
<tr>
<td>Programme enrolled on (if applicable):</td>
<td>BSc (Hons) Computing</td>
</tr>
<tr>
<td>Project Title:</td>
<td>The use of Mobile Applications to support the development of arithmetic skills in visually or hearing impaired children at Key Stage 1 level.</td>
</tr>
<tr>
<td>Expected start date of data collection:</td>
<td>24/03/2017</td>
</tr>
<tr>
<td>Approximate duration of data collection:</td>
<td>3 weeks</td>
</tr>
<tr>
<td>Funding Body (if applicable):</td>
<td>N/A</td>
</tr>
<tr>
<td>Other researcher(s) working on the project:</td>
<td>N/A</td>
</tr>
<tr>
<td>Will the study involve NHS patients or staff?</td>
<td>No</td>
</tr>
<tr>
<td>Will the study involve human samples and/or human cell lines?</td>
<td>No</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Does your project fall entirely within one of the following categories:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper based, involving only documents in the public domain</td>
</tr>
<tr>
<td>Question</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Laboratory based, not involving human participants or human samples</td>
</tr>
<tr>
<td>Practice based not involving human participants (e.g. curatorial, practice audit)</td>
</tr>
<tr>
<td>Compulsory projects in professional practice (e.g. Initial Teacher Education)</td>
</tr>
<tr>
<td>A project for which external approval has been obtained (e.g., NHS)</td>
</tr>
</tbody>
</table>

If you have answered YES to any of these questions, expand on your answer in the non-technical summary. No further information regarding your project is required.

If you have answered NO to all of these questions, you must complete Part 2 of this form.

In no more than 150 words, give a non-technical summary of the project:

For this project, I will be looking at the effectiveness of using mobile applications in order to aid children with either visual or hearing impairment with the development of their arithmetical skills that are required to be known by the National Curriculum. I will be determining the design necessities that would be required in order for an application to be useful to both teacher and student, as well as researching if any applications exist and critically evaluating the success of them in aiding visually or hearing impaired children. I will also be looking at the usefulness of applications already in existence and determining whether they are of value to the learning of a special needs child. I will converse with teachers with experience working with SEN children to determine whether having access to mobile applications within a classroom environment would be valuable to help with the development of arithmetical skills and any barriers that would exist in implementing this in the classroom.

DECLARATION:
I confirm that this project conforms with the Cardiff Met Research Governance Framework.

I confirm that I will abide by the Cardiff Met requirements regarding confidentiality and anonymity when conducting this project.

STUDENTS: I confirm that I will not disclose any information about this project without the prior approval of my supervisor.

Signature of the applicant: M. Goddard  
Date: 20 March 2017

FOR STUDENT PROJECTS ONLY

Name of supervisor: C. Tryfona  
Date: 20 March 2017

Signature of supervisor: C. Tryfona

Research Ethics Committee use only
PART TWO

A RESEARCH DESIGN

<table>
<thead>
<tr>
<th>A1 Will you be using an approved protocol in your project?</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2 If yes, please state the name and code of the approved protocol to be used</td>
<td>N/A</td>
</tr>
<tr>
<td>A3 Describe the research design to be used in your project</td>
<td>In this project, I will be using the inductive approach to research. This is because it is the most fitting approach to the project as it involves the collection of qualitative data, as well as taking in to account human thoughts to a topic area. I will be using books and journal articles for data collection in this project, focusing on books about educating young people as well as those with special needs, human-computer interaction and mobile application design. I will also be looking at the National Curriculum for information about the required learning for children at Key Stage 1 and for children with special needs. There will be a qualitative assessment of the application prototype where participants, in this case by teachers who support students with additional learning needs.</td>
</tr>
<tr>
<td>A4 Will the project involve deceptive or covert research?</td>
<td>No</td>
</tr>
<tr>
<td>A5 If yes, give a rationale for the use of deceptive or covert research</td>
<td>N/A</td>
</tr>
<tr>
<td>A6 Will the project have security sensitive implications?</td>
<td>No</td>
</tr>
<tr>
<td>A7 If yes, please explain what they are and the measures that are proposed to address them</td>
<td>N/A</td>
</tr>
</tbody>
</table>

B PREVIOUS EXPERIENCE

| B1 What previous experience of research involving human participants relevant to this project do you have? | None |
**B2 Student project only**

What previous experience of research involving human participants relevant to this project does your supervisor have?

Catherine Tryfona has around ten years of experience supervising student research projects, including projects involving human participants.

**C POTENTIAL RISKS**

**C1 What potential risks do you foresee?**

In this project, there are risks involved for the researcher, participants involved and for the project itself. 1). The risks that the researcher faces are the setting up and arranging of the interviews. This is due to the fact that it is down to the availability of participants and cannot be determined by the researcher. Another risk to the researcher comes with getting valuable information from the participant, as the information gathered will be irrelevant if it is not useful. This also comes from the questions asked of the participant being tailored to getting useful information. 2). Risks that will apply to the project are finding suitable literature to underpin the primary research that will take place and meeting deadlines for completion of the project. 3). Risks to the participant would be the confidentiality of their personal information and where it would be stored, as well as keeping their anonymity within the interview and within the project.

**C2 How will you deal with the potential risks?**

1). The risk of the arranging of interviews will be dealt with by planning the interviews well ahead of time, whilst checking with the participant in the run up to the interview that they are still able and willing to participate. The risk of getting valuable information from the participant will be dealt with by asking specific questions to the participant in order to get information that will be of value to the project. 2). Risks to finding suitable literature for the project will be overcome by using many different sources of information, such as books, journal articles, blogs, websites and news articles to get as much information that could be used in the project as possible. The risk of deadlines being met for the project will be addressed by setting up a timetable and setting achievable targets for the project to make sure it is completed on time. 3). The risks to the participant of the confidentiality of their personal information and keeping their anonymity will be solved by saving their information in a cloud based storage solution such as Dropbox, keeping their anonymity in the project by referring to them under an alias.

When submitting your application you **MUST** attach a copy of the following:

- All information sheets
- Consent/assent form(s)

An exemplar information sheet and participant consent form are available from the Research section of the Cardiff Met website.
Appendix B – Participant Information Sheet

**The use of Mobile Technologies to support the development of arithmetic skills in visually or hearing impaired children at Key Stage 1 level**

**Project summary**
The purpose of this research project is to research the usage of mobile technologies and applications as a learning aid for the mathematical skills of visually impaired or hearing impaired children. Your participation will enable the collection of data which will form part of a study being undertaken at Cardiff Metropolitan University.

**Why have you been asked to participate?**
You have been asked to participate in the project because you have experience of working with and teaching children with visual or hearing impairment and therefore you fit the profile for the research of this interview, to which I believe you will have better understanding of the proposed questions and will be able to provide valuable feedback during the interview and in the testing of a prototype application.

During the interview, you will be asked questions regarding your experience of working with visually or hearing impaired children in a classroom environment, whilst also being asked about any experience you have of teaching using mobile technologies or applications. As well as the interview, there will be a testing stage where you will be shown a prototype mobile application which you will be asked to contribute feedback to. Your participation is entirely voluntary and you may withdraw at any time.

**Project risks**
The research involves participation in an interview which will be recorded for analysis of issues surrounding the topic area, as well as a testing phase for a prototype application which will be aimed at improving the prototype so that it is ready to be developed. I am not seeking to collect any sensitive or personal data from you, this study is only concerned with the topic at hand. There are any significant risks associated with this study and any information recorded from you will be kept secure. However, if you do feel that any of the questions are inappropriate then you can withdraw from the process at any time, or proceed with guidance as to any questioning which you do not approve of.

**How we protect your privacy**
All the information you provide will be held in the utmost confidence. The project has taken all precautions to ensure that you cannot be directly identified from the interview. Your personal details and your interview answers will be kept in secure locations and saved in a password secure environment. When the study is finished and analysis has been completed, all the documentation used to gather the data will be destroyed. Any recordings or video if taken will also be held in a secure and confidential environment during the study and destroyed upon completion of the project.

YOU WILL BE OFFERED A COPY OF THIS INFORMATION SHEET TO KEEP

If you require any further information about this project, then please contact:
Mark Goddard, Email: st20063632@cardiffmet.ac.uk
Appendix C – Participant Consent Form

PARTICIPANT CONSENT FORM

Reference Number: 2016D04805
Participant name or Study ID Number:
Title of Project: The use of Mobile Applications to support the development of arithmetic skills in visually or hearing impaired children at Key Stage 1 level.
Name of Researcher: Mark Goddard

Participant to complete this section: Please initial each box.

1. I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.

3. I agree to take part in the above study.

The following statements could also be included on the consent form if appropriate:

1. I agree to the interview / focus group / consultation being audio recorded

2. I agree to the interview / focus group / consultation being video recorded

3. I agree to the use of anonymised quotes in publications

_______________________________________   ___________________
Signature of Participant                       Date

_______________________________   __________   ___________________
Name of person taking consent              Date

____________________________________
Signature of person taking consent

* When completed, 1 copy for participant & 1 copy for researcher site file
Appendix D – Draft Testing and Interview Questions

Do you use any existing mobile computing apps to support the development of arithmetic skills in visually or hearing impaired children and, if so, what software products are you using?

What advantages have you found with such software?

What disadvantages have you found with the software you have used?

Is one of the biggest problems with using mobile applications in the classroom the access to mobile devices?

What are the biggest problems faced by visually impaired or hearing impaired children with regards to learning arithmetical skills?

Having reviewed the prototype app, please rate the following:

Ease of use
Very difficult    Difficult    OK    Easy    Very easy

How appropriate is the type of arithmetic for a child at KS1?
Very difficult    Difficult    OK    Appropriate    Very appropriate

How would you rate the effectiveness of the design in terms of its accessibility for visually or hearing impaired children?
Very ineffective    Ineffective    OK    Effective    Very effective

What changes would you make to the design?

What did you particularly like about the design?

How likely is it that you would incorporate such an app in to your teaching of visually impaired children at KS1?
Very unlikely    Unlikely    Possibly    Likely    Very Likely
Appendix E – National Curriculum
National Curriculum – Programme of Study
Mathematics
September 2013

Number – Number and Place value
Year 1
- Count to and across 100, forwards and backwards, beginning with 0 or 1, or from any given number.
- Count, read and write numbers to 100 in numerals
- Count in multiples of twos, fives and threes
- Identify one more or less of a given number
- Identify and represent numbers using objects and pictorial representations including the number line as well as equal to, more than, less than and most/least.
- Read and write numbers from 1 to 20 in numerals and words

Year 2
- Count in steps of two, three and five from zero, and in tens from any number, forwards and backwards
- Recognise the place value of each digit in a two digit number
- Identify, represent and estimate numbers using different representations, including the number line
- Compare and order numbers from 0 up to 100; use greater than, less than and equals signs.
- Read and write numbers to at least 100 in numerals and words
- Use place value and number facts to solve problems

Number – Addition and Subtraction
Year 1
- Read, write and interpret mathematical statements involving addition, subtraction and equals.
- Represent and use number bonds and related subtraction facts within 20
- Add and subtract one digit and two digit numbers to 20, including zero
- Solve one step problems that involve addition and subtraction, using concrete objects and pictorial representations, and missing number problems.

Year 2
- Solve problems with addition and subtraction using concrete objects and pictorial representations, including those involving numbers, quantities and measures, applying their increasing knowledge of mental and written methods
- Recall and use addition and subtraction facts to twenty fluently, and derive and use related facts up to 100
- Add and subtract numbers using concrete objects, pictorial representations, and mentally, including a two digit number and ones, a two digit number and tens, two two digit numbers and adding three one digit numbers
- Show that addition of two numbers can be done in a commutative order and subtraction cannot
- Recognise and use the inverse relationship between addition and subtraction and use this to check calculations and solve missing number problems

**Number – Multiplication and Division**

**Year 1**
- Solve one step problems involving multiplication and division, by calculating the answer using concrete objects, pictorial representations and arrays with the support of the teacher.

**Year 2**
- Recall and use multiplication and division facts for the two, five and ten multiplication tables, including recognising odd and even numbers
- Calculate mathematical statements for multiplication and division within the multiplication tables and write them using the multiplication, division and equals signs
- Show that multiplication is commutative and division of one number another is not
- Solve problems involving multiplication and division, using materials, arrays, repeated addition, mental methods, and multiplication and division facts

**Number – Fractions**

**Year 1**
- Recognise, find and name a half as one of two equal parts of an object, shape or quantity
- Recognise, find and name a quarter as of four equal parts of an object, shape or quantity

**Year 2**
- Recognise, find, name and write fractions of one third, one quarter, 2 over 4 and three quarters of a length, shape, set of objects or quantity
- Write simple fractions such as one half of six equals three and recognise the equivalence of two over four and one half.

**Measurement**

**Year 1**
- Measure, record, Compare, describe and solve practical problems for lengths and heights, mass and weight, capacity and volume and time.
- Recognise and know the value of different denominations of coins and notes
- Sequence events in chronological order using language
- Recognise and use language relating to dates, including days of the weeks, months and years.
- Tell the time to the hour and half past the hour, and draw the hands on a clock face to show these times.
Year 2
- Choose and use appropriate standard units to estimate and measure length and height, mass, temperature and capacity to the nearest appropriate unit using rulers, scales, thermometers and measuring vessels
- Compare and order lengths, mass and volume/capacity and record the results using more than, less than and equal to
- Recognise and use symbols for pounds and pence, combine amounts to make a particular value
- Find different combinations of coins that equal the same amounts of money
- Solve simple problems in a practical context involving addition and subtraction of money of the same unit, including giving change
- Compare and sequence intervals of time
- Tell and write the time to five minutes, including quarter past, to the hour and draw the hands on a clock face to show these times
- Know the number of minutes in an hour and the number of hours in a day

Geometry – Properties of Shapes

Year 1
- Recognise 2D shapes such as rectangles, triangles, squares and circles.
- Recognise 3D shapes such as cuboids, cubes, pyramids and spheres.

Year 2
- Identify and describe the properties of 2D shapes, including the number of sides and line symmetry in a vertical line
- Identify and describe the properties of 3D shapes, including the number of sides and line symmetry in a vertical line
- Identify 2D shapes on the surface of 3D shapes
- Compare and sort common 2D and 3D shapes and everyday objects

Geometry – Position and Direction

Year 1
- Describe position, direction and movement, including whole, half, quarter and three quarter turns.

Year 2
- Order and arrange combinations of mathematical objects in patterns and sequences
- Use mathematical vocabulary to describe position, direction and movement, including movement in a straight line and distinguishing between rotation as a turn and in terms of right angles for quarter, half and three quarter turns, both clockwise and anti-clockwise.
### Statistics
#### Year 2

- Interpret and construct simple pictograms, tally charts, block diagrams and simple tables
- Ask and answer simple questions by counting the number of objects in each category and sorting the categories by quantity
- Ask and answer questions about totalling and comparing categorical data


### Appendix F – POP App link to Prototype

POP App – [https://marvelapp.com/83gjcfe](https://marvelapp.com/83gjcfe)